GENERAL ELECTRIC REVIEW

VOL. IX No. 1 | PUBLISHED MONTHLY BY GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU SCHENECTADY, N. Y. | JUNE, 1907

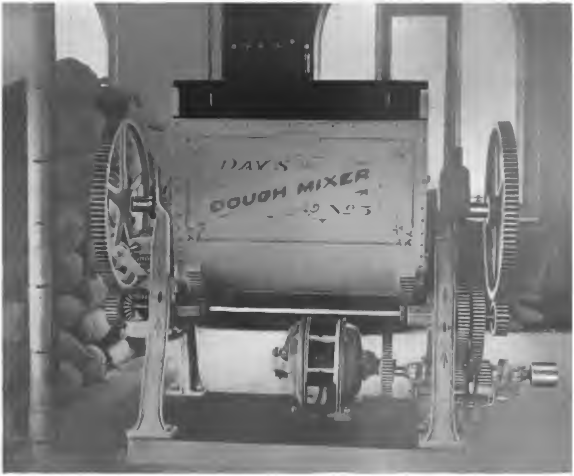
Sixteen Ton Flywheel Motor Generator for Hoisting Engine Plant at Wintershall Mine.

GENERAL ELECTRIC REVIEW

VOL. IX NO. 1

JUNE, 1907

CONTENTS



Dough Mixer Driven by 10 h.p. General Electric Induction Motor

Vol. IX No. 1 SCHENECTADY June, 1907

GENERAL ELECTRIC REVIEW

EUROPEAN PRACTICE IN ELECTRIC HOISTING ENGINES

By Eugen Eichel

In considering European electrical hoisting engines, it might be appropriate to start with a brief discussion of the reasons and the conditions which there exist and which facilitated the introduction of electric drive into this immense field of electric application.

It is a product of a large number of local and commercial conditions, which makes the electric drive of hoisting engines both an engineering and a commercial success, probably more so in this than in any other engineering problem. This being the case, conservatism might frequently induce mine owners to prefer the simple solution of installing the old fashioned steam engine, with its well known advantages and disadvantages, rather than to go to the trouble of making themselves acquainted with the new child of electrical engineering development. It therefore rests with the electrical engineer to thoroughly study the individual hoisting engine propositions and to convince the mine owner of the advantages of the electric drive by figures and actual facts.

On the other hand, the production of hoisting engine equipment may not appeal very strongly to the electrical manufacturer, because it requires special development work and may hamper, to some extent, the manufacture of standardized apparatus.

During 1901 and 1902 the former prosperous times of the German electric industry gave place to very adverse conditions. Orders for standard electricity works and railway equipment were not on hand, and the management and engineering staff of the large electrical concerns were led to seek new applications for electrical machinery which might be advantageously substituted for straight steam or mechanical drives. At the same time the mines and mills, which are mostly controlled by rich financial banking groups, suffered to such an extent by reason of the enforced idleness, and by the low prices of their products, that the owners were willing to use this ebbtide of the industry for making such improvements as promised to increase the efficiency and to decrease the operating costs of their plants.

Of course electricity had previously proved to be a very valuable help, as far as lighting and the drive of small auxiliaries, cranes and conveying apparatus was concerned. However, due to the efforts of the electrical engineers, there was a marked advance in the use of electric drive for important machines, such as large pumps, fans, air compressors, and mill machinery; as well as for coal screening and washing plants, mining locomotives, and rope haulage. The goal, however, was the electric drive of the main hoisting engine.

How far they were enabled to make this a success can be judged from the fact that more than sixty plants (with an aggregate capacity of about 44000 tons per 8 hour shift) were completed in about three years; and also that the size and output of plants on order are steadily increasing. For instance, 10 of the plants ordered during the last year from the Allgemeine Elektricitaets Gesellschaft, require each 1000 h.p. and over in hoist motor capacity; the three

Read before the Schenectady Branch A. I. E. E.

largest equipments comprising two motor outfits of respectively 2560 h.p., 3170 h.p., and 3260 h.p. Considered from the manufacturers' standpoint, this means an aggregate of 20000 h.p. in low speed machines for hoist drive, about 12000 kw., in high speed generators, and 7000 h.p. in standard high speed induction motors for the flywheel set; furthermore, some 10000 h.p. in standard power house machinery, and a large amount of standard switch board and other electrical appliances.

The great economy of space and the light foundations of the electric hoist drive are especially advantageous in cases of substitution for the old existing steam engine and boiler house outfits. The electric engine requires only about 30 to 35 lbs. of steam per shaft h.p., thus reducing the size of the boiler plant; and as it calls for very little space, and light foundations, it can be installed adjacent to the old plants without disturbing the hoisting operation, so that the interruption of the shaft service when changing from steam to electric drive is of very brief duration; generally the change can be effected between Saturday and Monday.

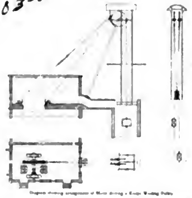


Fig. 1. Diagram of Hoisting Engine Plant Equipped with Koepe Disc

The present diversity of opinion in the electrical engineering profession in regard to the system best suited for the electrification of steam roads, had its parallel in Germany in 1901 and 1902 in reference to the proper choice of system for the electric drive of main hoisting engines, and a large number of discussions took place upon the subject at that time, with the final result that there are now two main systems in practical operation. First, the direct drive of the hoist by means of an induction motor, second, the drive of the hoist by means of a direct current motor, fed from a flywheel motor generator set, the latter being operated from an A.C. or D.C. network. This second system reduces the heavy load fluctuations, producing a nearly constant load on the power house.

The use of induction motors direct connected to hoists necessitates powerful generating units of heavy overload capacity at the power house. The heavily fluctuating hoist load causes a rather poor efficiency at the generating end, while the starting resistance of the induction motor reduces the efficiency of the system at the motor end.

The electric braking of the induction motor at the retardation period of the hoisting cycle, does not represent a regaining of the brake current energy, but on the contrary, has a rather bad effect upon the prime mover of the generators by suddenly relieving it of the load, thus causing a tendency to race, an objectionable effect which can be effectively diminished by using steam turbine driven generators.

On the other hand, since induction motors can be wound for moderately high voltages, such as 2300 volts, they may be supplied directly from 2500 volt generators without the use of transformers. In this way losses due to transformation are entirely avoided, transmission losses are reduced to a small amount, and large savings are effected in investment costs. A great drawback is the fact that the low speed of the hoisting engine does not allow the use of direct connected induction motors operated at more than, say, 25 cycles.

In Belgium and in the adjacent mines in the Northern parts of France there seems to exist a preference for induction motor drive. This is apparently due to the fact that the collieries operate a greater number of scattered pits from a central power house, which in addition to the hoisting engines, usually has a good constant load in the power required by the central coal washing and screening plant, and the electrically-driven fans and pumps. The distance from power house to shaft is not very large, and the connection is effected by means of underground lead covered steel armored cables, which are placed right in the ground without further protection. Mine run or coke oven gas gives a cheap fuel, and it is less the saving in fuel and more the convenience of the central power house and the reduction in boiler plant, as well as the great safety and easy operation of the electric engine, that induces the mine owner to choose electric drive.

Induction motor drives supplied with flywheel converters, as these are so nicely and safely operated by means of Ward Leonard control, and as this permits the purchase of current on the basis of a very moderately fluctuating, smoothly changing load.

Induction motor drive can be recommended for use in mines which are not too shallow, and for installations in which a power station feeds several hoists in addition to a large amount of other mining

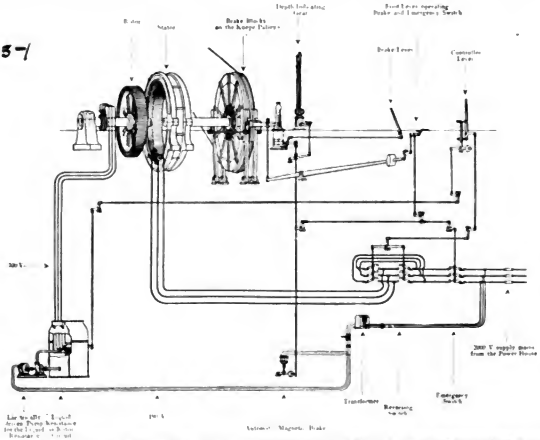


Diagram showing patented arrangement of Electrical Winding Plant as installed at "Preussen II" Coal Mine, by the Allgemeine Elektricitäts-Gesellschaft, Berlin.

Fig. 2. Wiring Diagram of Hoist Driven by Induction Motor

current from the large western American hydro-electric plants may probably be hampered by the atmospheric disturbances which are to be met with in long transmission lines; and, furthermore, by the standard frequency of 60 cycles. The slow speed hoist motors, as mentioned before, require current with a frequency of about 25 cycles, so instead of changing the frequency by means of a frequency changer set, it seems more reasonable to install D.C. hoist motors supplied by A.C.-D.C. machinery, such as fans, pumps, compressors, etc.

Hoisting plants equipped with fly wheel motor generator sets represent a steady load on the power stations. Their power house generator side has a very high efficiency, due to the good load factor. The total efficiency is decreased by the transformation losses, the losses due to the use of the slip regulator, which is inserted in the motor side of the flywheel converter, and the bearing and windage losses.

The no-load loss of the fly wheel motor generator is of serious moment in plants which run on very light duty during a large part of the day, but its influence is not of great importance in plants which "hoist fast" and have a good load factor. Contrary to the case of the induction motor hoist drive, the brake energy is regained usefully by accelerating the fly wheel, and this without any undesirable effect on the power station units.

Fig. 3. Induction Motor Hoisting Engine at Pit Preussen II

Another great advantage of the fly wheel converter is the fact that in case of a failure of the power supply, the stored energy of the fly wheel is sufficient to furnish the hoist motor with power for two lifts.

The use of fly wheel motor generators is to be particularly recommended if current is being bought from outside electricity works; for plants with a power station the main load of which consists of the power required for the hoist; and for mines in which they are forced to hoist from several levels, thus requiring several starting periods during one hoisting cycle.

The choice of the proper hoist drive, therefore, depends largely upon the existing or contemplated power station, and upon the load factor of the hoist, i.e., the number of starting periods during one cycle, the number of lifts during one hour, and the duty of the engine during various parts of the day.

The first large induction motor driven hoist was started for commercial service in December, 1902, at Pit Preussen II.

The hoisting engine is of the Koepe Disc Type, the disc having a diameter of 19.8 ft. It is designed for a useful output of 110 tons per hour, a useful load per lift of 4850 lbs. from a depth of 2300 ft., and a maximum hoisting speed of 3156 ft.-min. The hoisting motor is a 642 h.p. normal, and 1662 h.p. maximum, 50 r.p.m., 2000 volt, 25 cycle, three-phase A.E.G. induction motor with slip ring rotor.

The Koepe disc (Fig. 1) differs from the hoists that are more generally in use in being simply a pulley, around which the rope passes from two sheeves which are arranged in the head gear, whereas the more common hoists consist of either drums, around which the rope is wound, or bobbins or reels upon which the rope is wound in layers.

The friction on the circumference of the Koepe disc is sufficient to prevent the rope from slipping, while a tail rope connecting the rising and falling cages provides for balanced operation.

The diameter of the disc is made as small as possible in order to allow the highest possible speed for the driving motor. The reduction in diameter is limited by the strength of the rope and the specific surface pressure required between rope and disc for given load. The smaller dimensions of the Koepe disc, as compared with those of drums and bobbin hoists, result in a large saving of the energy required during the acceleration period, as

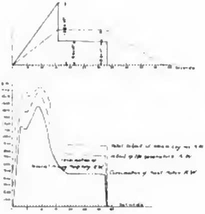


Fig. 4. Operating Curves of Hoist Driven by Induction Motor. Pit Preussen II

well as in a reduction of bearing and windage losses.

Fig. 2 shows a schematic diagram of the entire hoist plant, including the operating and brake mechanism. The operation of the hoist is effected by means of two levers, the brake lever for operating the air brake, and the controlling lever, which is connected to a double throw switch controlling the direction in which the motor is to operate, the electric circuit being open with the lever in the middle position. This same lever controls, also, the water rheostat which is inserted in the motor circuit of the induction motor for starting and speed control. As a safety device there is provided a foot operated release which opens the main circuit and throws the emergency brake in case of danger. The air brake is mechanically connected with the depth indicator and the above-mentioned main switch, as well as with a small electro-magnet so arranged that the brake is automatically set if the driver should fail to disconnect the motor at the proper time, or if the current is accidentally interrupted.

The water resistance consists of three electrodes dipping into a tank through which the water is being circulated by means of a pump operated at constant speed. The speed regulation of the hoist motor is effected by means of throttle valves which allow the water level in the tank to rise or drop; thereby covering more or less surface of the electrodes and decreasing or increasing the resistance that is placed in the motor circuit.

Fig. 3 shows the appearance of the hoist, which is of very simple design, and has worked so far satisfactorily.

Fig. 4 are operating curves showing the speed, effective output and kw. consumption during one cycle. The upper part of the diagram shows the relation between the speed and the h.p. requirements of the hoist. The speed is increased during the first 16 seconds, (the acceleration period) from zero to 3180 ft.-min. This speed is maintained up to the 33d second, at which time the current is cut off and the motor is coasting up to the 53d second. The h.p. required for the acceleration rises within the first 16 sec. to a maximum of 1380 h.p., and drops during the running period to only 540 h.p.

The lower curves show the influence of this fluctuating load on the power house, the upper dotted line the total output of the steam engine in kw., the second dotted line the output of the generators in kw., the full line, the actual consumption of the

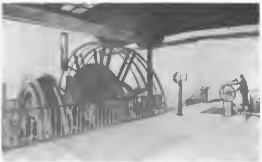


Fig. 5. Hoisting Engine Driven by 500 h. p. Induction Motor. Grand Hornu, Belgium

hoist motor in kw. The area between the second and the last mentioned lines represents the constant load of the power house, consisting of pumps, fans, etc. This curve shows very plainly the disadvantage of feeding one large induction motor driven hoisting engine from a power house when this violently fluctuating load is the main load.

A more recent plant, using large induction motor driven hoists, is that at Grand Hornu, Belgium. This plant is operating very satisfactorily and comprises three hoisting engines which are supplied from one central power house. The peaks of the hoisting engines overlap each other to a great extent, thus avoiding the large power fluctuations in the power house and improving considerably the load factor and the general economy.

Two of the three hoisting engines are identical and are direct driven, each by a 493 h.p. normal, 926 h.p. maximum, 42.5 r.p.m., 23 cycle, three-phase A.E.G. induction motor. The hoisting engines are of the bobbin type, designed for a useful output of 71.5 tons per hour, at a maximum hoisting speed of 2160 ft.-min. and a useful load per lift of 5720 lbs. from a pit depth of 3300 ft. The third unit is somewhat smaller, and is equipped with a 246 h.p. normal, 444 h.p. maximum, 37 r.p.m. A.E.G. motor designed for a one hour output of 58.6 tons, at a maximum hoisting speed of 1662 ft.-min., from a pit depth

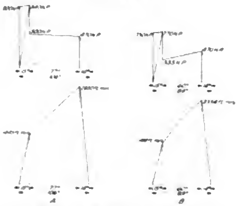


Fig. 6. Speed, Efficiency and Horse Power of "Grand Hornu" Hoist

of 2299 ft. The first engine was started for commercial operation in June, 1904.

Fig. 5 is a view of the hoisting engine, the electrical equipment of which is similar to that of the "Preussen" hoist. In

The curves, Fig. 8, refer to another Belgium plant, namely, that of the "Esperance and Bonne Fortune Mine", the hoist of which is not induction motor driven, but comprises a 250 h.p., 40 ton fly-wheel

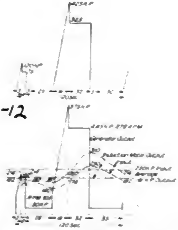


Fig. 8. Equalization of Horse Power Output by Flywheel Converter. "Esperance & Bonne Fortune" Mine

converter for supplying a 350/700 h.p. D.C. hoist motor. The left hand curve shows the characteristic fluctuating input required by the hoist motor, while the right hand curve shows the corresponding

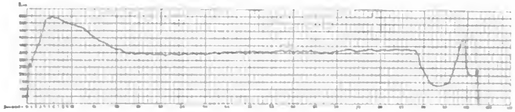


Fig. 7. Kw Consumption During One Lift of Hoist at Grand Hornu

accordance with the Belgium law, the platform for the hoist operator is raised, enabling him to see the landing.

Power is supplied from a central power house, the main unit of which is a 4000 K.V.A., 1000-1250 volt, 23.5 cycle, engine driven three phase generator, made by the A.E.G., and as a reserve there is also a 2000 K.V.A. unit.

Fig. 6, A and B, shows the relation between speed and h.p. required when lifting from various levels, while Fig. 7 shows a watt consumption curve taken with a recording wattmeter while hoisting from the 2300 ft. level.

output of the generator and the input of the induction motor from the flywheel set. These curves show the equalizing property of the flywheel converter when used in connection with a constant resistance inserted in the rotor circuit of the induction motor. An even greater equalization can be obtained when an automatic slip regulator is used.

This leads us to the discussion of hoisting engine plants with motor flywheel generator sets. The first plant was installed at Pit Wetterschacht of the Donnersmarkhutte, and was started in May, 1903, in connection with a small hoist having a useful load of 2750 lbs. to be lifted 1650 ft. at a maximum speed of 990 ft.-min.

Fig. 10 shows the rather crude flywheel set, which consists of a 123 h.p., 500 r.p.m., 1000 volt, 50 cycle induction motor; a 16.5 ton flywheel, and a 144 kw. compensated Deri type D.C. generator. The 226/355 h.p., 150 r.p.m. hoist motor drives the hoist by means of 1:6 single reduction gear. The electrical equipment was furnished by the Union Electric Co. (now merged with the Allgemeine Elektr.-Ges.) and the mechanical part by the Donnersmarkhütte. The supply systems were designed by Mr. Ilgner, the chief engineer of the Donnersmarkhütte, and represents a clever combination of a number of well known pieces of apparatus. First, the shunt motor with speed control by means of a field rheostat (or the induction motor with regulating resistance in the rotor). Second, the flywheel for furnishing peak load energy for driving the generator which supplies the hoist motor. Third, this generator, which should preferably consist of a compensated or commutating pole machine, in order that it may furnish an

Fig. 10. 125 h.p. Flywheel Motor Generator Set at "Donnermarckhutte"

excessively large current at a low voltage, as required during the acceleration periods of the hoist. Fourth, the well known Ward Leonard system of speed control for the D.C. hoist motor.

Fig. 11 is a wiring diagram of a complete outfit of an A.E.G. flywheel converter hoisting engine drive. From the three-phase supply mains, current passes through the main oil switch A O S and enters the stator of the Type M induction motor. The shaft upon which the rotor of this machine is mounted also carries a heavy fly wheel and, in addition, the armature of the D.C. generator, which latter machine is separately excited from the exciter "E".

Fig. 11. Wiring Diagram of Hoist Equipped with Flywheel Motor Generator Set

The reversing field rheostat "RCR" for the Ward Leonard control is inserted in the field winding of this generator, and by means of this small apparatus, the potential of the generator can be gradually increased or decreased, and the direction of the armature current reversed at will, thus controlling the direction of rotation and speed of the hoist motor.

E.F.S. is the emergency field rheostat, which operates by gradually short circuiting the field winding of the generator, thus stopping the current supply of the hoist motor. It is useful in event of the failure of the main reversing field rheostat, or in case of the emergency brake being applied.

The emergency brake can be operated, first, by hand; second, automatically, by means of a mechanical connection to the depth indicator (an instrument driven from the shaft of the hoisting engine, and which indicates the position of the cage), and third, automatically or at will, by short circuiting the winding of the electro-magnet "B.M.", which is inserted in the hoist motor field circuit and when energized, keeps the emergency brake in the lifted position. Automatic setting of the emergency brake takes place if the hoist motor excitation fails, and also in event of an excessive overload tripping the circuit breaker "AMC", which closes the switch "SCS".

This circuit breaker is set for a very high overload and in order to protect the induction motor against too great a load and, furthermore, to allow the drop of speed which is necessary to enable the flywheel to give up its stored energy, the slip regulator "SSR" is inserted in the rotor circuit. The rheostat is automatically operated by means of a torque induction motor "SR" supplied from a series transformer "SRT", which, in turn, is inserted in the main leads feeding the main induction motor. Thus, the torque of the torque motor increases with increasing load on the main induction motor. Attached to the

Fig. 12. Diagram of Available Winding Speeds Control Cams. Depth Indicator connected with Speed Control

shaft of the torque motor is a two arm lever, carrying on one arm three electrodes which dip in the water resistance, and on the other arm a weight, which can be adjusted to counterbalance to any extent the weight of the electrodes, and the torque of the motor. As long as the current does not exceed the desired average amperage, the electrodes are deeply immersed in the water resistance and little or no resistance is inserted in the rotor circuit; if, however, the main current becomes excessive, the torque of the torque motor overcomes the counter balancing weights and raises the electrodes in the water resistance, thus increasing the resistance in the circuit of the rotor and reducing its speed. Instead of the A.E.G. water resistance device, slip relays are sometimes used, which comprise A.C. relays that close a D.C. motor circuit, the motor, when thus started, driving the contact lever of a metal rheostat.

A necessary part of the hoisting engine equipment is the safety device by means of which the driver is prevented from accelerating or retarding at an objectionably high speed. Since, according to Ward Leonard control, the speed of the hoist motor must be practically proportional to the potential of the flywheel generator, and this potential is varied by means of the small exciter field rheostat, very simple means are required to limit the speed at which this rheostat can be operated.

Fig. 12 shows one of the various designs in use. The lower part is an outline drawing of the mechanical layout. Starting from the right hand side, we notice that the operating lever of the hoist is interlocked by means of a side rod, first with a two arm reversing lever, which operates the field rheostat, and second, with a bent lever, one arm of which rests against one of two adjacent cams. These cams are gear driven from a shaft which in turn is bevel gear driven from the above mentioned depth indicator. The stroke of the hoist operating lever is limited by the stroke of the bent lever, and simultaneously with it, the operation of the interlinked lever of the exciter rheostat. Furthermore, each point on the circumference of the cams corresponds to a certain position of the cages which are to be hoisted, since the cams are gear driven from the shaft of the hoist. It is possible, therefore, to shape the cams according to a predetermined hoist cycle speed. The center part of Fig. 12 shows the actual shape of the cams, one of which is limiting the forward, and the other the backward stroke of the operating lever. The operating lever, shown in the illustration, is in the "backward" retardation position, and a few moments before the lift is finished. The shaded lines in the upper diagram show the speed at which the operator could run, while the actual speed at which he operates the hoist is indicated by the full line; the ordinates representing the hoisting speed in meters per second, and the abcissae the time required per hoisting cycle.

Again starting from the left hand side, we notice that the hoisting speed is gradually increased until the maximum free running speed of 18 m-sec. (3560 ft.-min.) is reached, when after a few seconds the speed is gradually decreased to zero. The shaded line indicates that the operator is still able to run during a considerable time at a very low speed, a feature necessary to enable him to adjust cages, etc. Finally, however, the possibility of hoisting at even the low speed is prevented, as is shown by the two lines coming together that indicate the actual and the available hoisting speeds.

To summarize: First, after the cage has reached the landing, operation at a very low speed is possible up to a certain time; furthermore, the power is not cut off entirely if the operator should fail to shut down. Second, should he fail to stop properly, the cage is automatically brought to a standstill after it reaches a position which is dangerously near to the head gear. Third, the operator can make no mistake with regard to the direction of starting, as when the lever is in the standstill position, it can be thrown in the reverse direction only.

The safety of operation warranted by electric drive is not a matter of problematical advantage, but its value can be expressed in dollars and cents.

For instance, the German and the Austrian Governments allow a speed of 1980 ft.-min. when hoisting men by the electric hoist, while they do not allow a higher speed than 1188 ft.-min. for steam engine driven hoists. With a not very large number of miners and a depth of 1900 ft., 30 minutes of useful operating time can be saved in this way and added to the daily operation of the mine. An actual saving of $10000 per year is claimed by an Austrian mine employing 2000 miners. This, of course, in addition to the greater output of ore hoisted by reason of the increased speed and the reduction of the time required for the setting of multi-floor cages.

To be continued.

THE UBIQUITY OF THE ELECTRIC MOTOR

By F. M. KIMBALL, Manager General Electric
Company's Small Motor Sales Department

Within the past fifteen years the electric motor has became truly ubiquitous. Adopted at first on a limited scale and with considerable hesitation in connection with mechanical processes it soon found its way into printing offices where it gradually acquired an unassailable reputation as the most desirable of all small sources of power, until in this beginning of the Twentieth Century, it has been assimilated into substantially every manufacturing industry, into an unending list of general commercial applications and, more recently it has entered the domain of the home and is now fully recognized as an indispensible adjunct in connection with the mechanical or semi-mechanical processes necessitated by modern household requirements.

Applications of motors in machine shops, in connection with transportation and the more prominent manufacturing industries have been so universal that they no longer excite any comment or particular interest, the absence of electric motors in a modern factory being really more noticeable than their presence. Turning, however, to the more highly specailized motor applications we find many uses which, while little known to the public at large, are ingenious and interesting.

The power supply in many large modern bakeries is distributed electrically; the unobtrusive motor furnishes power to sift the flour —to mix the bread, see cut p. 2,—to operate the revolving and continuous ovens,—to stamp out cookies, cakes and fancy forms of pastry,—and one of the latest achievements is the development of a motor driven pie making machine which rolls out the crusts, forms them, fills the pies and delivers them to an endless belt, ready for the ovens. The paste for cakes is beaten up in a motor driven machine;—the filling for pies is prepared by means of electric power; eggs are beaten and frosting prepared by the same means and many bakers have adopted electric automobiles for delivering their wares. The substitution of the compact and cleanly individual electric drive in place of the oil-dripping shafts and dust-making and dust-carrying belts has exercised a vast influence toward ensuring a high standard of cleanliness in all the bakeries that have adopted it. Purchasers are not slow to preceive the improved conditions under which food supplies are thus produced and distribute their patronage accordingly.

Within two or three years many of the best laundries have equipped their washing machines, mangles, centrifugal dryers and wringers, collar and cuff ironers and other similar machines with motors. They have also taken advantage of the improvement in the electric flat iron to effect a substitution for the stove heated iron or the malodorous gas iron; in addition to the hygenic benefits achieved by this substitution, a large element of damage to the clothes through overheated irons has been eliminated as the electric iron can be maintained at a substantially constant temperature under practically all conditions of use.

Nearly all the large hotels and restaurants employ the electric motor for operating dish washing machines, knife cleaners, silver buffs, ice cream freezers and meat choppers,—while the dairies find the motor driven churns, bottle washers, and butter workers far more satisfactory and cleanly than the old time belt driven machines.

Stores, restaurants, clubs and markets find the use of motor driven refrigerating machines a great improvement over a reliance on ice with its drip, undesirable feature of daily delivery, uncertainty of refrigerating effect and, particularly, during the season just passed, the refrigerating machine has afforded a welcome insurance against the exhorbitant demands of the ice companies and a full protection against shortage of natural ice.

Manufacturers of velvets, silks and ribbons have recently taken up the electric drive very actively; the delicacy of the fabric wrought and the large damage done to the high-cost materials employed, due to the oil and dust thrown by belts has induced large manufacturers to adopt the individual electric drive for their looms, winding machines and in their finishing rooms. The power thus supplied, is perfectly steady and uniform, insuring increased production, and the cleanliness of the drive prevents in a great measure the damage and waste arising from the production of "seconds."

Turning to the use of motors in fractional horse power sizes,—we find a truly wonderful expansion in the field of application. Physicians, surgeons and dentists have developed many very important and ingenious pieces of apparatus for use in the particular treatment of various diseases or for performing specific operations, which require a small supply of power. These devices are frequently of the greatest therapeutic value and enable relief to be extended to patients in cases where all previous methods of treatment have failed. Among the devices so used are static electric machines, air pumps, vibrators, atomizers, centrifuges, saws, drills and cauteries.

In barber shops electric motors furnish the supply of hot or cold air for drying the hair or spraying the face after shaving. Massage of the scalp and face is also done by motor driven machines. There are, indeed, almost endless forms of motor driven massage machines and in some of the more recently equipped gymnasiums motors are employed to drive exercising machines which are adapted to develop the various muscles of the body, either collectively or locally without voluntary action on the part of the person undergoing treatment.

Thousands of small motors are used for flashing the electric signs with which our metropolitan cities are so attractively illuminated each night.

In the larger tailoring establishments motors are used for operating sewing machines, cutting machines and sponging cloth.

Much of the manifolding apparatus, now so important an adjunct of the modern business office, is driven by electric power and recently a motor driven office phonograph,which is largely used to supplement the work of stenographers, has been widely marketed.

The immense number of batteries formerly required in all telegraph offices has been largely superseded by the small motor-generator set, the care and maintenance of which does not involve a fiftieth part of the expense necessitated in keeping the battery cells renewed and in proper condition.

Improved railway signals are operated by small electric motors and the larger department and mail order stores have adopted electrically operated letter sealing machines which close and seal envelopes with wonderful rapidity.

During the past two or three years a vast number of domestic sewing machines have been equipped with motors to the extreme satisfaction of the ladies and with the elimination of the most disagreeable feature of machine sewing.

Very satisfactory electrically driven washing machines are also now coming on the market for domestic use and these, in connection with small motor driven mangles materially ameliorate the strenuous activity of washing days.

A recent application of the small motor is in connection with floor waxing machines. The growing popularity of hard wood floors has necessitated the invention of special methods for their care and these machines do the work in a much superior manner to hand work and with a fraction of the labor. They were first brought out in Germany but improved forms have recently been manufactured in America.

A very effective form of carpet sweeper is supplied with a small motor to revolve the brushes and a recent motor driven appliance embodies a domestic vacuum cleaning process by means of which a great part of the labor of daily sweeping and dusting, as well as the semi-annual house cleaning, is eliminated.

A recent invention consists of an electrically operated carpet renovator which is used very much as the carpet sweeper is used; it beats the carpet or rug in place, brushes up the dust and, by means of an exhaust blower sucks the dust and lint into a dust proof receptacle, thereby rendering the operation of rug cleaning much more complete and less offensive than is ordinarily the case.

Many of the popular mechanico-musical instruments rely for their successful operation on the motor drive; the phonograph, the graphophone and other talking machines are all so driven, as well as many forms of self-playing pianos and organs. The bellows boy in the organ loft of our churches has been retired in favor of the motor driven blower and even the clocks in our church towers are now being automatically wound by electric power.

The inventors of the country have become fully aroused to the large and profitable field of motor applications which has been opened through improvements in the quality and reliability of small electric motors and the reduction in their price and they are daily finding new uses for them in novel and labor saving applications. Although progress in the adaptation of small motors to commercial and domestic uses has been so rapid and has covered such a wide field, the ultimate possibilities are as yet but faintly realized. The first decade of the Twentieth Century finds the electric motor in common use; in the second decade its employment will be almost universal.

THE SYSTEM OF THE NEW YORK EDISON COMPANY

By S. D. Sprong

Part II

All relays and instruments are provided with permanent switches in series, so that if necessary, they may be readily adjusted and checked, even while the circuits are in service. As a record of the load curve, and also as a check against the recording wattmeters on the generators, half-hourly readings of the indicating wattmeters on the generators are taken; and on peak lead the readings are taken every quarter hour. These readings are integrated for each day and month. As an indication of the high average accuracy of the meters, the monthly readings of the indicating and recording instruments usually check within ½ of 1%, and are never out more than one per cent. without the error being accounted for.

The distribution of all current from both Waterside stations is under the exclusive control of one man who is called the system operator, and who is the exact equivalent of the train despatcher of a steam railway system. He has entire control of the system, including the Waterside stations. Feeders and rotaries are put into or out of service only on his order, and he receives at frequent intervals, reports from all the sub-stations, giving the load on each of the high tension feeders, and the reserve held in the storage batteries.

In front of the system operator is a large outline map of the city, with all the stations and high tension feeders painted in. Small hooks are fixed at the feeder ends, on which the operator places a blue tag if the feeder is dead, or a red tag giving the load on the feeder if it is in use. When a feeder is tied through one station to reach another, it is shown on the operator's board by a piece of elastic ribbon with a ring on each end, which are placed over the feeder hooks, thus completing the connection through the station. In this way the system operator can tell at a glance what feeders are connected to Waterside bus, their routes, and the loads they are carrying. If a feeder is being held off for repairs, this is also indicated by a tag.

The means of communication between the system operator and the sub-stations was worked out with considerable care to avoid interruption of the telephone service. The operator's desk is a special form of telephone central board, located within the glass inclosure of the operating gallery. From this board one or more trunk lines run to every sub-station, the lines leaving Waterside by two independent routes.

Where the telephone trunks enter the basement of Waterside station, branches are tapped on and carried through a separate conduit to a point within the bus house, where a duplicate switchboard is installed. This reserve board may be used if for any reason the regular board becomes inoperative, or the location untenable.

As an auxiliary to the telephone, we have recently perfected after considerable experimentation, a signal system somewhat on the lines of a fire alarm. Its principal purpose is to convey to all the sub-stations simultaneously, certain easily interpreted signals that will reach the operator in whatever part of the station he may be at the moment. Under certain conditions, the system-operator may have reason to apprehend more or less extensive trouble, consequently all the sub-stations should be notified immediately. For the system operator to notify serially about twenty stations by telephone would be a very slow method, and absorb his entire attention at a critical time. We have therefore arranged to install at the system operator's desk, a series of ten signal buttons. These are connected in multiple to the private telephone trunk lines to all sub-stations.

By pressing any button, its particular signal will be announced on a large gong in all the stations of the Company simultaneously. The most important is the "Stand By" signal, cautioning the operators to have their apparatus and batteries arranged in the best way to meet a possible system disturbance.

By the use of sensative D. C. relays and high impedance coils, the signal system is connected directly to the telephone lines without interfering with their use telephonically, and without the ringing current operating the relay.

As already stated, both Waterside stations are situated on adjacent city blocks. The conservatively rated capacity of No. 1 is 58,500 kw., and No. 2, when fully equipped, will have a rating on a similar basis of about 80,000 kw., but with an overload capacity of 120,000 kw. It is our present intention, and has been the practice to date, to operate both stations as one, by means of heavy ties between the high tension buses.

There are four sets of ties, with a combined normal capacity of 45,000 kw., connecting their respective sections of bus. The conductors are 1,000,000 c. m., with varnished cambric insulation and lead

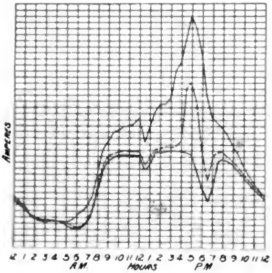


Fig. 1. Load Diagram

covered. Each phase is carried through a separate line of tile conduit, and at each end has two 1200 ampere oil switches in series, or four oil switches in series on each tie between the buses of the two stations. The interconnection of the excitation buses has already been described.

Speaking geographically, the relative locations of boiler and engine rooms of the stations are the reverse of each other, thus bringing the boiler rooms on opposite sides

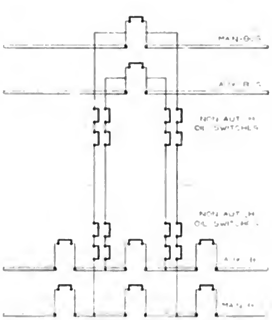


Fig. 2. High Tension Connections between Waterside Stations, New York Edison System

of 39th street. The steam and water mains of both stations are interconnected through tunnels under the street, in this way uniting the mechanical as well as the electrical elements of the generating equipment.

For communication between the operating galleries, there has been installed the usual telephone system, and there will be in addition a pneumatic tube. To insure the greatest possible safety for the workmen, all high tension feeder and switch work is carried on by an elaborate system of written orders and receipts, and it is for the transmission of these that the pneumatic tube is provided.

It may be reasonably questioned whether the operation of two such large stations in multiple insures a larger factor of safety to apparatus and service than independent operation. To the apparatus, of course it does not, but our experience has demonstrated its real value to the service in every-day operation because of the obvious fact that the greater the capacity in multiple, the smaller will be the effects of a short-circuit on the system. The fact that nearly all the converting apparatus is of the synchronous type, and that the capacity connected at any one time is above 120% of the generating capacity, adds materially to the stability of the system under momentary short-circuit.

The first principle of independent operation would be the possibility of either or both generating stations supplying any sub-station. This provision requires elaborate precautionary measures to prevent connecting the systems together; greater care and deliberation in the ordinary operation of the stations, and in the confusion and uncertainty arising from emergencies, less assurance and promptness on the part of the operators and a generally lower "factor of precision" in the Operating Department. The uncertainty as to time and the wonderful variety of situations that accidents bring about without a moment's notice, make it incumbent on the engineers to provide means to insure operating stability by the simplest means possible. After these have been provided there remain but two elements in reserve for cases of trouble, which have to be depended upon to put the system on its feet again—the storage battery, and the operator on duty. To insure high efficiency at this critical time, the capacity of both should be expended on the main object, as directly, and with as little complication as possible.

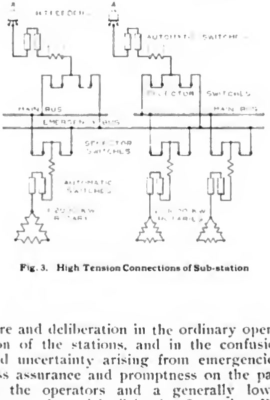


Fig. 3. High Tension Connections of Sub-station

Leaving Waterside stations, the usual precaution of routing feeders to the same sub-station by independent routes is employed. The two feeders making up one group are arranged to supply widely separated sub-stations, and no sub-station is supplied exclusively by feeders from any single section of Waterside bus.

Entering the sub-station, the feeder is carried through iron pipe, or clay conduit, to the terminals of a large capacity oil switch. The pipe is used where space is limited or canters are close together, or where there are a number of bends in the run.

The high tension bus arrangement in the sub-stations comprises a general or emergency bus, connecting to all feeders and machines, and a sectional main bus with a feeder for each independent section. To this section of main bus is connected a capacity of apparatus equal to the normal capacity of the feeder, or about 2000 kw. The feeder may, however, be connected to the emergency bus, thus making it possible to put any machine, or group of selected machines, on any feeder.

The oil switch on the feeder has an overload relay similar to the Waterside end, but adjusted to a somewhat smaller load. From the automatic switch, the feeder is connected to the common point between two non-automatic oil switches, which act as selectors to throw the feeder on either the emergency bus or the sectional main bus. The equipment on the high tension side of the converters is a duplicate of this, but used in the reverse order, that is, first selecting one of the buses mentioned, then through the automatic switch to the high tension side of the static transformers, which are connected in delta. All oil switches are remotely controlled from the D. C. switchboard. The 170 volt secondary side of the transformers is connected in double delta, six phase, through an induction regulator, to the rotary converter.

In reference to the regulator, I might anticipate a little to explain that the new 1000 kw. converter equipments now on order will not include an induction regulator.

Equivalent regulation will be obtained by what is, in effect, an auxiliary 150 kw. A. C. generator, mounted on the rotary shaft between the collector rings and the armature body. The low voltage winding on the small generator will be connected in series with the taps from the collector rings to the winding on the converter armature. By varying the strength and direction of the fields of the auxiliary generator, a suitable voltage range on the A. C. side of the converter armature will be obtained.

Of the sub-stations in operation, the largest has a total capacity in converters of 11000 kw. The size of the converter units in general use are from 500 to 2000 kw.

All converters are started from the D. C. and without difficulty, although the connection between the A. C. side and the secondary of the static transformers is left closed. About 25% full load current is required to start in this manner. There is a difference of less than 10% when the secondary circuit is open.

The converters are connected to the D. C. bus through a shunt operated circuit breaker on one side, which affords ample protection if the rotary frame is not allowed to become grounded. 1/10 ohm or more is sufficient to prevent a dangerous current flow to ground. The circuit breaker is normally left closed, but may be opened either by hand or a speed limiting device mounted on the end of the rotary shaft. Experience has shown that the circuit breaker must positively trip at as low as 12% of normal voltage, if a run-away of the rotary is to be prevented under certain conditions of depressed voltage.

From the D. C. buses, 1,000,000 c. m. concentric feeders supply the outers of the 3 wire net work. No fuses or automatic disconnecting devices are employed on the feeders, or anywhere on the distributing system except at the service inside curb line on the customer's premises. There is nothing to be feared from a short-circuit on a 1,000,000 c. m. concentric feeder on a 270 volt bus, as the current never reaches more than 200% of normal full load.

The concentric feeders referred to as 1,000,000 c. m., are in reality made up of an inner conductor of 1,022,000 c. m., and an outer conductor of 979,000 c. m., or a difference of about 4% in favor of the inner.

Fig. 4. Switch on Positive Side of 2000 kw. Converter. Sub-station, New York Edison System

By making the inner conductor of 4% lower resistance, partly offsets its natural increase of resistence resulting from the higher temperature it necessarily attains under load.

This disparity in temperature between the inner and outer conductors becomes rather marked, as tests show that after a five hours' run at 1000 amperes, the outer attains a temperature of 53° C. and the inner 63.5° C. or a difference of 10.5 degrees. These readings were taken on an ordinary winter day, with a cable temperature at start of about 4° C.

As all current from the converters and feeders is fed into the three wire net work at 240 to 300 volts on the outers, the neutral is determined by the battery which is always floating and can satisfy sudden demands of unbalancing.

The battery is assisted in maintaining the neutral by the usual balancer set, made up of two 75 kw. 150 volt shunt wound generators with armatures mechanically coupled.

This set will take care of a neutral current of 1200 amperes, which is ample capacity, as the unbalance on each station is usually less than 100 amperes. This remarkably small neutral current is the result of the rigid requirements of the Company that all lighting above five amperes

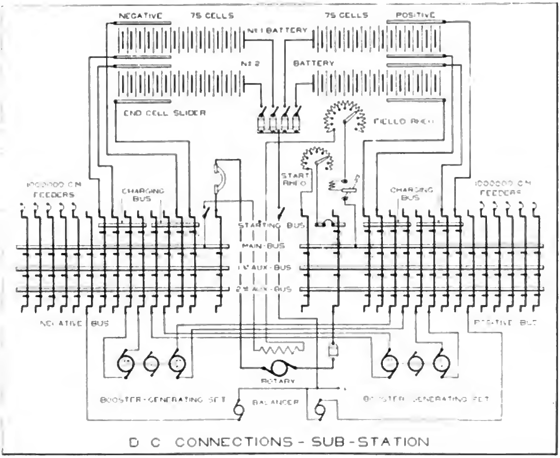


Fig. 5.

Diagram Showing Low Tension Circuits and Connections in Sub-station of New York Edison Company must be equally divided on the three wire system, and all motors over five horse-power must be supplied from the outers at 240 volts. This careful balancing of the load is carried to an extreme in New York, and to a far greater extent than on any other Edison three-wire system.

The sub-stations are provided with the usual D. C. instruments of the edgewise pattern. The ammeter on the converter having zero in the centre of the scale, so that the current necessary to start the rotary, the extent of any reversal, or its load when operating inverted, may be observed. Each machine has a power factor indicator enabling the operator to maintain 100%. All synchronizing is done on the dark period; in Waterside stations by means of lamps, voltmeter and synchroscope in multiple; in the sub-stations, by a lamp and hot-wire voltmeter in multiple, one acting as a check on the other. Automatic synchronizing has never appealed to us very strongly. In railroad work, where the voltage and load fluctuate abruptly, it may be a valuable aid in the prompt handling of the apparatus, but in a lighting system the conditions are quite different. If placed in series with the circuit controlled by the operator, and in this way acting as a check on his judgment or attention, it might prevent some trouble.

Experience suggests the general principle that there should be avoided as far as possible, any arrangement of apparatus that, for its proper use, fixed sequence of manipulation is necessary.

Where this condition cannot be avoided, automatic interlocking should be resorted to, as it may be said, and without disparagement, that no amount of experience, training, or knowledge of consequences, will eliminate that peculiar frailty in the human makeup which sometimes permits an operator to reverse the usual order of handling his apparatus.

A system should therefore be reduced to its lowest terms of simplicity, not only for regular operation, but because the difficulties of complication become emphasized in cases of emergency.

The New York Edison system has the proud record of never having been completely shut down since it was established and regularly operated as a commercial enterprise—covering a period of nearly 25 years, (1882-1907.)

In contemplating the use of Edison service, the question is never asked by residents of New York as to the possibility of the current supply failing. Even with this honorable record, every possible provision should be made for such a contingency.

Notwithstanding the consistent simplicity of the system, it was only after the most careful consideration, and extensive eperimentation covering a period of some months, that a method could be formulated which appeared to entirely meet all the conditions necessary for positively starting up the system from shut-down.

The rules, printed in pamphlet form and issued to all operating department employees, are in outline as follows:

On the first word of extensive trouble on the high tension system, all D. C. feeders are thrown on the auxiliary bus, thus clearing the main bus to which all converter fields, auxiliaries, station lighting and control circuit are connected; the storage batteries remaining connected to all buses. If the cessation of alternating current supply is prolonged and the batteries become exhausted to the point where the lamps in the station give no useful light, the batteries are disconnected from the auxiliary buses, thus cutting the D. C. network clear by the throw of one switch, and reserving the remaining charge in the battery to supply the station lighting and auxiliaries through the main bus. Even after the exhaustion resulting from such severe service, the battery will be immediately capable of supplying all station demands for a considerable time. Tests have shown that after a battery has been discharged under heavy overload down to a terminal pressure of only 30 volts, it will, when relieved of the overload, come back to 120 volts within one minute and carry 600 amperes at about this voltage for 1½ hours.

All converters being at standstill, and all high tension feeders dead, one or two converters, as the load on the sub-station may require, are closed on a high tension feeder, designated by the system operator.

The D. C. switches and field switch are open. At Waterside, a generator, preferably a turbine because of its uniform acceleration, is at standstill and connected to the bus, the generator having maximum excitation. On word from the system operator, the generator is started very slowly and gradually brought up to about 1/3 speed, or 6 to 8 cycles. When the generator starts, all the converters start promptly, taking about full load current at first. After they have a fair start, the field switches are closed for a few seconds on the discharge clip, which gives the fields only a trace of excitation, but enough to properly fix their polarity and bring the converter approximately into step, when the field switch is finally closed. The frequency and voltage are held low so that the converters may be closed on the D. C. system at the minimum possible pressure, which is about 1/3 normal.

As most of the converters will be fully loaded under these conditions, the frequency is held low in Waterside till additional converters can be started from the direct current furnished by the one already running, and synchronized with the system. As this synchronizing is done at very low frequency and voltage, the ordinary instrument and lamps are not suitable. As great accuracy is not essential, a special lamp is used which is a modification of the familiar Hylo type. The switch is in the lamp base and connects the regular 250 volt filament when screwed into the socket. By turning the lamp backward about ⅛ turn, the large filament is disconnected and a 60 volt filament substituted.

Additional generators at Waterside are started and synchronized with the first one, using a special synchronizing plug having a low voltage candelabra lamp mounted in it. In starting up with a turbine, it is impossible for the engineer to observe the speed with any accuracy, and as a low range frequency indicator could not be obtained in the market, we developed in our laboratory an indicator having a range from 5 to 30 cycles.

It has been well said, that to do a thing well in an emergency, it should be done as often as possible before the emergency arises. Therefore starting up drills are regularly practiced, and they are so arranged that some of the apparatus and operating force in every sub-station is included in a drill at least once every month.

In closing allow me to refer briefly to some data corrected to January 1, 1907, on the commercial scope of the New York Edison Company. We have twenty-three sub-stations, with a battery capacity at the three-hour rate of 9000 kw., and an aggregate capacity in converters, batteries and a few remaining direct current generators of 110,000 kw.

The total lengths of high and low tension feeders and mains, all of which are underground, are: 183 miles of high tension feeder; 37 miles with rubber insulation, installed previous to 1899, and 146 miles with paper insulation, installed subsequently; 225 miles of low tension feeders; and 483 miles of mains. The maximum load for 1906 was on December 17th, and amounted to 683,000 amperes, at 142 volts, or 97,000 kw. at the D. C. bus. The total connected load in 16 candle-power equivalents, is 4,762,000, made up of 2,243,000 incandescent lamps, 32,300 arc lamps; 92,000 16 candle-power equivalents in miscellaneous uses, and 139,000 horsepower in motors.

I wish to refer especially to the very extensive use of electric motors as shown by these figures; covering every class of service from the smallest to that of the greatest importance, as illustrated by the motor driven air compressors in the tunnel work under the North and East rivers for the Pennsylvania R. R. Co. There are two air compressing stations. The one on the East side of the City has compressors directly connected to 500 kw. 250 volt direct current motors. The compressors operate continuously, but supply air intermittantly as required by the work, the demand controlling the supply through automatic governors. The load is therefore a variable one and fluctuates irregularly between zero and full load. The equipment in the West side station is similar, except that the compressors are driven by 3-phase 6600 volt induction motors directly from our high tension system.

The D. C. motor has practically absorbed the power distribution field, as the few remaining gas engines are rapidly disappearing and no new installations are being made. The superiority of the Edison D. C. system is fully attested by the magnitude of the Company's business; the almost infinite variety of uses to which it is successfully put, and the reliability of service which can be secured under principles permitting the efficient use of means to that end. I refer to the use of storage batteries directly on the system, and the fact that with a network, all mains are supplied from both ways and no section is dependent on any feeder or group of feeders.

All districts of the City are connected together in one solid network. This adds immeasurably to the rigidity of the system, as illustrated by the fact that a 1,000,000 c.m. feeder is occasionally burned off without attracting the attention of the operator, or in any way affecting the system. The sub-stations feed into the network through 1,000,000 c.m. feeders at such points as will give them their share of the load. The problem is to maintain constant and uniform pressure, which is met by having three bus voltages and transferring the feeders from one to the other as the changing load conditions require.

The application of the D. C. system to electric elevator service has been of the greatest importance, both to the Company in the completeness with which it can handle the entire service of large buildings, and the use of a larger percentage of the total flour space it secures to the property owners.

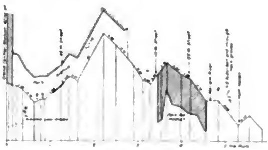
The substitution of Edison service for isolated plants is common also as a reserve or "break-down" for such plants, and to supply night service, the plant operating only during the day.

The commercial position won for the New York Edison Company by years of enterprise, and liberal treatment of both engineering and commercial problems, is secure, and I believe you will agree that it is in the fullest and most comprehensive sense of the term, a Public Service Corporation.

TRACTIVE POWER OF ELECTRIC LOCOMOTIVES

The following is copied from the Railroad Gazette of May 10th:

"On the afternoon of April 26, northbound train No. 19 (Lake Shore Limited), consisting of nine heavy Pullman cars hauled by a Central-Atlantic type steam locomotive, was disabled and stopped in the tunnel on the 0.5 per cent. up-grade



Profile of Road from Grand Central Station to Mott Haven

under 66th street, New York City (see profile). Following this train was a local train of seven standard day coaches hauled by one of the new electric locomotives. The electric locomotive, coupled on behind No. 19 and pulling its own train, started the entire load on the grade without assistance from the steam locomotive, which was dead. The 16 cars and two locomotives weighed approximately 1,000 tons. The electric locomotive started with good acceleration and pushed No. 19 north to 125th street up the 1.02 per cent. grade one-half mile long from 72nd street to 83d street, without any difficulty and at good speed.

Of the 477 trains now entering and leaving the Grand Central terminal, 135 are New Haven trains handled by steam locomotives, and the remaining 342 trains are New York Central. Of the 342 trains, 280 (equal to about 82 per cent.), are now handled electrically, and it is expected that the remaining 62 trains will also be handled electrically within the next week or two. The partial change to date has resulted in a marked improvement in the visual conditions in the Park avenue tunnel."

INTERNAL COMBUSTION ENGINES FOR AUTOMOBILE AND MARINE PURPOSES

By H. S. BALDWIN

The following paper refers to engines of constant volume, rather than those of constant pressure, as, for example, the Diesel or Brayton types. I say this, since all automobile and marine engines are built on the constant volume principle, and time will not permit of a discussion covering more than the subject of my talk.

Historical and General

It is always interesting to know the beginnings of things, so I will speak briefly of the early inventors and experimenters who devoted their time and thought to the subject of internal combustion engines; but before doing so, it would be well to define motors of this type as those in which fuel—usually in the form of an explosive mixture of gasoline vapor and air, sometimes as a liquid—is drawn into a cylinder, where it is compressed and ignited, causing sudden expansion, or, as we say, explosion, the energy of which is converted into useful work by means of a sliding piston. In order to utilize this straight-line motion so that it can be made to propel automobiles, power-boats, or shafting, it is necessary to change it into rotary motion, and this is done by means of the connecting rod and crank-shaft, exactly as in the case of the steam engine with which you are all familiar.

It should be remarked in passing that all small gasoline engines are single-acting, it having been found impractical to pack the piston-rod, as in the double-acting steam engine, on account of the high temperature within the cylinder. A single-acting engine may be defined as one in which work is done on only one side of the piston. Even in the case of the single-acting gasoline motor, the problem of lubricating the piston and cylinder walls is not a simple one, but it is much facilitated by the cooling effect of the jacket water. Later in this paper, under the head of "Cylinder and Crank Arrangement," I will say a few words regarding stationary gas engines for large power units which, on account of their size, may be made double-acting.

About 1678, one Abbe Hautefeuille conceived the idea of operating a motor by means of gunpowder. I have no record at hand to tell of the results of his experiments, but it is safe to say that they were not highly satisfactory, as the proposition of rapidly supplying solid explosive matter to a red-hot explosion chamber would naturally be a very serious one. Perhaps the Abbe in the course of his tests became careless; "didn't know it was loaded," so to speak, and thus did not live to make any record of his work.

From the above date down to 1861, many attempts were made to build motors of the internal combustion type, and while none was wholly successful, we must recognize the efforts of these early inventors as of great value in keeping alive and developing the idea which we now see worked out in practical form in the modern gasoline motor.

Four-Cycle Motor

In 1861 a French engineer, by the name of Beau de Rochas, laid down the following fundamental principles on which explosion engines should be designed, and, with the exception of the second proposition, these are recognized as correct to-day.

First. Maximum cylinder capacity with minimum circumferential surface.

Second. Maximum piston speed.

Third. Greatest possible expansion.

Fourth. Maximum pressure at the beginning of expansion.

The reasons against high piston speeds are practical limitations in the mechanical design of the engine, it having been found that a cylinder of great length gave awkward proportions, while the other alternative—short stroke and high rotative speed—caused the moving parts to wear rapidly.

Thus it was Beau de Rochas who invented the four-cycle, or, more correctly, the four-stroke cycle gasoline engine of to-day. The word cycle is derived from the Greek word meaning circle, and in this connection it refers to a complete series of events in the engine cylinder; namely, suction, compression, expansion, and exhaust, which require four piston

A paper presented before the Lynn General Electric Engineering Society.

strokes or two complete revolutions of the crank-shaft.

In a vertical cylinder engine the first downward stroke of the piston draws in an explosive mixture of gas; the return stroke compresses this charge, which is ignited when the piston has reached approximately the top of the cylinder; the second downward stroke is a working one caused by the expansion of the exploded gas, and the final stroke upward is the exhaust, and clears the cylinder of burned gas preparatory to a repetition of the cycle.

While Beau de Rochas was the first to tell *how* all this should be done, it remained for Dr. Abel Otto, a German scientist and mechanic, to construct the first practical four-stroke cycle engine, which he did in 1877; consequently it is not strange that we sometimes hear the term "Otto cycle" used to describe this type.

Builders and users of four-stroke cycle engines invariably call them "four-cycle" motors, and this is the term we shall use hereafter.

Two-Cycle Motor

There is another type of explosion motor, used largely to propel small power-boats, and which is receiving considerable attention in connection with automobile work, although at this date there are only two makers of prominence in the United States employing it. I refer to the two-stroke engine, or, as it is commonly known, the two-cycle engine. A patent was issued in England in 1838 to a William Barnett for a two-cycle engine, and to him is given the credit for first compressing the explosive mixture in a gas-engine cylinder before igniting it. You will note that Barnett worked twenty-three years before Beau de Rochas. From what records I have available, it seems that Barnett did not perfect his motor and that the first practical two-cycle engine was made by Mr. Dugald Clerk in 1880. The Clerk engine gave a power stroke for every revolution, which you will note is twice as many as in the case of the four-cycle engine. This result was accomplished in the following manner:

An auxiliary pump was operated by the crank-shaft, giving an initial pressure of four to six pounds to the gas charge, the object of which you will see immediately. The first downward stroke of the piston of the engine caused a partial vacuum to be formed. Now when the piston had nearly reached the end of its stroke, it uncovered a hole or port in the cylinder which allowed atmospheric air to rush in, after which a second port was uncovered and a charge of gas under pressure was injected into the cylinder, mixing with the air and forcing some of it out. All this for the first downward stroke. In ascending, the piston first covered the gas port, then the exhaust port, after which the charge—having no means of exit—was compressed until the piston reached approximately the top of the stroke, when it was ignited. While the upward stroke was taking place, the gas pump was at the same time sucking in a charge to be compressed during the following piston stroke, at the end of which it was injected into the cylinder. You will readily see that an engine of this kind has one working stroke for every revolution.

Clerk's construction has been modified somewhat in mechanical detail in the present two-cycle engine, but its principle has been retained. Almost all two-cycle engines now built, either for marine or automobile purposes, draw the vapor charge into the crank-case, where it is compressed by the downward stroke of the piston, thus doing away with the above-mentioned pump.

There is another form of two-cycle engine, which is termed the "three-port" type. We call it the "three-port" type for the reason that an additional port is provided in the cylinder wall for permitting the gasoline vapor to enter the crank-chamber. This port is closed and opened at definite times by the movement of the piston, which does away with the inlet valve ordinarily employed on two-cycle engines.

Fuels

It may seem strange that so many years were required to develop the internal combustion engine, but we must remember that the early explosives were of a solid nature, as, for example, gunpowder, and that these could not be put to practical use.

Gas was made from coal by the Rev. Doctor Clayton in 1739. He called the porduct "spirit of coal," and obtained it by heating coal in a retort. Doctors Hales and Watson mention the properties of coal gas in treatises written by them at about this time. The idea of using coal gas for purposes of illumination seems to have originated with Mr. William Murdoch, of Redruth, Cornwall, England, who in 1792 made very complete apparatus for generating gas. In 1798 Murdoch improved his methods and constructed a gas plant for the celebrated steam engine shop of Boulton & Watt at Soho. This was first publicly illuminated in 1802 and aroused the greatest enthusiasm.

Naturally the discovery of a gaseous fuel created new interest in internal combustion engines and much experimenting resulted, but it was not until crude oil and its products of kerosene, gasoline, and benzine were available that the small power gas engine of practical form appeared. Petroleum was discovered in England as early as 1847, and in America about 1854. As you all know, crude oil or petroleum is a natural product which is obtained in certain parts of the world, principally in this country and in Russia, by drilling holes deep into the ground. Our greatest oil fields are in and near Pennsylvania, and in some of the Southern States. By heating crude oil in a retort or still, it is made to give off vapor, and the degree of temperature regulates the kind of distillate or product.

The following table is interesting and shows how little gasoline is obtained from petroleum, also all the separate products with the percentage of each:

Products.	Per Cent. Each.	Specific Gravity.
Gasoline,	2	0.650
Benzine,—naphtha,	10	0.700
Kerosene, light,	10	0.730
" medium	35	0.800
" heavy	10	0.890
Lubricating oil,	10	0.905
Cylinder oil,	5	0.915
Vaseline,	2	0.925
Residuum and loss	16	
	100	

Practically all explosion engines of small power and many large ones derive their energy from some one of these oils, which are called hydrocarbons.

Petroleum not only furnishes the fuel, but cylinder oil for lubricating the piston and cylinder walls. This is a heavy mineral oil which will withstand high temperatures and yet retain its lubricating properties. Without cylinder oil the gasoline engine would not be possible, so you will readily appreciate what an important event was the discovery of crude oil.

Various other gases used in internal combustion engines are:

Natural Gas, which is obtained directly from the earth in certain places.

Acetylene Gas, liberated by the action of water on calcium carbide.

Producer Gas, made by the limited action of air alone upon incandescent fuel.

Water Gas, made by the action of steam alone upon incandescent fuel, and

Semi-Water Gas, made by the action of both air and steam upon incandescent fuel.

These are used in the large stationary engines, with the exception of acetylene gas, which, on account of its expense, extremely disagreeable odor, and bulky form of the carbide, is not used at all now, although a few years ago some small motors were constructed for this purpose.

Alcohol

There is one other fuel to which I want to call your attention, and an important one it is. I refer to alcohol, which for several years has been receiving a great deal of attention throughout the civilized world with a view to making it more available for the manufacturing arts and especially for explosion engines. Last year Congress passed the Payne Free Alcohol Bill, signed by President Roosevelt June 7, 1906, which was intended to permit farmers to distil ethyl alcohol from decayed or refuse vegetation, on the condition that it be "denaturized" by the addition of a certain percentage of methyl or wood alcohol. Prof. Elihu Thomson was deeply interested in this bill, and the data and scientific facts which he presented before the committee of Congress without doubt had much to do with its passage.

While the new law was a great achievement and represented a distinct advance, it nevertheless imposed conditions on the would-be distiller which rendered it impossible to produce denaturized alcohol at a profit, and for this reason steps are now being taken to strip the law of some of its cumbrous features and make it workable.

One of the defects was the explicit stipulation that a certain amount of wood alcohol should be the denaturizing agent. It happens that the production of wood alcohol is controlled by large combined interests, such as the Standard Oil Company, and for this reason the farmer could not use it profitably to mix with his grain alcohol. Another serious obstacle was the requirement that all alcohol be placed in bondage storage. In Germany, where the internal tax was provisionally removed several years ago, they have a practical system which is somewhat as follows: There are government inspectors appointed to look after the manufacture of alcohol in a given district. When a farmer wishes to distil alcohol he sends for the inspector, who calls and inspects the retort and other apparatus, sealing the receptacle into which the alcohol flows from the still. The farmer is then free to work his still whenever he wishes, until the sealed tank is filled. He must then call in the inspector again, who sees that the alcohol is either immediately denaturized, or imposes the imperial tax if it is to remain pure. Some small fee is collected by the inspector for his services. They employ a cheap denaturizing agent, such as bone oil or the like, which adds little to the cost of the alcohol.

As the subject of alcohol, in this connection, is a comparatively new one, I will take the liberty to speak somewhat fully regarding it as a fuel for explosion engines, especially in comparison with gasoline.

Taking gasoline as essentially Hexane $C_6 H_{14}$ and assuming that the alcohol used contains 90% of pure $C_2 H_6 O$, it can be shown that nearly twice (1.94) as much alcohol as gasoline, by weight, is required to chemically unite with all the air taken into a given cylinder in one suction stroke.

The heat of combustion of gasoline is 19,000 B. T. U. per pound, and that of alcohol 10,000 B. T. U., or approximately one-half, which accounts for the above figures.

Now alcohol (specific gravity .81), is heavier than gasoline so that the ratio 1 to 1.94 reduced to terms of bulk becomes 1 to 1.7. In other words, theoretically 1.7 gallons of alcohol would be required for one gallon of gasoline in a given engine designed to use the latter fuel. There is a peculiar property of alcohol vapor which permits it to be compressed in the explosion chamber of an engine, without preignition, to nearly double the pressure possible with gasoline vapor. The significance of this fact is clearly that when alcohol is used in a specially designed engine, it has a thermodynamic advantage over gasoline, and an actual experiment, testified to before the committee of Congress, showed that a motor which gave 10 B. H. P. with gasoline, gave 11.3 B. H. P. with alcohol fuel, without any change in the engine whatever. If these figures be correct, the equivalent, in actual practice, of 10 gallons of gasoline would be 15.4 gallons of alcohol, which would mean that we must have 10-cent alcohol to compete with 15-cent gasoline when used in an automobile engine with no change. As all small engines are at present designed with compression spaces adapted to gasoline, it is very possible that Benzol $C_6 H_6$, or some other chemical, may be added to alcohol so that its combustibility and thermodynamic characteristics may become more nearly those of gasoline, as far as engine output is concerned, as distinguished from potential energy, which would not be changed.

I will cite a recent comparative test made to show the thermal efficiency of each fuel when used in an engine especially designed for it:

Highest thermal brake efficiency, alcohol 31.5%

Highest thermal brake efficiency, gasoline 23%.

On this basis the equivalent of 10 gallons of gasoline is 12.4 gallons of alcohol. So if gasoline sells for 15 cents per gallon, alcohol must sell for 12 cents in order to compete with it in point of cost.

Alcohol is now being manufactured in Cuba for 10 cents per gallon, and United States Agricultural Department experiments have demonstrated that it can be produced from corn-cobs at three cents per gallon; this, however, is a remarkably low figure, and a price of 12 cents probably more nearly approaches the actual cost per gallon, but it cannot be long before its selling price will be down to that of gasoline or below it.

$$L_r = \sqrt{(0.0378 - 0.056)^2} = 0.0182$$

If the transmission line is 150 miles long, operates at 25 cycles, and carries 96 amperes, we get:—

$$\text{the induced E.M.F.} = 2\pi \frac{25 \times 0.0182}{10^3} \times 96$$

$$= 0.2748 \text{ volts per mile.}$$

$$\text{or } 150 \times 0.2748 = 41.2 \text{ volts.}$$

It is evident from the above that the induced E. M. F. depends largely upon the actual position of the two telephone lines in reference to the power lines.

It is an advantage to have the plane of the two telephone lines parallel to ground, since then the difference of the two distances between any main line conductor and the telephone conductors is a minimum. It is undesirable to have the plane of the telephone line at right angle to the ground. Furthermore, the greater the distance between the telephone lines, the larger is the inductance.

Thus, the worst condition is to have one telephone conductor only, and to use the ground as return, since this condition introduces both undesirable elements.

As is seen, the induced E.M.F. is proportional to the current, thus if the phenomena is prominent, the difficulties in communicating should increase with the current and be, perhaps, specially prominent with rapidly charging currents. Transposing the three wires will overcome this trouble.

When ground is used as the return conductor, there is, of course, no possibility of transposing the wires.

Instance (b) Three insulated power wires, telephone line strung on the same pole line, but having one metallic conductor only, the other conductor being ground.

We then have, assuming E to be ground, the inductance in m. h. per mile of transmission between D and ground caused by the current in A:—

$$L_a = \frac{322}{10^3} \times {}^n\lg \frac{4a_2}{d} - \frac{322}{10^3} {}^n\lg \frac{2a_1}{d}$$

$$= \frac{322}{10^3} \times \left({}^n\lg \frac{4a_2}{d} - {}^n\lg \frac{2a_1}{d} \right)$$

$$= \frac{322}{10^3} {}^n\lg \frac{2a_2}{a_1}$$

In a similar way:—

$$L_b = \frac{322}{10^3} {}^n\lg \frac{2b_2}{b_1}$$

$$\text{and } L_c = \frac{322}{10^3} {}^n\lg \frac{2c_2}{c_1}$$

The resultant is:—

$$L_r = \sqrt{\left[L_b - \tfrac{1}{2}(L_a + L_c)\right]^2 + (L_a - L_c)^2}$$

$a_1 = 10.5$ ft. $= 126$ in.
$a_2 = 30$ ft. $= 360$ in.
$b_1 = 16$ ft. $= 192$ in.
$b_2 = 36$ ft. $= 432$ in.
$c_1 = 10.5$ ft. $= 126$ in.
$c_2 = 30$ ft. $= 360$ in.

Fig. 2.

Substituting in the above equation we get:—

$$L_a = \frac{322}{10^3} \times \frac{{}^{10}\log \frac{720}{126}}{0.434} = 0.5615$$

$$L_c = \frac{322}{10^3} \times \frac{{}^{10}\log \frac{720}{126}}{0.434} = 0.5615$$

$$L_b = \frac{322}{10^3} \times \frac{{}^{10}\log \frac{864}{192}}{0.434} = 0.4843$$

$$\text{and } L_r = 0.073$$

In the transmission discussed in the last instance, the induced voltage would therefore be 174 volts. Obviously if the transmission lines had been properly transposed, this voltage would not have been found.

With one transmission line accidentally grounded, but the other two perfectly insulated, there should be no change in the inductive effect, since the currents and their phase relation are not disturbed (neglecting the charging current).

If, however, the ground is used as one of the main conductors, (as will be the case when operating with a grounded Y system and one of the main lines is accidentally cut out) difficulties arise. The circuits are then illustrated in Fig 3, where conductor B is assumed as ground.

The telephone lines are between the main lines, and the flux caused by B is combined with the other fluxes in opposite direction, thus the resultant:—

$$L_r \text{ is } \sqrt{[L_b+\tfrac{1}{2}(L_a+L_c)]^2+\tfrac{1}{4}(L_a-L_c)^2}$$

In this case transposition does not help matters, since one wire—the ground—is not transposed.

Under this condition the expressions for L_a, L_b and L_c are respectively:—

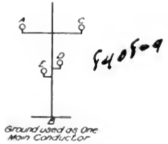


Fig. 3.

$$L_a = \frac{322}{10^3} \,{}^n\lg \frac{a_2}{a_1}$$

$$L_c = \frac{322}{10^3} \,{}^n\lg \frac{c_2}{c_1}$$

$$\text{and } L_b = \frac{322}{10^3}\left({}^n\lg \frac{4b_1}{d} - {}^n\lg \frac{4b_2}{d}\right)$$

$$= \frac{322}{10^3} \,{}^n\lg \frac{b_1}{b_2}$$

Instance (c). Ground used as main line conductor. The telephone lines are not grounded.

a_1 = 126 in.
a_2 = 150 in.
c_1 = 126 in.
c_2 = 150 in.
b_1 = 240 in.
b_2 = 216 in.

We have then:—

$$L_a = \frac{322}{10^3} \times \frac{{}^{10}\log \frac{150}{126}}{0.434}$$

$$L_c = \frac{322}{10^3} \times \frac{{}^{10}\log \frac{150}{126}}{0.434}$$

$$L_b = \frac{322}{10^3} \times \frac{{}^{10}\log \frac{240}{216}}{0.434}$$

and $L_r = 0.0899$

And for the transmission given in previous instance the voltage induced in the telephone line would be 199 volts.

If in addition the telephone circuit had only one single conductor and the earth was used for return for one of the main conductors, we would have the following.

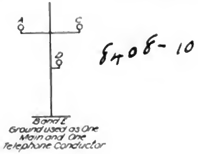


Fig. 4.

A three-phase transmission line using two conductors only and the ground as the third, and a single metallic conductor telephone line with ground return — what would be the induced voltage?

$$L_a = \frac{322}{10^3} \,{}^n\lg \frac{2a_2}{a_1}$$

$$L_c = \frac{322}{10^3} \,{}^n\lg \frac{2c_2}{c_1}$$

$$L_b = \frac{322}{10^3} \,{}^n\lg \frac{4b_1}{d} = 0 \text{ as long as}$$

$4b_1 = d$, which is the case, since d is the diameter of the "ground", which is very large compared with any of the other distances. Applying these equations to the same practical instance we get:—

$$a_1 = 126 \text{ in.}$$
$$a_2 = 360 \text{ in.}$$
$$c_1 = 126 \text{ in.}$$
$$c_2 = 360 \text{ in.}$$

and $$L_a = \frac{322}{10^3} \frac{{}^{10}\log \frac{720}{126}}{0.434} = 0.5615$$

$$L_c = \frac{322}{10^3} \frac{{}^{10}\log \frac{720}{126}}{0.434} = 0.5615$$

and $L_r = 0.56$, which gives an induced voltage of 1268 volts.

This condition is therefore the worst, and no transposing will help matters.

B. ELECTROSTATIC EFFECTS

It was shown in connection with the discussion of corona effects, that the potential E_x, a given distance from a conductor at potential E, could be expressed as

$$E_x = E \frac{{}^n\lg \frac{R}{x}}{{}^n\lg \frac{R}{r}}$$

where R is the distance from the conductor to ground potential.

r is the radius of the conductor.
E is the potential to ground.
E_x is the potential above ground at a distance x from the conductor.

Referring now to Fig. 1, using the same notations as previously, and denoting the distance of the three wires to ground as R_a, R_b, R_c, respectively, we then get for conductor D:—

$$\text{Voltage due to A} = E \frac{{}^n\lg \frac{R_a}{a_1}}{{}^n\lg \frac{R_a}{r}} = E_a$$

$$\text{Voltage due to B} = E \frac{{}^n\lg \frac{R_b}{b_1}}{{}^n\lg \frac{R_b}{r}} = E_b$$

$$\text{Voltage due to C} = E \frac{{}^n\lg \frac{R_c}{c_1}}{{}^n\lg \frac{R_c}{r}} = E_c$$

Again these voltages are 120° apart, thus the resultant voltage above ground for D is:—

$$E_d = \sqrt{[E_b - \tfrac{1}{2}(E_a + E_c)]^2 + \tfrac{1}{4}(E_a - E_c)^2}$$

In a similar manner the resultant voltage of E from ground is found by substituting a_2, b_2, c_2, instead of a_1, b_1, c_1.

It is evident from this that static voltage is much dependent upon the size of the main conductors, the larger the wire the higher charge on the telephone wires.

Instance (e). Transmission lines not grounded. Metallic telephone circuit, and voltage between the lines 60,000. Size of line conductor No. 000 B & S, d = 0.41.

We have then:—

$$E_a = \frac{60000}{\sqrt{3}} \times \frac{\log \frac{360}{125}}{\log \frac{360}{0.205}} = 4910$$

$$E_c = \frac{60000}{\sqrt{3}} \times \frac{\log \frac{360}{125}}{\log \frac{360}{0.205}} = 4910$$

$$E_b = \frac{60000}{\sqrt{3}} \times \frac{\log \frac{432}{192}}{\log \frac{432}{0.205}} = 3670$$

therefore $E_d = \sqrt{(3650 - 4920)^2} = 1240$ volts.

The voltage induced statically on E is found in a similar way.

$$E_a = \frac{60000}{\sqrt{3}} \times \frac{\log \frac{360}{150}}{\log \frac{360}{0.205}} = 4058$$

$$E_c = \frac{60000}{\sqrt{3}} \times \frac{\log \frac{360}{150}}{\log \frac{360}{0.205}} = 4058$$

and $$E_b = \frac{60000}{\sqrt{3}} \frac{\log \frac{432}{216}}{\log \frac{432}{0.205}} = 3138$$

and $E_E = 920$ volts.

Now assume that a telephone circuit of one metallic conductor is used, and that ground is used as the other, as in instance (b) in the previous discussion.

It is evident then from reasoning and equations, that the potential on the metallic conductor is not changed, but the other —the ground—remains, of course, at zero or ground potential.

Assume next, as in previous instance (e), that the telephone circuit consists of two metallic conductors, but that one of the main power lines—B—is grounded.

We have then E_a and E_e are $\sqrt{3}$ times the values given in instance (e), since the voltage between ground A and B is now the full line voltage. The voltage due to B is, of course, zero, since B is at zero potential. We get therefore as resultant potential on D:—

$$E_D = \sqrt{\quad - (\sqrt{3} \times 4910)^2} = 8500 \text{ volts}$$

and E_t = 7010 volts

an enormous potential when considering the telephone lines.

On account of static and conductive effects we must therefore expect the greatest trouble with the telephone installation when ground is used as one of the three lines in a three-phase system.

Transposition does not help matters as far as static stresses are concerned. The voltage all along the line may not then be the same, but at any point it will be the resultant of the static stresses due to the three main conductors.

The telephone line is therefore always likely to have some static voltage, which in case of very high voltage transmissions and relatively short distance between the telephone lines and main lines, might be considerable.

The danger from such static stresses might be great in a long line, so that it is desirable that the operator should stand on a very well insulated platform, but even then an unpleasant shock may be had, caused by the charging current of the person.

By using a telephone transformer and grounding the neutral of the secondary winding, considerable protection is offered, however.

SOME SELECTIVE CEILING DIFFUSER SYSTEM INSTALLATIONS

By Lyman Clark

When the concentric diffuser was first introduced, the merchants and manufacturers of New York responded very promptly, with the result that there are now about fifty-five hundred of them installed.

It was very natural, therefore, that the Selective Ceiling Diffuser System should receive a like consideration and that the demand and its introduction should be simultaneous.

Fig. 1. Fraas and Miller's Store by Day Light

Owing to certain details of building construction, as well as the first cost of this system, it necessarily requires considerable investigation on the part of the purchaser before he can bring himself to adopt a means of illumination which differs so radically from the plain arc lamp that he has been so accustomed to.

The New York Office has been fortunate in securing installations of the Selective Diffuser System in buildings embodying nearly all classes of construction; from wood frames with metal ceilings, to steel frames with plaster ceilings. They have also made installations having peculiar electrical features, such, for example, as the following: The Myers Store at Albany, which is superbly illuminated on three phase, thirty-eight cycle current;

the Title Guarantee & Trust Company, of New York, which has a recessed design on a plaster ceiling; the Bedell Company, of New York, where is installed an elaborate design in a metal ceiling, made especially for them and in harmony with the arc lamp equipment. In addition to these,

Fig. 2. Fraas and Miller's Store Lighted by Selective Ceiling Diffuser System

the temporary Grand Central Station has installed the system on a brick arched ceiling, plastering flush around the diffusing lamps, the latter being of a special twin carbon type, the carbons burning in multiple on 110 volts continuous current at five amperes each.

One of the latest and best installations

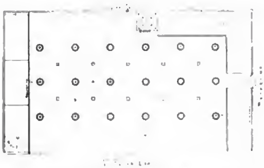


Fig. 3. Diagram Fraas and Miller's Store showing arrangement of Ceiling Diffusers

is in the furniture store of Fraas & Miller, Brooklyn, New York. These people were so impressed with the installations they had visited that they were willing to go to an expense to which few merchants would have gone, in order to secure the best possible lighting results. They did not own their building and had only a lease for ten years, yet, with permission of the owner, the architect was instructed to alter the framework to accommodate the ceiling lamps of the recessed design. The expense for this, together with the lamp equipment and cost of installing, was borne by Fraas & Miller.

A plan of the first floor is shown, together with illustrations of the store both in daytime and at night. The ceiling is sixteen feet from the floor, the area 9975 feet, and the energy consumed practically 1.15 watts per square foot. At the left of the elevator on each floor are installed carbon break push button switches, which control G. E. automatic switches on the panel board. This affords the salesman an opportunity, when taking a customer through the store, to illuminate the entire floor immediately upon leaving the elevator.

WONDERFUL RECORD ENDS

United States Smelter Stops Generator After Five Years' Operation*

An electric generator installed in the United States Smelter at the first of the year 1902 by the General Electric Company has been stopped after running continuously since that time. The machine which made this wonderful record has been running 24 hours a day for five years without a stop for any cause whatever, and is today in just as good shape as it was when put in over 43,800 hours ago. It has needed no repairs and needs none now. It is the regular type of 200 horsepower generator, and was one of the first pieces of machinery installed when the smelter was being equipped. During its phenomenal run it has supplied the entire smelter with power. It was stopped because it is to be replaced by a 750 horsepower generator of the latest General Electric Curtis steam turbine. The new machine will take hardly one-fourth the space of the old type of generator and is noted for the lack of vibration found during operation. It is claimed that a dollar can be balanced upon the machine while it is running a smelter or any big plant.

*From "Deseret News", April 8, 1907

THE NEW PHILADELPHIA OFFICES AND WAREHOUSE

The present building which has been occupied by the Philadelphia Office of the General Electric Co. for the past seven years is located at 218-226 South Eleventh Street. These quarters comprise five floors and basement and contain approximately 31000 square feet, of which about 7000 have been used for offices, and the remaining 24000 for repair shop, stock rooms, etc. In addition about 5000 square feet has been occupied in a separate warehouse very inconveniently located some four miles distant.

The new offices, which are about ready for occupancy, are in the Witherspoon Building, a modern office building located at the corner of Juniper and Walnut Streets, within five minutes' walk of either the Pennsylvania or Reading Rail Road Stations, and in the best business section of the city. The offices will occupy about 9100 square feet, or the eleventh floor, which has been rearranged to suit the requirements.

There will be eleven private offices, one large room (containing over 5000 square feet), and two separate rooms for the stenographers. The large room referred to will be lighted by a combination of arc and incandescent lights, especially designed by Mr. W. A. D. Ryan.

Witherspoon Building, Philadelphia

Warehouse

For the special purposes of the General Electric Co., a five story and basement reinforced concrete building is being erected at 1223-1233 Washington Ave. for occupancy about September first. This building is directly on the Pennsylvania Railroad System, being connected thereto by a siding. Incoming shipment will be received directly on this siding, where cars will also be placed daily for outgoing consignments.

New Philadelphia Warehouse of General Electric Co.

The building will be 120 feet on Washington Avenue, by 75 feet deep to the rear street. Excellent facilities in the way of elevators, hoists, overhead track, etc., will be furnished to afford the quickest and most economical handling of the work. A sprinkler system will be installed which, with the reinforced concrete construction, will minimize the insurance rate.

Each floor will contain approximately 11000 square feet, the total floor space being 66000 square feet, an increase of 175 per cent over the present shop and storage quarters. The principal floors will be used for storage purposes, with the exception of the second, which will be devoted entirely to repair shop purposes, and the machine tool equipment here installed will be in accordance with the most modern practice of direct motor drive.

NOTES

Mr. F. M. Denton, who entered the Power and Mining Department from the Pittsfield Works of the Stanley Co. in January, has accepted a position at the Carnegie Technical School at Pittsburg. He will instruct the third year students in the subject of Alternating Currents.

* * *

Mr. Fellenberg, who for a number of years has had charge of the Switchboard Manufacturing Dept. of the A. E. G., recently paid a visit to the Schenectady Works. He is making an extended trip in this country for the purpose of studying high tension transmission systems.

* * *

Mr. A. L. Rohrer has recently returned after a month's absence devoted to an extended trip among the Western universities and colleges in behalf of the Testing Dept.

The following institutions were visited, and as a result, the Testing Dept. will shortly receive graduates from each: Univ. of Missouri, Univ. of Arkansas, Oklahoma Mechanical College, Univ. of Kansas, Univ. of Nebraska, Univ. of Colorado, Univ. of Utah, Univ. of California, Leland Stanford University, Univ. of Oregon, Oregon Mechanical College, Univ. of Washington, Washington Mechanical College, Univ. of Idaho, Univ. of Montana, Univ. of Minnesota, Univ. of Wisconsin. This is the second trip of the kind that Mr. Rohrer has made, the former one having been among the colleges of the Middle Western States. With the exception of four, none of the above institutions have been called upon before.

Mr. Rohrer states that as a result of the prosperous business conditions, there is a great demand for college graduates at the present time in all parts of the country.

* * *

Mr. A. S. Loizeau has resigned from the Railway Engineering Dept. to take the position of First Assistant to Mr. Phillip Torchio, Chief Electrical Engineer of the New York Edison Co. In his new position, Mr. Loizeau will confine his attention largely to construction work.

Within the past few days we have had the pleasure of a visit from Dr. E. Rosenberg of Berlin, who is well known as the inventor of a new D.C. generator that gives a constant potential at widely varying speed, and a constant output with a drooping characteristic.

The first of these features makes the machine peculiarly adapted for train lighting, and the second for use with searchlight projectors, arc welding and gasolene electric motor cars.

Dr. Rosenberg has been associated with the A. E. G. for a number of years.

* * *

The results obtained by Mr. Mathes of the Union Electric Co. of Dubuque, during his recent elaborate display of electrical devices, and lectures on cooking by electricity, were such as to greatly encourage other Central Station men to inaugurate similar educational exhibitions.

The affair was held under the auspices of the Women's Club, and while nothing was offered for sale, it being a purely educational project, the attendance, by actual register, was nearly 7000 for the ten days that it continued. This means that practically everyone who was likely to be interested in matters of this kind was present and was shown the convenience and economy of household electrical devices.

There is no question that through the Woman's Clubs Central Station men can advertise current-consuming devices to excellent advantage.

* * *

We have received word as we are going to press of the death of Mr. W. B. Kirkpatrick, who has been in charge of the Mill and Power Department of the New York Office.

He has been associated with the New York force since May, 1906, at which time he was transferred from the Power and Mining Department of the Schenectady Works.

Mr. Kirkpatrick was an excellent engineer and salesman. He was sound in his judgment and had the confidence of his customers and associates, who regarded him as one of the best and most promising commercial engineers in the organization.

SCHENECTADY BRANCH AMERICAN INSTITUTE ELECTRICAL ENGINEERS

Meetings of the Month

The first meeting in May was held at the Schenectady High School upon Thursday the 2nd, the subjects of the evening being "Electric Hoists in Mines". Mr. K. A. Pauly, of the Power & Mining Dept. of the General Electric Company, read the first paper, and Mr. Eugene Eichel the second. Mr. Pauly's paper was devoted particularly to American practice and was illustrated by numerous photographs of installations in this country, together with valuable operating curves. Mr. Eichel's contribution discussed the foreign practice, and was also fully illustrated; the first portion of his paper appears in another part of this issue of the REVIEW.

On May 9th, Mr. C. E. Eveleth spoke upon "The Electrification of the West Jersey & Seashore R. R." His talk was illustrated by about 75 lantern slides, and embraced the following subjects:

Description of location and traffic conditions of the various branches of the West Jersey & Seashore R. R. Co.; requirements of service, and a review of the speed operation on the electrified division; specific description of line electrified, and causes leading up to the electrification.

Next followed a discussion of the general outline of the commercial engineering and construction organization, with their division of responsibility. The problem of electrification was then taken up in de-

Notices of the Year's Meetings

tail, Mr. Eveleth giving a description of the work to be accomplished, as follows: The installation of three 2000 kw. Curtis turbines with auxiliary apparatus, buildings, etc. The installation of seven substations, 68 car equipments to be provided, 145 miles of third rail, and 160 miles of track to be bonded, (the drilling required for bonding these tracks being equivalent to boring a 1 in. hole through three miles of solid steel, giving some idea of the magnitude of the undertaking). Seventy miles of duplicate three-phase transmission line. All to be finished within six months.

A general description was given of the method of predicting the rate at which work must be accomplished to have the entire undertaking completed in six months. About sixty curves showing the rate of progress were plotted before any constuction was begun, and then the progress of work kept up as nearly as possible to the predetermined rate. These curves covered all such items as foundations for buildings, walls, roofs, flooring, installation of apparatus, installation of transmission line, track bonding, third rail bonding, etc.

Lantern slides were then thrown on the screen and various reminiscences of incidents occurring duing construction were recounted.

On May 16, Prof. Elihu Thomson delivered a lecture upon "The Panama Canal", which was copiously illustrated with lantern slides made from his private collection of photographs taken during his recent trip to the Zone.

The attendance at this lecture was very large, every seat in the High School being occupied and many of the audience being compelled to stand.

May 23rd was the last meeting of the year and was devoted to business matters, followed by a smoker. This was held at Odd Fellows' Hall, and closed one of the most successful seasons ever experienced by an Institute branch.

The Year's Work

During the year there have been held a total of 33 meetings, at which were presented 25 original papers, many by noted engineers not connected with the Branch. The membership has been increased from a total of less than 200 in the fall of 1906 to over 900 at the present time.

At a preliminary smoker held in September of last year, plans were laid for the season 1906-7, and it was decided to maintain a course of weekly lectures for the benefit of the members and associates of the Institute residing in and near Schenectady and to others who wished to affiliate with the Branch by the payment of nominal dues to defray current expenses. A four-page prospectus was issued outlining the aims of the association and giving a partial list of speakers who had signified their willingness to address the meetings. All members and associates of the American Institute of Electrical Engineers were, of course, members of the Branch, but to those not members or associates all the privileges of the Branch were extended for an annual fee of $2.00. A special student membership for men in the testing departments of the General Electric and American Locomotive Companies, students at Union College, Rensselaer Polytechnic Institute, etc., was also started, for which the dues were $1.00 per year. There was no initiation fee for any class of membership. A Membership Committee was appointed, consisting of 16 men, and an energetic campaign undertaken to interest nonmembers of the Institute in the work of the Branch. The result was so satisfactory that the Treasurer's report shows returns of 397 full members at $2.00 each and 347 special members at $1.00 each, a total of $1141.00 received from dues during the year.

The immediate effect of the increased activity in Institute work was to bring into membership with the national body a large number of new associates, and whereas the July membership list of the Institute for 1906 shows but 132 names under Schenectady, the present membership is approximately 191, with a large number of applications still to be acted upon. It is expected that next year there will be a still further increase in membership to the national body from those who have been interested in the Branch work this year, and who will prefer to become associates rather than remain simply Section members in 1907-1908.

The first two or three meetings of the year were opened to all who desired to attend, and the interest was so great that the High School auditorium, where the lectures were held, and which seats approximately 900, was often taxed to its full capacity. After the first few lectures, however, admission was by ticket only, but members could obtain tickets for their friends without difficulty from any of the Membership Committee. These tickets to be valid had to contain the name and address of the holder, and in this way the Membership Committee obtained a list of those interested and secured a large number of new members.

During the year, four evenings were set aside for the discussion of papers read in New York, the papers in general being abstracted by some local authority. For example, the discussion of the paper on "The Substitution of the Electric Motor for the Steam Locomotive," by Messrs. Stillwell and Putnam, read on January 25th, was opened by Mr. Potter at the Branch meeting of February 7th, and was participated in by Messrs. Fortenbaugh, Slichter, Eveleth and Dodd, of the General Electric Company, and Mr. William Dalton of the American Locomotive Company. There were 25 original papers presented on a wide range of subjects during the year, and four evenings were devoted to topical discussions or debates on subjects of general interest, at which many valuable original contributions were presented.

Newspaper Notices

Although the closing year has been one of extreme activity from an educational standpoint, the social features have not been overlooked, and besides the informal smoker held at the commencement of the year, when the season's work was laid out, there have been two entertainments, which a large percentage of the total membership has attended and which, from all indications, were highly enjoyed.

The expense of these smokers was borne entirely by the Branch, no additional assessment of any kind being made on the members.

The complete programme for the season just closed was as follows:

October 5, T. C. Martin, "Technical Journalism"; October 12, E. G. Acheson, "Inventions and Discoveries"; October 20, R. W. Raymond, "Professional Ethics"; October 27, topical discussion "Thury System", Messrs. Taylor, Eveleth, Noeggerath and Wilkinson; November 2, S. A. Moss, "Gas Turbines"; November 9, Topical discussion "Municipal Ownership", A. B. Lawrence, A. V. Thompson and others; November 16, W. S. Franklin, "The Second Law of Thermo Dynamics;" November 23, F. O. Blackwell, "Hydro-Electric Developments"; November 30, W. S. Andrews, "Pioneer Work in Electric Lighting"; December 8, C. P. Steinmetz, "Transformation of Electric Power into Light", (Discussion of his paper read in New York Nov. 23); December 15, Topical discussion, "Metric System"; December 22, V. G. Converse, "Ontario Power Co."; January 5, E. E. F. Creighton, "Lightning Protection", (Discussion of R. P. Jackson's paper read in New York December 28; January 12, E. J. Berg, "Parallel Operation of Alternators"; January 19, Topical discussion, "Industrial Betterment", Messrs. Steinmetz, Cravens, Hewett, McMillan, Crane, and Maxwell; January 24, Maxwell Day, "Centrifugal Fans", and H. B. Emerson, "Motor Drive for Metal and Wood Working Machinery"; January 31, E. J. Berg, "Abnormal Voltages and Currents in Transmission Lines"; Feb. 7, Discussion, "Electrification of Steam Railroads", (paper read in New York by Messrs. Stillwell and Putnam January 25), Messrs. Potter, Fortenbaugh, Slighter, Eveleth, Dodd and Dalton; Feb. 14, W. L. Merrill, "Electricity in a Paper Mill"; February 21, C. W. Stone, "A Comparison of the Different Systems of Electric Lighting", and F. F. Barbour, "Qualifications and Duties of an Electrical Apparatus Salesman"; February 28, W. S. Moody, "Design of Transformers"; March 8, Smoker in Odd Fellows' Hall; March 14, S. D. Sprong, "System of the New York Edison Co."; March 21, Richard Fleming,

"The Electric Arc Lamp"; M
W. Larson, "Mine Locomotive
ing"; April 4, "Lightning Prote
cussion of papers read in New
29th), Messrs. Steinmetz,
Creighton and DuBois; April
Hill, "Multiple Unit Control
Motors"; April 25, E. J. Berg,
of Cables and Magnetic Condu
2. Two papers on "Electric
Mines", one by K. A. Pauly, a
by Eugene Eichel; May 9, C.
"Electrification of the West
shore Railroad"; May 16, Elih
"Panama Canal"; May 23, S
business meeting.

The annual business meeti
tion of officers was held durin
of May 23rd. A large numb
officers were re-elected, the
as follows: Honorary chair
Steinmetz; chairman, D. B. Ru
chairmen, E. H. Anderson,
strong, E. A. Baldwin, E. E.
William Dalton, G. H. Hill
riam, A. L. Rohrer, C. W.
sponding secretary, W. C.
cording secretary, J. M. Ku
A. S. Kappella; librarian, H

A summary of the Treasur
the year, presented at this
follows:

Balance on hand May, 190
Dues collected from member

Total receipts ....

Cost of meetings, including
opticon, report, announcem
cuts for newspaper a
membership cards, postage,
tor's service at High Scho
entertainments ....

Expenses of sending delegat
New York to attend In
meetings ....

Contributions to Schenectady
lic Library ....

Total ....

Balance on Hand..........

Two items of the Treasur
worthy of notice. One is th
to the Schenectady Public
Institute Branch received a
ago, a number of books

from the General Electric Engineering Society through the affiliation of that society with the Branch, and these books are maintained in special bookcases at the Public Library. $37.50 of the annual donation of the Branch is devoted to the purchase of new books to increase this collection, $12.50 being taken as a fee for maintaining the books in good condition and other librarian services. The selection of books is in the hands of a special committee.

In order to stimulate interest in the topical discussions as well as the other work of the Branch, delegates were appointed during the year and their expenses paid to New York to attend the regular meeting of the national body. There was the added advantage in this system of bringing non-members of the national body, who alone were eligible to receive the free trips, in contact with the New York members and create a desire to join the Institute.

QUESTIONS

This section is open to inquiries upon engineering subjects. The questions will be submitted to the respective departments and such as are of general interest will be answered in this column, while those of less importance will be answered by letter.

Q. If a three phase transformer were loaded with equal KVA on each phase, but with power factors of 70-85-100 per cent respectively on the phases, how would the regulation be affected?

A. The regulation would be approximately the same as though each phase had a power factor of 85 per cent, which is the average power factor of the three phases.

C.E.A.

* * *

Q. How is the regulation of a transformer affected by an overload?

A. The regulation is increased approximately in direct proportion to the load.

C.E.A.

* * *

Q. How does the core loss of a constant potential transformer vary by the use of different taps in the winding?

A. The core loss remains constant when the impressed voltage across the taps is reduced so that the same voltage is obtained across the secondary terminal. On the other hand, if the impressed voltage is kept constant for all taps, then the secondary voltage is increased, and the core loss will be increased approximately 1.8 per cent for each per cent in increase in secondary voltage.

C.E.A.

* * *

Q. If an unbalanced three wire distribution system is used, where separate transformers are used on each side of the neutral, is there any danger of injuring the transformers?

A. There is danger of burning out some of the transformers on the side of the system containing the smaller capacity, when the transformers on the other side are loaded. For instance, to take an exaggerated example, suppose a 50 kw. transformer to be connected on one side of a system, and one of 5 kw. capacity on the other, the 50 kw. being loaded. In this case the entire 50 kw. current would be passing through the smaller transformer and a burn-out would probably result.

C.E.A.

* * *

Q. Under what conditions of feeder service should the IR or BR regulators be recommended?

A. In the induction regulator, the moving element consists of a comparatively heavy armature, and therefore has quite an appreciable inertia. Its time element does not well adapt it to feeders that are subjected to sudden and wide variations. Its operation is extremely satisfactory on lighting feeders, where the load builds up gradually, or on feeders controlling both lighting and motor loads, provided the motors are not of sufficient capacity to cause extreme and sudden variations in voltage.

The moving element of the BR regulator consists principally of very light copper segments no heavier than the commutator on a small motor. It therefore has very little inertia, and can be revolved through its entire range in a few seconds. The BR regulator is therefore admirably adapted to feeders carrying rapidly fluctuating loads.

M.O.T.

ABSTRACTS OF IMPORTANT TECHNICAL ARTICLES

Illustrated *
Profusely Illustrated **

High Voltage Direct Current and Alternating Current Systems for Interurban Railways

(Western Electrician, May 4, '07, p. 374)

Abstract of a paper read by Mr. W. J. Davis, Jr. (G. E. Railway Dept.) before the Chicago branch of the American Institute of Electrical Engineers.

Peoria Power House of the Illinois Traction Company

(Western Electrician, May 4, '07, p. 379*)

The Illinois Traction Co. has one power house at Riverton and one at Danville, in addition to the new power house at Peoria, which is equipped at present with the following apparatus: Two 2000 kw. 2300 volt, 25 cycle three-phase Curtis steam turbine units; one 70 kw. 2400 r.p.m., 125 volt Curtis turbine exciter; and one 75 kw. induction motor generator exciter; in addition to 2300-33000 volt step up transformers; and two 750 kw., 500 volt D.C. induction motor driven units for city supply. The power house will feed the transformer stations on the Peoria-Bloomington line as far as Decatur. The Peoria-Bloomington, and the Bloomington-Decatur lines, as well as all through lines now built north of Springfield, will be operated by single-phase current.

One hundred and twenty-five miles of track will be equipped with General Electric apparatus, and the rolling stock comprises four motor GE-A605 (75 h.p.) cars to operate on D.C. and single-phase current. The interurban cars, which have a seating capacity for 58 passengers, are 51 ft. 6 in. long, and weigh 40 tons. They are geared for a speed of approximately 50 miles per hr.

An Example of Recent Factory Construction The Automobile Works of the White Company, Cleveland, Ohio

(The Iron Age, May 2, '07, p. 1320**)

The new Automobile Works of the White Company employ about 1000 men in their large new shops. These comprise four main buildings, each of which is supplied with lighting current by means of a 50 kw. 440-110 volt transformer. The shops are equipped with 440 volt three-phase motors, fed from the central power house, which contains a 500 kw. General Electric generator, space being provided for the installation of a 1000 kw. unit as well as a 150 kw. machine for night service. Group drive is principally used for the large number of small tools, each length of line shaft having its own motor. Sixty of these, ranging in capacity from five to fifty h.p., are in use.

New Cars in Toronto

(Street Railway Journal, April 27, '07, p. 731)

The new motor cars of the Toronto & York Radial Railway are to be operated over the 55 mile division between Jackson's Point and Toronto.

The 28 ton cars have a length over all of 55 ft. 7 in., a width of 9 ft. 3 in., and a seating capacity of 62 passengers. They are supplied with a four motor GE 73 (75 h.p.) equipment with type M control.

New Substation of the Portland Railway Light and Power Co.

(Electric Railway Review, May 18, '07, p. 641)

From the hydro-electric power plant known as the Cazadero Station, a 33000 volt, 33 cycle, three-phase current is transmitted 40 miles to feed two 1000 kw. rotary converters for railway supply, and one 1400 h.p., 11000 volt, 33 cycle synchronous motor frequency changer of 2300 volts, 60 cycles, for general lighting and power purposes.

In addition to the necessary step down transformers, auxiliaries, and the elaborate switchboard plant, 11 constant current mercury arc rectifier sets are installed for operation of magnetite arc lamps used for street lighting. The entire substation equipment has been furnished by the General Electric Co.

Mechanical Refrigeration and the Central Station

(Electrical World, May 18, '07, p. 991*)

A brief illustrated discussion of the problem of mechanical refrigeration, a subject which is of interest to the Electric Central Station Managers as opening up a new field of electrical application. Detailed data are given pertaining to the cold storage temperature to be provided for various food stuff. Specific information is also furnished regarding the equipment of the wholesale fruit firm of I. C. Sherman & Co., New Bedford, Mass. This concern is operating an automatic refrigerating equipment that is electrically driven by a 5 h.p., 220 volt General Electric Motor.

The capacity of the plant is 2.5 tons of ice in 24 hrs. and the electric power is furnished by the New Bedford Gas & Electric Company.

The New Turbine Power Station of the Dallas Electric Corporation

(Street Railway Journal, May 18, '07, p. 856)

The new power house located in Dallas, Texas, contains at present:

Two 1500 kw., 60 cycle Curtis Steam Turbine two-phase generators.

Three exciters, one of 30 kw. capacity being engine driven; and the other two, one of which is 35 kw. and the other 85 kw., are driven by induction motors, as are also two 500 kw., 600 volt D.C. generator sets.

Space is provided for enlarging the station output by installing one additional 1500 kw. steam turbine, and a 500 kw. motor generator set.

The station output is at present controlled from temporary panels in the switchboard plant of an old station near by. Its power is largely distributed to a new substation that is located in the center of the business district of the city, and that contains one 500 kw., induction motor driven D.C. generator connected to a 250 volt three wire system.

The electric equipment is of General Electric make.

GENERAL ELECTRIC REVIEW

VOL. IX No. 2 — PUBLISHED MONTHLY BY GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU SCHENECTADY, N. Y. — JULY, 1907

Three Hundred Thousand Volt Testing Transformer

(See page 61)

GENERAL ELECTRIC REVIEW

VOL. IX NO. 2 | Copyright 1907 By General Electric Company | JULY, 1907

CONTENTS

General Electric Two Arm Home and Distant Signal

(See Page 63)

GENERAL ELECTRIC REVIEW

THE PANAMA CANAL

By PROF. ELIHU THOMSON*

Some two years ago the Commercial Clubs of Boston, Chicago, Cincinnati and St. Louis, which are affiliated clubs, proposed by a trip to the Isthmus, to set at rest so far as possible, some of the doubts, misconceptions and rumors concerning what was going on there. Finally, in order that there might be enough volunteers for the trip, there were added other attractions, such as a visit to the island of Porto Rico and trip across the island, a

Fig. 1. Special Train at Colon, Panama R. R.

*Address delivered before the Schenectady Branch, A. I. E. E.

visit to Jamaica and a trip into the interior, and also a similar visit to noted places in Cuba, such as Havana, Santiago, Guantanamo. With these exceptional attractions added, a sufficient number expressed a willingness to take the trip, and in consequence there were about twenty men from each of the four clubs, or between eighty and ninety men in all, who embarked upon the trip, the main object of which, however, was to reach the Isthmus and see the work being done there.

In December last a steamer of the Hamburg-American Line was chartered to take the party to the various places mentioned and make stops as long as might be desired. The ship was the unfortunate "Prinzessin Victoria Louise," which shortly after being selected went on the rocks off Kingston harbor, so that it became necessary to find another steamer suited for the journey, the choice finally resulting in the "Prinz Joachim" of the same line being chartered.

The party from Boston went on board at New York, and the steamer touched at Charleston, S. C., where the western members embarked, and from there a run of 1200 miles was made to the island of St. Thomas of the Danish West Indies, over a sea which, as the journey progressed, became warmer and deep indigo in tint, though very lonely. The only signs of life noticed were a few flying fish and dolphins sporting. No ships were seen, although the weather was perfectly clear. There was some dread of increasing heat, for though it was winter in the north, many had the notion that traveling down into tropical latitudes would mean suffering from excessive heat. In reality no such suffering was experienced at any time during the whole trip. What discomfort there was was from cold when we got back.

While within the tropics, we experienced what would be perhaps the warmer part of our June weather, and even while at the Isthmus, where we were only 8 or 9 degrees from the Equator, the temperature was quite moderate.

From St. Thomas, which is a mountainous island rising from the sea, we went directly to San Juan, Porto Rico, and thence to Ponce, a port on the southern side of Porto Rico. In the journey of 900 miles to Colon, tropical conditions were accentuated. Myriads of flying-fish were disturbed by the motion of the ship. Usually they leave the water when pursued by dolphins, but any moving object causes them to rise.

As we approached nearer the Equator, we of course saw at night the North Star getting closer and closer to the northern horizon, and looking south the southern stars came up, and finally there appeared the great Southern Cross, the well reknowned spectacle of the southern sky. It is not a very good cross, but answers well as characterizing the southern sky. On getting a little south of our temperate latitudes, the great star called Canopus, one of the brightest in the sky, became visible. This star is interesting as being one of the very largest bodies in the universe the size of which has been estimated, and as being many thousands of times larger than our sun.

We were also able to see the renowned star, Alpha Centauri, the nearest known body to us, and it is about four years of light away. It cannot be considered very neighborly when we know that light travels over 180,000 miles per second.

The more serious part of the trip began when we were on the journey from Porto Rico to Colon. An organization was perfected on board the steamer during this journey. The visiting body was divided into eight investigating groups or committees, each of which had its own particular subject to consider. For example, there was a committee on administration, another on sanitary and health conditions, another on the effects of climate on white labor, another one on food and housing, another on the nature and efficiency of the plant, and another on the progress of the canal work, etc. The work of inspection was so distributed among the committees, and in some cases sub-committees were appointed, that each member of the visiting body had his own work laid out for him in advance.

By express order of President Roosevelt it was arranged that when the body arrived at Colon, the men who were at the heads of the various departments of work on the Isthmus should respectively meet the particular committees and be prepared to answer inquiries or impart any information which might be needed. As a result there was obtained in a short time, a very comprehensive view of the situation at the Isthmus, and time during the return sea journey north from Colon was devoted to getting together the various reports of the committees, which were unanimously favorable.

During the whole trip the weather was very good. The only storms experienced were off Cape Hatteras, which has the reputation of stirring up anybody who is at all susceptible. Personally, I am one of the immunes so far as sea-sickness is concerned, and therefore had no hesitation in again passing Cape Hatteras on the return journey to New York, though some of the party who had experienced its terrors in going down, preferred to leave the ship at Charleston and come north by train.

As to the canal scheme itself, you know that twenty-five or thirty years ago the French started to dig a canal. It had been mooted for hundreds of years as a desirable thing, but it was started in good earnest under similar conditions of construction to those of the Suez Canal. But unfortunately for the French—I say "unfortunately"—they were ahead of their time. There were many things in science to be known before attempting such a work as they undertook, and it was only when those things became known, that the possibility of constructing the canal existed. They attacked the problem when it was really impossible. One may talk about graft, corruption, and so on, doubtless very great at the time, but it was a desperate task even from the start, for there was no possibility of controlling the conditions of health and disease. Later on this was solved.

The French undertook to build a sea-level canal, that is, to cut down the whole Isthmus of forty-five miles to sea-level, so that no locks would be necessary. And that scheme, even today, would be a most gigantic undertaking. One has only to look at the conditions to realize how difficult and how tremendous a piece of work that would be. To cut down the whole forty-five miles to forty feet below sea-level would take probably not less than thirty or forty years and cost three or four times as much as the proposed arrangement which has been adopted by Congress.

The adopted scheme is, that at eighty-five feet above the sea level there shall be a great lake held back by an enormous dam at Gatun. On the Panama side there is also to be a lake, not nearly so great as the other, and but fifty-five feet above sea level.

As one approaches Colon from the sea, there is noticed a town lying on land which is but very little above the sea level, but as the tide here is only twenty-six inches as a maximum, no trouble is experienced with tidal variations. Colon practically

Fig. 2. Steam Shovel at Site of Gatun Locks

rests on a coral reef. Here are docks for the shipping where are landed supplies for the canal and such merchandise as is carried across the Isthmus by the existing Panama Railroad. The dock facilities here are quite modern.

On our arrival at Colon the various committees met the men of the administration force with whom they were to travel and from whom they were to acquire as much information as possible in the short time permitted. A special train was arranged for carrying the party over the Panama Railroad to Panama.

On arriving at Colon one is reminded of a remark of the President's in his Canal message to Congress, for he sees a considerable crowd apparently doing nothing. Perhaps this is the colored labor to which he alludes as having been taken to the

Isthmus at considerable Government expense, to become loafers at Colon, or unsanitary shack dwellers in the jungle. The country near Colon is very flat, low, and inclined to be marshy, but the low places are gradually being filled in. Much drainage work has been accomplished, and also street paving, so that there is an enormous improvement in the health conditions as compared with former times.

At Mount Hope, just outside of Colon, are great storehouses which contain practically everything required for life and for work except food. A catalogue of the things one may see in these buildings would fill volumes, but as the distance of the Isthmus from manufacturing centers is very great, it is necessary to have a large stock of materials and articles close at hand.

Farther on, or about seven miles from Colon, is the site of the proposed great Gatun dam, and here one obtains an impression of the magnitude of the canal enterprise. This dam is to be 7700 ft. long between hills and 2600 ft. wide at its base, while the crest of about 100 ft. wide will be at a height of about 130 ft. above sea level. Near the middle of the crest will be a great spill-way of concrete to allow excess water to run off. This great dam will impound the waters of the Chagres River, which river has always been a stumbling block in other plans of construction, as it is subject to excessive floods, having been known to rise about 40 ft. in one hour. The water above the dam being 85 ft. above sea-level, there will necessarily be a set of locks in three tiers or steps of about 30 ft. each, to allow vessels to pass from the high level to sea level and vice versa. These locks are to be double, or in duplicate, so that ships may be passing each way at the same time.

Fig. 3. Gatun, Site of Proposed Dam

I confess to having had a prejudice, in company with many others, in favor of a sea-level canal, and the feeling that the Government might be making a mistake in not adopting such a construction, but a view of the conditions on the spot caused an almost instant change of opinion. To construct a sea-level canal would be a lengthy, stupendous task, and before its completion the financial burden would become tiresome and perhaps exhausting for any people, while the Chagres River would be a constant menace. With the construction of the dam at Gatun, the Chagres River simply supplies water for working the locks, as a fresh water lake is obtained of 110 sq. miles in extent above this dam capable of easily impounding the water of the severest river floods. It is said that the foundations, which at the time of our visit were being sounded by diamond drills, have been found satisfactory for the construction of the dam and locks. Figures 2 and 3 give views of the site of the dam, and it is noticeable that there is a little town which will be covered by it. The tropical jungle has largely been cleared away from the parts shown where work is going on, so that the ground is almost bare of vegetation, with the result of a highly satisfactory sanitary condition. Many of the temporary dwellings or tents seen at Gatun will be replaced as soon as modern construction of screened buildings can be erected.

Fig. 4. Cut in Rock at Bas Obispo

On leaving the site of the Gatun dam we passed over some rolling country and followed up the Chagres River for quite a long stretch. Here the Panama Railroad, which originally was a single track road, has been double tracked, except for nine miles along this particular stretch, and the work of double-tracking this is under way. It is expected that there will soon be a complete double track from Colon to Panama, and this will greatly facilitate not only the transportation of supplies, but also the transportation of material and earth.

Fig. 5. French Scrap

The views along the railroad are often very beautiful and picturesque as vistas are opened up while the railway winds its way to Panama. Those having cameras would often wish that the train might stop so that pictures of some of the beautiful views passed might be recorded. This country will practically all be under water when the canal is constructed. Vessels may steam at full speed through much of this body of water.

About twenty miles from the site of the Gatun dam we reach the first real hard work of canal digging. This is the rock cutting at Bas Obispo, where is the beginning of the continental divide. Much cutting has been done at this place, but there is an immense amount of rock blasting yet to be accomplished. There is here a black, igneous rock, like a basalt, volcanic in nature.

Leaving this point we soon reach Empire, where there are shops for construction work, such as planing mills, modern machine shops, etc. We found some such shops at Christobal near Colon. The equipment is modern and well adapted to the kind of work which is to be done in the repair and erection of machinery.

From Bas Obispo the journey leads to Culebra, where the deepest cut is to be made, but on the way, at Empire, we see long lines of French locomotives on a side track. In fact, all along the canal site is seen strewn the French machinery or "French scrap" as it is called,—locomotives, cars, trucks, rails, earth shovels, etc., etc., which originally have cost millions of dollars. The locomotive engines, though of fine construction, are too small, and out of date. This is true also of much of the other machinery, such as the construction cars, dredges, &c. Some have said that the French tried to build the canal with toys, but in reality these toys accomplished a great deal of work. It is very doubtful if twenty-five or thirty years ago our engines would have been any better, or as good. I was told by one of the canal engineers that the material in the French scrap and the character of construction was of the very finest, and that the fire-boxes of these scrap locomotives were of copper, while the fire-tubes were of white metal. The French scrap is not yet gathered up because the railroad facilities are taxed to the utmost to do the canal work, and the opportunity for collection must come at a later date. Some day it will doubtless be collected. About this part of the canal zone, or part of the strip of land ceded to the United States by the Government of Panama, are many of the administration

Fig. 6. Looking Down into Culebra Cut

buildings, Police Station, Court House, and the like. Near Culebra Cut there has grown up a fair sized town, the town of Culebra, where the buildings are on high ground, cleared of jungle, well drained, and where the habitations are thoroughly screened to keep out the mosquitoes. The government of the zone is, of course, practically a despotism, and the United States is the despot, though, so far as could be seen, conditions were none the worse for that. At Culebra is the large Culebra Hotel, where there is a restaurant capable of furnishing, as was experienced, a very good meal, well served and well cooked. As one looks from a point near the town of Culebra, down into and along the great Cut, one realizes perhaps more than at any other time the magnitude and stupendous character of the work undertaken, and it must be borne in mind that the French did most of the existing cutting at Culebra, and with what has been condemned as their "little toy machinery." They, however, cut down from a summit level of 333 feet above the sea, 160 ft., leaving for the lock construction of canal about 127 ft. more to be cut down with a corresponding width in order to obtain proper slopes on the side. In the nine miles of

Fig. 7. Within Culebra Cut

cutting, which includes Bas Obispo and Culebra, the major part of the cutting to make the canal, there will have to be removed some 50,000,000 of cubic yards of earth, and it is expected that much of this will be utilized in constructing the dam at Gatun. Were a sea-level canal to be constructed, the cutting at Culebra would have gone down 85 ft. more, and the whole 45 miles across the Isthmus would have to be cut away about 40 ft. below sea level. This deepening would mean, of course,

Fig. 8. Hotel Tivoli at Bay of Panama

great widening for safe slopes. The lock construction confines most of the work of excavation to nine or ten miles.

Passing through the great Culebra Cut the further end towards Panama is reached, and lastly the site of the second set of locks, or Pedro Miguel, as it is termed. At this point a single drop of about 30 feet by a duplicate lock, will be made, to enter a fresh water lake of some ten square miles in area, held back by a couple of dams at a place called La Boca, and here, at what is called Sosa Hill, near the La Boca dam will be constructed a set of locks with two drops in flight bringing ships down to sea level.

Instead of the mere tide of twenty-six inches at Colon, the tide on the Panama side may be a maximum of twenty-four ft.

Both at the Colon and at the Panama end it will be necessary to dredge a channel out to sea for several miles and this channel goes very near the Pacific docks of the present Panama Railway.

Two or three miles away is the city of Panama on Panama Bay, and just within the edge of the Canal Zone and just outside of the city of Panama is a fine hotel, built by the United States Government on elevated land, and called the Hotel Tivoli. It furnishes a convenient dwelling place for men engaged in important work on the canal and has all modern conveniences. At the same time it is constructed to suit the conditions in the tropics, and is thoroughly screened.

The building of the canal largely depends upon preventing infection by disease germs, and it has been shown that at least two and perhaps more of the serious tropical complaints, are the direct result of infection carried by mosquitoes. Continual war is thus waged against the mosquito pest. According to the authorities, to convey yellow fever, a person who has the fever, and who is, of course, carried at once to the hospital, must be bitten by a particular species of mosquito within three days of the inception of the disease, for after three days the infection is not carried. The mosquito which has bitten the patient must live somewhere for twelve days in order that his biting of another person may

Fig. 9. Shore of Panama Bay, at Panama

convey the disease, the period being the incubation period of the germ in the mosquito. The person may, of course, be bitten by a stegomyia mosquito, which carries yellow fever without being infected. Under the conditions just mentioned, since the hospitals are fumigated so as to destroy insects in them each day, and are thoroughly screened, it is difficult to imagine yellow fever propagated or conveyed from one person to another. Another variety of mosquito conveys malaria. It was

sequently, there are regular brigades of men going around with cans of oil sprinkling the pools of water, and called the "mosquito brigade."

By careful attention to the distribution of wholesome food and the sanitary conditions, the Canal Zone has become remarkably healthy, so that for a year and a half there has not been a single case of yellow fever, and such infectious diseases as have appeared, have largely arisen outside of the Zone among the new comers. Connecessary that much of this be known before work could be successfully undertaken, and it is only in recent years that this knowledge has become available. The French were attempting to do the work without it and necessarily failed.

Returning for the moment to the city of Panama we find that it is an old Spanish city. Here the sun and moon rise out of what appears to be the Pacific Ocean, which is to the east of Panama. Being so near the Equator the nights and days are almost equal in length, or about twelve hours each, all the year round. Formerly Panama had miserably dirty and muddy streets, but later they have been paved and kept clean, so that the health conditions in Panama, like those in the Canal Zone, have been vastly improved. There are many interesting buildings in the present city, which was built after the destruction of the older Panama by buccaneers. The ruins of this older town are still seen on a site about six miles from the present City of Panama.

As to the labor conditions in the Canal Zone, there are a great many negroes, largely from Jamaica and other West India islands, though the proportion of whites, many of whom are from the north of Spain and from Italy, is increasing. It has been found as a matter of fact that the white labor is much more effective and reliable. A curious condition with regard to the negro laborer was discovered in that he was content to live on food which did not particularly nourish him. He would buy bananas, yams, watery foods containing very little real nourishment, with the result that he could not perform sustained labor. The Government at last prescribed proper nutritious rations and withheld thirty cents a day out of his pay for them. The result has been a great improvement in the amount and character of the work done.

I wish to say before concluding that there was a general unanimity of opinion of the whole body of men that visited the Zone, that things there were in very good shape indeed. Everyone was surprised to find the conditions so good, and while it is true that very little actual digging had been accomplished, yet everything points to the possibility of it. It was absolutely necessary that these conditions of health and food, distribution of supplies, etc., should all be arranged beforehand; otherwise the work would be very expensive and seriously handicapped. I think that a great deal of praise should be given the men in charge for bringing about the splendid conditions.

There is a reasonable hope, it seems to me, that the canal will be brought into existence now, and that the work will go on to the finish. And since it is a government enterprise, every citizen should be interested in its progress. It means a great deal for this country and also for the world at large.

At the same time, as you will readily understand, one of the chief incentives to the construction of the canal by the United States Government must be the providing of an easy passage for war vessels. Otherwise we should have to possess as gigantic a navy for the Pacific coast as for the Atlantic. It would take too long to make the trip around Cape Horn, and it is too much to expect all vessels to do as the Oregon did.

Some have said that it will injure the trans-continental railways, and some have charged that the railways are at the bottom of the resignations of important men in the Zone. I do not believe that this is true. The railways of to-day are very much hampered to take care of the traffic offered, and there is no reason for them to fear a canal when we consider the enormous growth of the world's commerce.

The conditions in the Canal Zone should be constantly improving. People are going there with their wives and children; schools have been established under good supervision. Amusements, such as baseball and the like, are being introduced, and the climate appears to be favorable. It is true that the rainfall on the Colon side of the Isthmus is very large, over 140 in. per annum. At Panama, it is said to be less than 50 in., or about what we have along the Atlantic seaboard. On the Colon side the showers may be heavy enough to interrupt work. If, however, nothing unforeseen intervenes, such as serious labor complications, most of us may witness the completion of this great world's enterprise in a few years' time.

ELECTRICAL ENGINEERING PERSPECTIVE

By HENRY H. NORRIS,
Professor of Electrical Engineering, Cornell University

Definition of Electrical Perspective

The successful engineer is he who has the ability to "to see things in space," just as the architect builds up a structure in imagination before any working plans are drawn. It is impossible for the beginner to do this, as he must first become familiar with detail. As soon, however, as he has mastered the elements of this subject, he begins to put them together to form more complicated thoughts; the power to do this being a measure of the success of his previous mental training.

Sound electrical engineering practice consists in the application of a few simple principles which stand out very clearly when the subject is viewed as a whole. The student and observer of electrical principles and practice is at first bewildered by the multitude of forms taken by electrical devices. Each seems to be a separate entity, and it is only after long association with them that their essential unity becomes apparent. It is useless to point out to the beginner that the armature coils of the direct current generator and the primary winding of the induction motor are essentially the same. He will not believe it, for he knows that one invariably rotates, while the other is usually stationary; that one is a closed winding, while the other is usually open; that one receives single or poly-phase alternating current, while the other gives out continuous current. When he has had more experience, he sees in each of these machines certain elements which are common to both, while their differences appear comparatively unimportant. This process of relating the essential features of various devices to each other and to their fields of application, may be called for convenience, *electrical perspective.*

Illustration of Electrical Perspective

Such a perspective view of electrical apparatus shows that it comprises three kinds of circuits; (a) electric, (b) insulating or dielectric; and (c) magnetic. In each device at least two of these circuits are present. The design of these devices involves, therefore, the economical application of conducting, insulating and magnetic materials.

THE ELECTRIC CIRCUIT has for its function the provision of a conducting path for the current, which is the vehicle for the transmission of energy to and through the apparatus. The apparatus usually is designed to change the variety of the energy. The change is in general accompanied by the production of a counter electromotive force in the circuit, which is the evidence of the resistance to the change of form of the energy. For example, in a motor, the electrical energy is transformed to mechanical, and the motor e.m.f. appears in the armature.

An electric circuit consists of two parts; the transmission line, and the machinery windings. The function of the transmission line is to transmit energy with least loss; that of machinery windings is to generate electromotive and magnetomotive force. For the latter purpose, two arrangements of the circuit or circuits are employed. The first, which may be termed localized windings, produce m.m.f.s in a definite direction. This arrangement is found in transformers, field coils, etc. The second is the distributed winding which produces a rotating field, and which is found in direct and alternating current generator and motor armatures; in the primary and secondary windings of induction motors, etc. The distributed winding produces an approximation to a sine distribution of m.m.f. in all cases.

THE MAGNETIC CIRCUIT has for its function the provision of a path for the magnetic flux, which in general is the connecting link between two electric circuits. The flux is produced that it may cut or be cut by one or more electric circuits, into or from which energy is being transformed. In all electrical apparatus involving a moving part or armature, there is a combination either of two distributed windings, or of one distributed and one localized winding. Distributed windings produce magnetic fields which rotate with respect to the conductors of the winding.

In the case of revolving armatures in which the winding rotates in one direction at exactly the same speed as the m.m.f. rotates in the other, there results a fixed position for the m.m.f. of the distributed winding, except as the maximum value is shifted backward and forward by a change in power factor, or by the shifting of the brushes.*

THE DIELECTRIC CIRCUIT. In order that the electric circuit may perform its duty, it is essential that the energy and its vehicle the current be confined to their path, the conductor. This requires that the latter be surrounded by insulating material of sufficient resistance to prevent leakage, and much more important, of a dielectric strength great enough to provide against rupture with a reasonable factor of safety. The provision is made not only against the ordinary strains of service, but against the excessive e.m.f.s introduced by lighting and by electric surges from the transmission line. The dielectric materials must have sufficient mechanical strength to resist the pressure and vibration incident to service, and they must not be unduly susceptible to the effects of heat and moisture.

Perspective View of Electrical Apparatus

APPARATUS	CIRCUITS INVOLVED	WINDINGS	MAGNETOMOTIVE FORCE
Transformer	Electric, Magnetic, Dielectric	Two or more localized	Two or more fixed
Induction motor. Induction regulator. Induction generator.	Electric, Magnetic, Dielectric	Two distributed	Two rotating
Synchronous motors, alternators, converters, D.C. Generators and motors.	Electric, Magnetic, Dielectric	One localized One distributed	One fixed One rotating

etc., etc.

Summary. This illustration of perspective indicates the essential simplicity of electrical apparatus. Naturally, the detail requires careful analytical study. It is a great satisfaction for an electrical engineer, when he learns of a new development in his business, to be able with facility to relate this to his previous knowledge. He can then follow the details to the extent of his ability and inclination. These remarks have been written particularly to the graduate apprentices, who while in college, may have had difficulty in co-ordinating their knowledge. The apprentice period gives an excellent opportunity for them to do this, surrounded as they are by examples of the best modern practice.

* The writer finds that students have most difficulty in appreciating the relations of the rotating and the fixed m.m.f.s in electrical machinery windings.

COMMERCIAL CENTRIFUGAL COMPRESSOR WORK

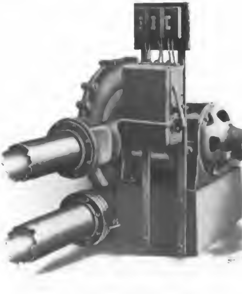
By DR. SANFORD A. MOSS

After an extensive series of experiments, covering a number of years, commercial work has been begun by the General Electric Co. on a line of direct-connected units for supply of air at moderate pressures in large quantities. These units are principally adapted for air blast for gas or other furnaces for various industrial purposes such as hardening, soldering, annealing, melting, smelting, etc. They are applicable to any case where a comparatively large quantity of air is required at pressures from about one to four pounds per square inch. These units are much simpler, more efficient, more durable and easier to operate and maintain than positive pressure blowers which have hitherto been used almost exclusively for such service.

Centrifugal Compressor Driven by 11 h.p. Induction Motor

The units consist of a modified form of fan blower integral with the driver, which may be either an induction motor, a direct current motor or a steam turbine. Owing to the fact that the driver and centrifugal compressor are part of the same machine, a very harmonious and compact design has been possible. Speeds, etc., have been selected to give most efficient operation as a unit, and there has been no hampering from considerations of belt or gear drive, etc.

The "Centrifugal Compressor" itself is a modified type of fan blower, consisting simply of an impeller rotating in a case, thus giving a maximum of simplicity. It is more highly perfected than the ordinary fan blower, however. It successfully accomplishes results beyond the range of fan blowers and maintains much greater pressures. The machines are, in fact, what are often called turbine compressors, and are closely related to so-called turbine pumps. The present line of machines has



Centrifugal Compressor

but a single stage, and is suitable for pressures up to about four pounds per square inch. Lines of multistage machines for greater pressures are in process of development.

The machines are not adapted for pressures less than about 0.88 pounds per square inch, which is equal to 14 ounces per square inch, or 1.8 inches of mercury, or 24 inches of water. The ordinary type of fan blower, or ventilating fan, should be used for all lower pressures.

These machines will come in competition principally with positive pressure blowers. It is believed that they will give much more satisfactory pressure regulation and that the avoidance of belting, gearing, and wearing and sliding parts, will give much greater durability and efficiency, and easier maintenance.

The photographs show a machine which has been in continuous commercial service for a long time in Bldg. No. 63, River Works, Lynn factory. It supplies air blast for gas furnaces of various kinds and has been accepted as a shop plant machine, displacing a number of positive pressure blowers. Reports from shop plant officials indicate that the machine is operating very satisfactorily. It has required no attention or adjustment of any kind since being put in regular service. Efficiency tests recently made give the same results as original tests when machine was new. This is as it should be, since there is no possibility of deterioration. This is in marked contrast to positive pressure blowers, which are always found to decrease greatly in capacity and efficiency as wear occurs.

This machine is rated for 750 cubic feet of free air per minute, at a pressure of 1.7 lbs. per square inch. As in all of these machines, the pressure is practically constant, regardless of load. This is well shown in the present case by the fact that the blast gate in the discharge pipe line may be opened or closed, thereby putting on or off the full factory load, without giving any variation of pressure in the discharge pipe at the machine. This machine is driven by an 11 h.p. squirrel cage induction motor, 220 volts, three-phase, 60 cycles. This motor has but two poles, and therefore has the maximum speed possible with 60 cycles; 3600 r.p.m. synchronous speed. A standard starting compensator gives satisfactory starting characteristics. The efficiencies of the machine under all circumstances have been carefully investigated and found to compare very favorably with competitive types.

The standard line of machines which has been laid out covers a number of different sizes for various capacities and pressures. In addition to the machine shown in the photograph, a number of other machines of this standard line have been built and are being built for various places in the General Electric factories, such as the Lamp Works, Iron Foundry, etc.

METAL FILAMENT LAMPS

By W. R. WHITNEY, PH. D.
General Electric Company's Research Laboratory

When Mr. Edison performed his well known experiments from which the present carbon incandesdent lamp resulted, he also made the first metal filament lamps. The chemistry of the rarer metals was then not so far developed as to make trials with the recently discovered materials possible to him. His attempts to make platinum serve as a filament are well known, but none of his processes for raising the melting-point were sufficient. A platinum filament melts apart or shrivels up before it is as luminous as a carbon filament at standard efficiency or is sufficiently luminous to be a practical lighting agent. Carbon then took up a position which a quarter of a century of experiment has hardly shaken. During this time about every conceivable form of carbon, and carbon from every conceivable source, has been tried as filament: charred silk and cotton fibre, compressed lamp black, graphite, carbonized bamboo, etc., etc. This basic material has been so thoroughly studied that the filament of today is a very complex structure. Many of them consist of a core or base of jet black carbon which is made from a cellulose solution squirted into fibre just as artificial silk fibre is made. This carbon base of the filament is surrounded by a skin, or shell of graphite, which gives it a steel gray appearance and raises its light efficiency. The whole is then finally changed by subjecting it to the highest temperature of the electric furnace, so that it partakes of some of the properties of a metal, which properties were not previously characteristic of it. During this development it was known that metals of very high melting-point could contend with carbon if they could only be isolated, purified and made into suitable form. Perhaps the first metal filament lamp on the market was the osmium lamp of Auer von Welsbach. This was a distinct advance over carbon in efficiency, but the resistance of this metal is so low that four or five long filaments in series have to be put into each 110 volt lamp. The process of manufacture is difficult. In fact, after considerable effort, but one factory in the world has succeeded in making this lamp. The cost of the material is also excessive and it is so rare in nature that it is actually impossible to appreciably effect the world's lamp supply by it.

Doubtless Von Welsbach's successful experiments made other students more active in this field, and many of the promising metals were probably soon being investigated. There are several which are superior to osmium, but the difficulties of making filaments from them are very great. It is for this reason that the newer metal filaments are the product of well equipped laboratories, where much effort has been expended in overcoming mere obstacles of manufacture after a general and long line of attack has been laid out. As far as metals are concerned, it is probably nearly true that the higher the melting-point the more efficient will be the lamp.

Dr. Werner Von Bolten, chemist of the Siemens & Halske Company, a student from Prof. Ostwald's laboratory, where also Dr. Walter Nernst was formerly assistant, studied with particular success the metals niobium and tantalum. He found that both, when in vacuo, resisted very high temperatures, but as tantalum was more difficult to melt, his laboratory's attention was devoted to this element. The efforts were directed to the reduction of the ore and to the perfecting of the filament form of the metal. The metal had not been drawn into wire prior to his experiments. The development of this lamp has caused search to be made for tantalum mineral, which was previously little known. Plenty of it is now to be obtained, so that the cost of the metal in the lamp ought to be small, compared to the cost of labor in producing it. Tantalum has such a high conductivity that about 2 ft. of wire, not larger than a human hair, must be suspended in each 110 volt lamp. At the temperature of operation the wire softens so much that it has to be supported at distances of about 1" apart throughout its length. This makes the Tantalum Lamp appear distinctly different from the other incandescent lamps. This lamp was the result of a splendid piece of careful research work which the

Fates seemed to have allowed a newer discovery to partially overshadow.

The Tantalum Lamp is capable of reducing the cost of light to about half the carbon-filament value, and such a change, if the lamps were rapidly introduced, would doubtless disturb the conditions in the light market. Under the single and simple condition that the saving in cost be equally divided among the parties concerned, there would certainly finally be a great increase in the number of incandescent lamps used. Long before these new lamps could be supplied in sufficient number to enlighten consumers as to their real value, promises of still newer and better lamps are made. It is noticeable, however, that each of these different kinds of lamp, including the carbon filament, possesses some one characteristic differing from those of the others which may well permit it to demand continued usage.

The discovery of the method of obtaining metallic tantalum and the development of the supply of ores will doubtless prove a boon to other industries. It is a metal peculiarly like steel, but possessed also of other properties, which make its trial in other fields exceedingly interesting.

The latest known arrival in the field of incandescent lights is the Tungsten Lamp. Tungsten has long been known as a metal, but few have seen it except as a powder. Its alloys with iron are quite common. It had been difficult to obtain it pure, and in the impure state it was very promising as a filament material. It was impossible to draw it into a wire, as was done with tantalum, though a melted mass of it could be produced in an arc-furnace. Therefore additional experiments had to be made. Filaments are now commonly produced from the fine powder, which is mixed with some kind of binder to form a paste, and after squirting through a die the resulting threads are subjected to some process to remove the foreign material. One of the simplest processes is to use sugar paste and to drive out the residual carbon in an inert atmosphere. Like its competitors, the osmium and the tantalum filaments, about 2 ft. of wire are necessary for 110 volt lamps. Its melting-point is higher than either of these and satisfactory lamps are made having nearly twice the efficiency of the Tantalum Lamp.

How much farther may we expect to go in improving the electric light? Evidently we cannot do better than devise a lamp which shall turn into light all the energy supplied to it. What part of the supplied energy is thus utilized in our present lamps? No one knows. It is apparently not a simple task to determine the efficiency of a lamp, and yet what we want to know is very simple. Electrical energy is measured in joules or its rate of use is measured in watts. These two bear the same relation to each other as do a price and a salary rate. A good 32 c. p. carbon lamp consumes energy at the rate of about 100 watts, but most of this is radiated or conducted away as useless heat.

To determine what part of this is effective as light one investigator has submerged a lamp in a glass vessel of water and measured the rate of heating of this water by the energy supplied to the lamp under two different conditions. In one case the vessel was transparent and in the other opaque. Evidently the difference in energy in the two cases might be expected to be due to the escape of light-energy when transparent walls were used, as the heat would be absorbed by the water. On this basis he concluded that .188 watts was all the energy actually necessary to produce one candle power, or for the 32 c. p. lamp about 6 watts. As the 32 c. p. carbon lamp really consumes 100 watts, the light efficiency becomes only 6%; that is, 94% of the energy is wasted.

Another able investigator has separated the entire radient energy of a lamp into a spectrum, and then collected the visable part of the spectrum—that is, the light rays —and determined their energy by the heating effect produced by it upon a very sensitive thermometer or bolometer. This also seems a very proper method of determination. The results differ greatly from those previously cited for he found about .12 watts per candle. On this basis, only about $3\frac{1}{2}$ of the 100 watts of our 32 c. p. lamp are really used as light.

Our best present lamp, the Tungsten, will give for a practical life about 80 candle power for 100 watts, instead of 32 c. p. According to our first method of calculation this lamp is using about 15 watts for light and wasting about 85. According to the second method its efficiency is about 9%.

In either case it is evident that there may still be great improvements made in electric lighting, and that until our lights are at least six times as efficient as at present something remains to be done.

In this connection it is worth while explaining for the uninitiated how different kinds of incandescent lamps are compared as to usefulness. The buyer of lamps, the public, that great authority which not only exerts the power of veto on all the schemes of the lampmaker, but which also practically determines his entire operation, has apparently decided that an incandescent lamp cannot in general be renewed more frequently than once in 500 hours. Oftener is too troublesome. Therefore it demands a lamp which will give the most or cheapest light for that period. This has carried with it the practical effect that if the lamp does not burn out at about its 500th hour, it will have reached about 80% of its original lighting power, so that it is then worth while to displace it by a new one. If the public were willing to frequently replace old lamps by new, it would demand the lamp which burns itself out or runs down to the 80% point in a shorter period than 500 hours, as the cost of light itself would be less and the efficiency would then be greater.

A carbon filament lamp will last about 50 hours while giving light at about 50% greater efficiency than the one actually demanded by the public, but the public will not pay for the greater number of lamps and take the trouble of replacing them so often. This method of replacement of carbon incandescent lamps also determines the efficiency at which new kinds of incandescent lamps must burn in practice; that is, if the new lamp is to burn out in time, let it be burned at as high an efficiency as possible without becoming destroyed or getting below 80% of its original light-value at the end of 500 hours.

A point which has always very greatly impressed us in this connection and one which could not fail to appeal to any observer, is the enormous light which any type of incandescent lamp is capable of giving for a short time, if it be "driven hard". In such a case it will die soon, but the thought involuntarily presents itself, why cannot this wonderfully efficient condition continue? An inert material is in a perfect vacuum. Why should it change or decay? For example, a carbon incandescent lamp will operate a short time at five times the normal efficiency. Some of the metal filament lamps will even do very much better than this and for some minutes deliver light at an efficiency superior to four candles per watt. This means that a small lamp, meant to be operated at 30 volts and give 30 c. p., can be driven by application of say 65 volts, to give for a short time a light of 400 c. p., which is nearly equal to that given by a good enclosed arc. On the basis of the lowest determination of the electrical energy actually necessary to produce one candle power this lamp is burning at nearly 50% light efficiency. On the basis of the higher determination referred to, it is yielding 75% of the input as useful light. This is truly an enormous advance over the practical commercial efficiency of 3½ or 6%. Its interest to the investigator is very great, for it indicates to him that there is no inherent reason for placing an upper limit on the efficiency of incandescent lamps, which limit shall be much below cent per cent. It may well be possible in the future to reach a point where the waste of energy in transforming from electricity to light will not be greater than in the other necessary step: (the change from mechanical energy of the engine or turbine to the electrical energy of the generator). If no electric light had existed, even for a moment, which was much superior in efficiency to that well known in practical illumination, the student of this field might well have felt that his determination of the electrical energy per candle corresponding to the perfect efficiency possessed merely an academic value.

The self-destruction of the filament of an incandescent lamp is one of those failures which seem uncalled for. We think when their diseases are properly diagnosed that remedies will at least greatly prolong their life, if they do not make it practically eternal. A filament glowing at dull red heat has nearly an eternal life. It is only when taxed by high temperature that it wastes away. The wasting away of the filament seems to involve many of the new and interesting theories and phenomena connected with electric discharges in gases. Particles of the filament seem to be shot off from its surface so that the filament is gradually weakened and the glass also blackened.

These phenomena are common to all incandescent lamps and as their causes are in the future, more thoroughly investigated, it is probable that improvements at present only hoped for, will be realized.

SMALL TURBINE INSTALLATIONS

By B. F. Bilsland

While the General Electric Company has installed and in operation a large number of small Curtis Steam Turbine Sets, and while those installed have given very satisfactory service, still the merits of the small steam turbine as a prime mover do not seem to be fully appreciated. One reason for this may be that the small steam turbine sets are a new development, and that the public has not as yet sufficient confidence in them to allow of their many advantages having much influence when compared to the small engine set. Furthermore, they are used principally by those who are unfamiliar with the uniform satisfaction given by large turbine installations.

Fig. 1. 15 kw. D.C. Curtis Steam Turbine Installed in Baggage Car

The smaller turbine sets are designed with two bearings and a one piece shaft, while the larger size is provided with four bearings and a two piece shaft with flexible coupling.

The sets are built to operate at speeds suitable for generators of high efficiency and great mechanical strength. Simplicity, compactness, and substantial construction are embodied in a neat symmetrical design.

The oiling system is very efficient and satisfactory, the oil being supplied to the bearings at a slight pressure by means of a pump geared to the turbine shaft. This distribution is further supplemented by the use of oil rings. The oil is used over and over again, circulating in a closed

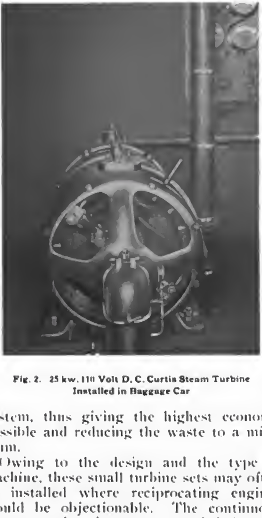


Fig. 2. 25 kw, 110 Volt D. C. Curtis Steam Turbine Installed in Baggage Car

system, thus giving the highest economy possible and reducing the waste to a minimum.

Owing to the design and the type of machine, these small turbine sets may often be installed where reciprocating engines would be objectionable. The continuous rotary motion is unaccompanied by the vibration always present in reciprocating machinery.

The small turbine units make ideal installations for supplying light, power, or heat, or all of these together; as well as for mills, machine shops, apartment houses, office buildings, and for train lighting, marine service, etc. They also make an excellent steam driven exciter set for supplying excitation for alternating current generators.

As the units occupy very little space it is possible to install them where no other machine capable of doing the same work could be placed, as well as in places where the space is very valuable, as shown in Fig. 1.

This is a 15 Kw. Direct Current Curtis Steam Turbine Set installed for the Pennsylvania Railroad Company in baggage car "Utopia." The photograph gives a very good idea of the small amount of space necessary for the unit by comparison with the limited floor area in a baggage car. This turbo-generating set is of sufficient capacity to furnish current for approximately 300 16 c.p. incandescent lamps at normal load, and 375 16 c.p. incandescent lamps at maximum load. The machine occupies not more than 27 cubic feet. For a switchboard, the wall of the car is made use of, the meters, switches, circuit breakers, rheostats, fuses, gauges, etc., being fastened directly on the wall.

On account of the light weight and the small size of these sets, as well as the absence of reciprocating parts, these turbines operate without vibration, and there is no necessity for heavy and expensive foundations. That a very inexpensive foundation is sufficient is shown in Fig. 2.

This figure shows a 25 Kw. Direct Current 110 volt Curtis Steam Turbine Set installed in a baggage car for the C. B. & Q. R. R. The foundation is made from four medium size timbers bolted to the floor of the car. As in the installation described above, the wall of the car is made use of for the switchboard. In this case the instruments are placed on a board and the board fastened to the wall.

Fig. 2 also gives a very good view of the generator, showing the relative size of the armature, and the compactness and neatness of the entire design.

A typical installation is shown in Fig. 4

This shows installed two 15 Kw. and one 25 Kw. direct current 125 Volt Curtis Steam Turbine Sets. These are a part of the exciter sets which are used to furnish excitation for testing the turbo alternators at Schenectady, N. Y. They are practically in constant service, and as a rule are kept running continuously from one week to another.

The cut also shows what a slight foundation is necessary, the small amount of space which is used, and that such a location would not be an ideal one for installing reciprocating engines.

The oiling system for the turbine sets has as before been described, and from this it is evident that the cost of lubricating is a very small item. This is not true in the case of engine sets, for the oil to the bearings is partially used and partially wasted, therefore, consumed. The cylinder oil in the exhaust steam is either entirely lost, or can be only partially saved by the use of a separator. This of course, adds to the expense of the installation and also slightly to the cost of operation.

The exhaust steam in the case of the turbine installation is entirely free from oil, and this is of no little value when it is likely to be used for cooking, steam heating, laundering, etc.

The care and attendance required in operating a turbine set is considerable less than that of an engine set. After a small turbine set has been placed in operation, and run a sufficient time to know that all parts are working successfully, very little more attention is needed, save for occasionally renewing the oil, and trying the emergency governor to see that it is working properly. With an engine, however, it is different, for it is necessary to visit the engine several times during a day to fill the oil cups, fill or tighten the grease cups and see that the lubricator contains oil and is working properly. It is also very evident that the amount of waste necessary for the engine is considerably more than for the turbine.

Water collects in steam mains and pipes and if not carefully handled when starting an engine, serious damage may result, still if damage is caused this way it is the result of carelessness. However, it occasionally happens that water is carried over from the boilers into the engine and blows out a cylinder head, thus causing expense for repairs and loss of the service of the unit. With the turbine such an occur-

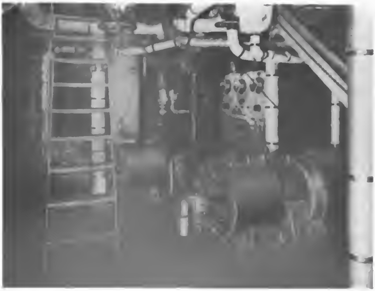


Fig. 3. Two 25 Kw. 125 Volt Curtis Steam Turbine Sets Installed on Hudson River Day Line Boat "Hendrick Hudson"

rence would simply tend to slow the speed of the set while the water was passing through the turbine. In all cases, however, good engineering will reduce the tendency to this trouble.

The weights of the turbine sets are approximately 50 to 60% less than those of the engine sets of the same capacity. This fact may be of great importance concerning the location of installation, also in regard to the cost of the foundation. The difference in weight, of course, makes the freightage less for the turbine unit.

Finally, the initial cost for purchase and installation of a turbine set is practically the same as that for an engine set of the same capacity, a slight difference being sometimes in favor of the one or the other. However, this depends upon the local conditions, and upon the type and quality of engine.

Fig. 4
Two 15 kw. and One 25 kw. 125 Volt Curtis Steam Turbines

With the steam turbine set the maintenance and repair charges are generally much smaller than those for a steam engine set. There is no change in efficiency over very extended periods of operation, and much less attention is required. This latter item results in considerable saving since a cheaper operator may be employed. Furthermore, the reduction in necessary floor space, with the consequent decrease in building expenses; and the greatly lessened cost of lubrication, are some of the points which will in general be found to place the steam turbine set far in advance of its old time rival.

HIGH VOLTAGE TESTING TRANSFORMERS

By J. J. FRANK

In the General Electric Review of December, 1904, there was an article describing two 160,000 volt testing transformers built for the Columbia Improvement Company.

At that time, the writer believed that such voltage was the highest that had ever been used for testing purposes, and considered the design of the transformers worthy of special mention.

The fact that the General Electric Company has recently built two transformers

Fig. 1
Section of one of the High Tension Coils of Testing Transformer

rated H-60-300-300000-2300/4600, one for the Wirt Manufacturing Company, Plymouth, Mass., and the other for the Power & Mining Department at Schenectady; in which the high tension voltage is, as the rating indicates, almost double the voltage of those previously descibed; suggests this as an opportune time to call attention to these higher voltage apparatus.

These transformers are oil insulated, and embody the latest ideas in mechanical and electrical design, to meet the severe strains incident to their operation at such high voltage.

They are core type, the core consisting of two vertical legs joined at the top and bottom by horizontal yokes. The interleaving of the yoke and the vertical legs is done in such a manner as not only to reduce the exciting current to a minimum, but also to materially increase the mechanical strength of the core structure over any other construction previously used.

The low voltage winding is placed directly on the core, and consists of one strip of copper, wound in a single layer.

The high voltage winding is divided into fifty separately wound and insulated coils, having but one turn per layer in each, These fifty coils taken together make a total of about 16,000 turns. The insulation between layers and between turns of the terminal coils, is reinforced to such an extent that it will withstand a test of 10,000 volts applied indefinitely. The section of such coil is shown in Fig. 1.

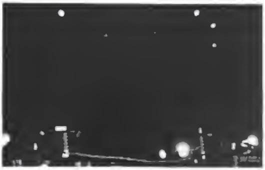


Fig. 2. Testing Transformer in Operation

By a peculiar method of assembly, the space between the high voltage winding and the low voltage winding is subdivided into a number of separate channels by concentric cylinders, requiring the use of no spacing strips or centering blocks of any kind in these channels, so that the insulation between the two windings is of the highest known quality.

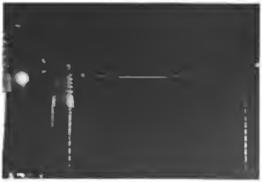


Fig. 3. Testing Transformer in Operation

The bushings for the high voltage leads consist of cylindrical sections filled with oil. This construction has demonstrated its superiority over the use of any solid material, and in the present transformers, the bushings have been subjected to a potential strain of 500,000 volts for hours, without any indication of weakness.

The transformer was designed to meet the following characteristics:

Frequency: 60 cycles.
Capacity: 300 Kw.
Primary voltage: 2300 4000.
Primary current: 65 amperes.
Secondary voltage: 300,000.
Secondary current: 1 ampere.
Efficiency at full load: 97.4%.

The above cuts show the transformer operating at different voltages, and to a certain extent, illustrate the strains to which the high voltage windings are subjected under normal working conditions. See also illustration on front cover.

Fig. 4. Showing Carborundum and the Reactive Coils

Referring to the above photograph, attention is called to the discharge across the carborundum resistance placed in series with the high potential lead. The flat disc-like coils on top of the bushings are reactive coils intended to take the strain occasioned by the discharge of the potential across the needle gaps, and thereby protect the terminal portion of the high potential winding.

RAILWAY SIGNALS

Part I

By F. B. Corey

Introductory

This series of articles is not presented with a view to instruct those already skilled in railway signal engineering. It has been prepared in response to a request for some elementary information of a general nature to enable the reader to clearly understand the fundamental principles of the operation of railway signals, and to place him in a position to discuss intelligently such simple matters relating to their operation as may be called to his attention.

Signal Engineering is a branch of the engineering profession which is very little understood by those who are not making it a special study. Something of its importance may be seen from the fact that the signal engineers in this country have a national association now numbering about 700 members and rapidly increasing. It is not strictly a branch of Electrical Engineering, for the greater part of the signal apparatus now in use is entirely mechanical, with no electrical connections whatever; and such devices present some most complicated mechanical problems. On the other hand, some of the large recent installations of signal apparatus are operated and controlled almost wholly by electricity, and the number and complications of the electrical circuits, both alternating and direct current, are most bewildering to one unfamiliar with this class of apparatus.

Broadly speaking, any device used to indicate to the engine-man, or the motorman, the condition of the track in advance of his train is a railway signal. According to their function, such signals may be divided into two general classes; those whose primary function is to indicate the condition of the switches, or to designate certain routes which may or may not be entered, i. e., interlocking signals; and those whose principal duty is to maintain a definite space interval between trains travelling on the same track in the same direction, i. e., block signals. According to their methods of operation, all railway signals are also divided into two groups, viz.: manually operated, and power operated. Each of these general classes might be further subdivided, both with respect to functions, and operating methods.

Through the popular press, our attention is often called to the fact that the railroads of England are more completely equipped with signals than are those in this Country. Notwithstanding this fact, it is on American railroads that the highest development in the art of railway signaling has been attained. The rapidity of development on this side of the water may be judged by the fact that in 1873, when the London & Northwestern Railway alone had interlocking plants aggregating 13000 levers, there was not a single railway interlocking in use on the American continent. Each year now shows an enormous increase in the use of signals in this country, but it will be many years before our roads will be equipped so as to compare favorably with those abroad, with respect to the quantity of signaling devices in use per mile of track.

In taking up this subject, perhaps the most logical course would begin with the consideration of mechanical interlocking, which is in many respects the foundation of modern railway signaling. At the present time, however, it seems best to first take up the matter of block signals, leaving the more complicated interlocking devices for future consideration.

Any system of railway operation in which the tracks are divided into sections, or blocks, and in which means are provided to prevent more than one train from occupying any one block at a given time, is a block system. Very early in the history of railway operation, a need developed for means to insure that trains, operating on a single track, which was then almost universal, should be protected against collision. About the year 1840, the so-called Staff System was originated in England, and this system, while not applicable to present conditions of high speed and congested traffic, is unrivaled both for simplicity and safety. This system in its simplest form, consists of a series of wooden or metal staves, on the two ends of which are marked the names or numbers of two successive stations. The possession of a staff by the engine man gives him authority to enter the block controlled thereby, and no train can enter the block without carrying the staff. As there is but one staff provided for a given section, it is obvious that only one train can enter at a time in case the "absolute" staff system is in force. This system necessitates trains alternating in direction, with the same number going each way daily. In order to permit one train to follow another, a modification called the permissive staff system was devised, in which tickets giving authority to enter the block are issued to the engine-man by the attendant at any station, provided he has the staff in his hand. Usually these tickets are kept in a box, the key to which is attached to the staff which is given to the engine man of the last train that is to pass in a given direction. Even with this modification, it is evident that the system is very limited in its application.

This system has recently been brought out in a much improved form, which greatly increases its flexibility. There are several instruments of this class, known as electric staff and tablet machines, in use abroad, and one such system is being used to considerable extent in this country. Reference to these devices will be made in a future issue.

The first electric block signal system which in any way fulfilled the requirements of modern railway operation, was the telegraphic block system. The first installation in this country was on the Pennsylvania Railroad between New York and Philadelphia, and the method is still used extensively, especially on single track lines. In this system the road is divided into sections, or blocks, of the proper length, usually 1 to 4 miles, and an operator is stationed in a tower at the entrance of these blocks, the necessary information for governing train movements being transmitted indication to the engine-man is given by means of hand operated signals, usually of the semaphore type.

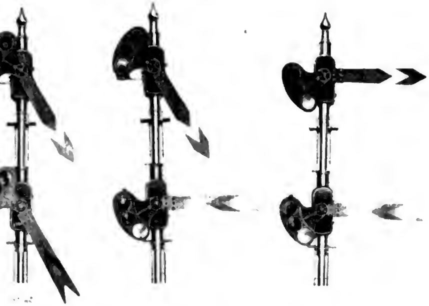


Fig. 1. Upper Part of Two Arm Home and Distant Signal

When a block signal is set at stop position, it should not be passed until after the train has been brought to rest. As a signal can be clearly discerned only at a limited distance, depending upon various weather conditions, as well as upon the topography of the country; it is obvious that if only one were provided at each block station, it would be necessary for the engine-man to approach each signal at a speed that would permit him to stop the train at it, from block to block by means of the bell signals or telegraphic instruments. The in case it were found at stop position. In order to avoid this difficulty, a second signal is installed, called the distant signal, which follows the movements of the other, called the home signal. The distant signal is so located as to enable the engine-man to bring his train to rest at the home signal in case it be found in stop position, as indicated by the distant signal.

There have been used, from time to time, various devices for giving to the engine-man the necessary visual indication of the condition of the track ahead. Formerly, various styles of banners and discs have been used, but the manufacture of these has been discontinued in favor of the semaphore arm, with the appearance of which all are familiar. There are a large number of discs and a few banner signals still in use, but as they are not considered to be good practice, we are at present concerning ourselves only with those of the semaphore type. When such semaphores are used, the distant signal is distinguished from other signals by the notched or "fish tail" end of the blade, while at night, lights of distinctive colors are used, so that no confusion can arise.

The distant indication must be given at sufficient distance in advance of the home signal to permit the engine-man to bring his train under proper control; and this distance can, in most cases, be made equal to the distance between two succeeding home signals, and thus place both the home and distant signals on the same mast. In most instances, in simple block signaling, both home and distant signals are placed on the same mast to give uniformity and to reduce the cost of installation. When signals are so mounted on a single pole, the home signal arm is placed nearer to the top of the pole, with the distant arm about 6 ft. below it.

With the signals above mentioned, it has been assumed that each signal arm may occupy either of two positions: the stop, or horizontal position, and the proceed, or inclined position. With a two-arm "home-and-distant" signal it is customary never to have the distant arm at proceed position when the home arm is at stop position. It is obvious that no confusion can arise from this practice, although, under these conditions, the distant signal does not always indicate in advance the true position of the corresponding home signal. With such an arrangement, it will be seen that each two-arm home-and-distant signal gives but three indications, viz.: 1st, both signal arms in proceed position, indicating a clear track for two blocks in advance; 2nd, the home signal at proceed position with the distant signal horizontal, indicating that the block about to be entered is clear and the succeeding block is occupied, or that the next home signal is at stop position; 3rd, both arms at stop position, indicating that the block must not be entered, except under the regulations there in force. The upper part of a two-arm home-and-distant signal is shown in Figure 1. A complete signal of this class, as manufactured by the General Electric Co., is shown on page 2. In these photographs, the distinctive shape

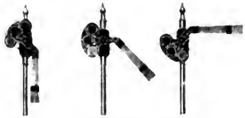


Fig. 2. Three Position Signal

of the distant signal blade will be noted. The shape of the upper or home signal blade is not uniform throughout the country, as the standards of various railroads differ considerably in this respect.

It is evident from the above, that all information conveyed to the engine-man by a two-arm home-and-distant signal, may be given with equal certainty by a single signal arm having three distinctive positions; and this brings us to the consideration of the three-position signal, as distinguished from the two-position signal. In such signals the stop, or danger position, is indicated by a horizontal arm, and the clear or proceed indication, by the arm in a vertical position. The distant, or cautionary indication, is given by the arm inclined at an angle of 45°. Such a signal is clearly shown in these three positions in Figure 2.

The night indication for signals is by no means uniform as regards color, except that red invariably indicates stop. The best practice for two-arm home-and-distant signals displays a red light for the stop position of the home signal, a yellow light for the stop position of the distant signal (caution), and green lights for the proceed positions of both. An older arrangement, and one at present more widely used, is a green light for stop position of the distant signal, and white light for the clear positions of both. With three-position signals the best practice is, red for stop, yellow for caution and green for proceed, although red for stop, green for caution and white for proceed is more largely used. The change from white to green for the proceed indication is now being made by several roads.

The simple telegraphic block system above mentioned does not at all meet the requirements of modern railway practice, as it depends entirely upon the reliability of each individual operator. Any system of block signaling in which an operator can give a clear signal without the active cooperation of another operator, and when the block is occupied, is manifestly unsafe.

The next step in advance, logically, but not chronologically, was the so-called controlled manual system, often called the Sykes system, on account of the name of its English inventor, Mr. R. W. Sykes. Probably the best known installation of this kind in this country is that of the New York Central & Hudson River R. R. between New York and Buffalo. In this system the levers controlling the signals are locked and released by so-called "lock and block" machines, which are controlled jointly by the operators at each end of the block, and by the moving trains themselves through the medium of the track circuits. The signals are held normally in stop position, and the joint action of the operators in two towers is necessary to clear them.

With the above facts of a general nature in view, we are now in position to consider the highest development in the art of block signaling, i. e., the automatic block signal system. This will be taken up in detail in the next issue of the REVIEW.

To be Continued

INTERNAL COMBUSTION ENGINES FOR AUTOMOBILE AND MARINE PURPOSES

PART II

By H. S. BALDWIN

Comparison of Gasoline Motor with Steam Engine

Before taking up the detail construction of the modern four-cycle gasoline engine, which is the subject of my talk tonight, I would like to make a few general observations on the advantages and disadvantages of this type as compared with the steam engine.

As the gasoline motor becomes better understood and its mechanical details more thoroughly worked out, it is forcing itself to the front as a motive power for automobiles, launches, yachts, and stationary purposes. The principal reason for this is that the explosion motor, as compared with the common type of steam engine, offers the great advantage that its fuel is burned or exploded directly in the cylinder and the heat energy immediately converted into useful work; i. e., the generator or boiler and engine are one.

Tests show a thermal efficiency of well-designed internal combustion engines of 20 to 30%, as against 10 to 15% in the steam plant. This is at present offset, however, by four inherent disadvantages; *first*, its inability to start under load; *second*, at low speeds its torque is low; *third*, it is impractical to change the direction of rotation of the engine; *fourth*, it cannot be started without compressing the first charge of gas by hand-cranking. It is also limited to a given maximum output.

Its economy of fuel consumption, relatively small bulk, lack of numerous pipes and valves under pressure, and ease of control are what give it its high standing in the motor world.

In passing, it is only fair to steam to state that very recent experiments, using a two-stage expansion-engine with highly superheated steam and heated receiver, show nearly the same thermal efficiency as is attained in the internal combustion engine. I doubt however, if these figures can be reached under commercial conditions.

I will devote the rest of my time to the detail construction and arrangement of the four-cycle gasoline engine, under the following heads:

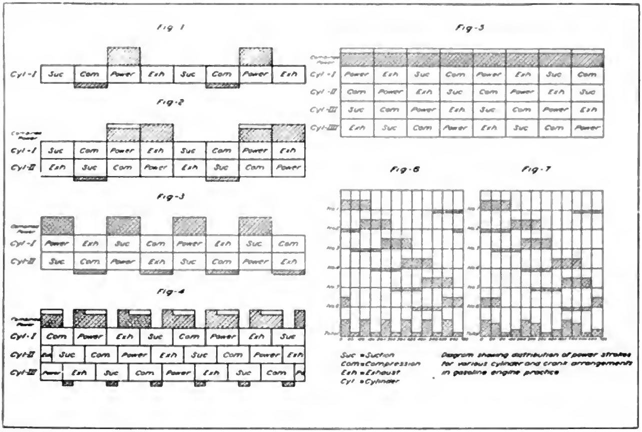
- Cylinder and crank arrangement.
- Valve setting.
- Carburetor.
- Ignition.
- Materials of construction.
- Management and operation.
- Methods of test.
- Formulas.

Cylinder and Crank Arrangement

Each of the following diagrams shows section lines, and each diagram represents four complete revolutions, of eight strokes.

No. 1. *Single Cylinder Engine.* Seven hundred and twenty degrees between explosions. Reciprocating parts unbalanced, requiring counter-balance.

No. 2. *Two Cylinder.*—Cylinders side by side, cranks 180 degrees apart, same distribution as opposed type, having single-throw crank. Two explosions occur in succession, followed by two idle strokes. Reciprocating parts are partially balanced



the relation of events in four-cycle engines having cylinders and cranks arranged according to the more usual practice met in explosion-engine design. No attempt is made to show the variation of pressure during the several strokes, but each is represented by a rectangle. The sectioned rectangles above the lines represent positive or useful work, while those below show negative effort in compressing the charge of vapor. Explosion strokes are indicated by in first case, but unbalanced in second.

No. 3. *Two Cylinder.*—Cylinders side by side, single-throw crank, same distribution of impulses as opposed type, having cranks 180 degrees apart. In first case, reciprocating parts are out of balance, while in the second they are very nearly balanced. In both cases explosions occur at equal intervals.

No. 4. *Three Cylinder.*—Cylinders side by side, cranks at 120 degrees. Power impulses 240 degrees apart. Reciprocating parts nearly balanced. Turning effort fairly uniform.

No. 5. *Four Cylinder.*—Cylinders side by side, crank pins No. 1 and No. 4, 180 degrees from pins No. 2 and No. 3. This is the most common arrangement for the larger touring cars. Explosions are 180 degrees apart and mechanical parts are very nearly balanced.

No. 6. *Six Cylinder.*—Cylinders side by side; one crank for each cylinder disposed at angles of 120 degrees around shaft. Very uniform turning effort as well as excellent mechanical balance. This arrangement is becoming more and more popular, for large touring cars, on account of its smooth running qualities.

No. 7. *Six Cylinder.*—Three cylinders opposed to other three. Crank-shaft has three throws, 120 degrees apart, with two connecting rods on each pin. Same remarks as for No. 6. This arrangement takes up less room fore and aft, but involves horizontal cylinders.

On the smaller touring cars and runabouts, either the single cylinder horizontal engine, or the double opposed with cranks at 180 degrees, is usually used, the latter being preferable.

There are other combinations of cylinders and cranks, as, for example, cylinders placed at an angle of 90 degrees or less, but the ones shown and described are those most employed for automobile work.

An interesting cylinder arrangement is that frequently employed in large gas-engine practice of to-day, and while it is not strictly pertinent to the subject, a short description may not be out of place. As has already been stated, small gasoline engines are invariably single acting, having only one power stroke, for each cylinder, for every four strokes of the piston. This effect is only partially corrected by the use of multiple cylinders. In modern gas-engine units of large powers it has been found possible and practicable to not only water jacket the cylinder walls, but pistons, piston rods, valve stems and heads, and in fact all moving parts subjected to the heat of combustion. Since these members can be kept at a moderate temperature, lubrication is possible and a way is opened for the double-acting gas engine. By arranging two double-acting cylinders in tandem with cross head and single crank it is immediately apparent that every stroke of such an engine may be a working one, and that it closely approximates the conditions met in a single cylinder double-acting steam engine.

Valve Setting

The subject of valve setting is an interesting one and a few words regarding it may not be out of place. It is almost universal practice in explosion-engine design to operate both intake and exhaust valves by properly shaped cams. These cams have their working faces disposed at certain angles which give the desired duration of valve opening. In addition to the above, the peaks of the cams are formed with small or large radii, according as sharp or gentle valve operation is required. While the face angle of the cam regulates how long the valves shall remain open or closed, its angular position with relation to the crank determines when these events shall take place. It would be perfectly natural, for one who had not considered the subject carefully, to assume that explosion-engine valves operate when the piston is at each end of the stroke. This is not the case, however, as it has been found necessary in practice to keep the exhaust valve open as long as possible —220 to 240 degrees—in order to thoroughly scavenge and as much as possible cool the cylinder. The intake valve is allowed to remain open from 165 to 210 degrees.

I have prepared the following table from data, which I have collected, for the purpose of illustrating more clearly the foregoing remarks. It should be noted that the intake valve in most cases opens and closes well past the top and bottom centre respectively; in other words, it is given a certain amount of lead.

Name of Engine

A. Maudsley Motor. Six Cylinder. 550 R. P. M. 9″ x 9″.
B. "Speedway Motor." Four Cylinder.
C. Olds Runabout. Single Cylinder.

D. General Electric Co. Four Cylinder. 900 R. P. M. 6″ x 6″.
E. Gas Engine and Power Co. Four Cylinder. 6″ x 6″.
F. Electric Vehicle Co. Four Cylinder. 5″ x 5″.
G. Wolseley Motor. Six Cylinders. 430 R. P. M. 9″ x 10″.
H. General Electric Co. Eight Cylinders. 8″ x 7″.

Table of Crank Angles

		A	B	C	D	E	F	G	H
Exhaust opens ahead bottom centre		43	40	38	40	40	45	38	40
Exhaust closes past top centre	Ahead	4	6	10	8	10	15	5	0
Intake opens past top centre		27	12	19	10	0	20	23	9
Intake closes past bottom centre		31	14	5	16	20	50	27	30

Carburetor

We have described many of the fuels used in explosion-engines, now let us see how they are employed. Take, for example, gasoline vapor. In order to render it explosive it must be mixed with a certain percentage of air, and the ratio of gas to air determines its effectiveness. By compressing a given mixture of finely divided gasoline and air it is more readily ignited in the explosion chamber of the engine and a high initial pressure is obtained, but it should be kept in mind that compression does not increase the total heat units of a definite volume of gas, consequently it does not increase the total foot pounds of work it can do. Compression simply causes the energy of the gas to be given out more rapidly with less waste, which is what is required in the explosion motor.

This table will show you the explosive effect of various mixtures of air and gasoline vapor at different pressures:

Gasoline Vapor and Air	Time in secs bet. ignition and highest Pressure at Atmosphere	Explosive force in lbs. per square inch. Compression in Atmospheres			Temperature of Combustion in Degrees Fah. at Atmospheric Pressure	
		3	4	5	Actual	Theoretical
1 to 13	0.28	156	208	260	1,875	3,542
1 to 11	0.18	183	244	305	2,196	4,010
1 to 9	0.13	234	312	390	2,803	4,806
1 to 7	0.07	261	348	435	3,119	6,001
1 to 5	0.05	270	360	450	3,226	6,854

The device used for mixing gasoline vapor and air is called a carburetor. The earliest form of carburetor was that of Daimler, which was of the surface type used by him in 1885. It consisted of a cylindrical tank partly filled with gasoline through which air was caused to pass by the suction of the engine to which the carburetor was attached. Means were provided to compel the air to bubble through the same depth of gasoline, irrespective of its height in the tank. Otherwise you will readily see that, according as the level dropped, the amount of gasoline vapor carried by the air would vary considerably. The principal objection to the surface carburetor was that the more volatile vapor was given off first, leaving a thick residue in the form of less easily vaporized oil at the bottom of the carburetor. This caused much loss of gasoline and gave very irregular and unsatisfactory results in the operation of the motor. Nevertheless, the early DeDion tricycle and many automobiles employed this kind of carburetor. In fact, it was the only type known until Maybach, in 1893, invented the float feed carburetor. This, in widely varied form, is the one most used to-day.

It consists of a small chamber containing a very light float which operates a valve to prevent the entrance of gasoline after a certain level has been reached. Thus it is often called the constant level carburetor.

Connected with this chamber, by a passage, is a nozzle having a small opening at the same height as the gasoline level in the chamber. Above and around the jet are baffles to break up or vaporize the liquid gasoline as it comes through. At one side of the jet is an opening to allow air, usually warmed, to mix with the vapor. Another opening allows the mixture of gasoline and air to be sucked into the explosion chamber of the engine.

You will see that the float feed carburetor gives uniform conditions of head of gasoline at all times, and as it receives the oil from the bottom of the supply tank there is no heavy sediment left, as was the case in the surface type. The gasoline usually runs by gravity until the float shuts it off, but in many automobiles it has been found convenient to place the main fuel tank below the level of the carburetor, and in such cases it is necessary to use the Mercedes pressure valve, which gives, by a shunt pipe from the exhaust, a pressure of two to three pounds per square inch, which is sufficient to force the gasoline up into the carburetor. There are several other devices used for this purpose.

A valve is provided so that the mixture of gas and air can be varied to suit given conditions of temperature and atmosphere.

Another valve, called the throttle, regulates the amount of mixture entering the engine, and this serves to regulate the engine speed, very much as does the throttle of the steam engine.

Only a few years ago the Krebbs carburetor of this type came out, embodying a new and valuable principle in carburetors; namely, the automatic variation of the quantity of air in accordance with the motor speed. To-day all good carburetors have some such features.

The reason for the above is that in starting an explosion engine using a liquid fuel, in order to have a standard mixture it is necessary to reduce the air intake; as the engine speeds up, however, the intake opening should be increased. This is necessary on account of the fact that the suction of liquid gasoline through an opening follows the law of liquids, whereas air follows the law governing gases. If, instead of liquid, a true gas were employed, then both components of the mixture would follow the same law and preserve a constant ratio throughout all variations of velocity.

There is one other type of carburetor used in connection with two-cycle engines, called a mixing valve. In simple terms, it is nothing more or less than a check-valve with the valve so arranged as to permit the entrance of a small amount of gasoline when it is sucked open, or, more correctly, when it is opened by atmospheric pressure. In the mixing valve, means are provided for varying the amount of gasoline which enters, usually a small valve. Needless to say, this device is somewhat crude as compared with the very complete float-feed type, but it serves the purpose of the two-cycle motor on account of its simplicity and rugged construction. It is also much cheaper to manufacture. Nevertheless, the float type of carburetor is being more and more used for two-cycle engines on account of its economy in the use of gasoline.

Ignition

Now that the charge is properly mixed, let us assume that it is in the explosion chamber of the engine under 80 to 90 pounds compression and the problem before us is to ignite it. In the early engines a closed platinum or iron tube was connected with the explosion chamber. This tube was externally heated to a high temperature by means of a Bunsen burner. When the charge of gas was highly compressed by the piston, it was forced into the tube, whereupon it ignited slightly before the end of the compression stroke. The hot tube device has now been abandoned, as it does not allow of regulating the time of ignition, which is highly essential in gasoline motors. One of its defects was that of pre-ignition, caused by the tube being clogged with dead or burned gases.

At the present time ignition is produced by two electrical systems; one called the high tension or jump spark, the other the low tension or make-and-break. Both depend on an electric spark or arc, and it is hard to tell which is the more popular. From a comparative table which I prepared a short time since it appears that most of the prominent cars abroad and many in this country use make-and-break ignition. On the other hand, the great majority of American cars have the jump spark.

In some ways the make-and-break system is preferable, so I will describe it first.

A contact device within the explosion chamber is mechanically operated from without so that the electric circuit is first made, then opened, just at the desired instant, causing an intensely hot arc to be drawn, which ignites the gas. It is necessary, of course, to insulate one of the contacts from the other and this is done by mica tubes or discs placed about the stationary contact. Current is generally supplied by magneto, which should be so connected to the engine as to give the maximum voltage at the proper time. If the magneto be used in connection with a four-cylinder engine, it should run at the same speed as the crank-shaft, and it is highly desirable that the armature be advanced and retarded with the spark cams in order to at all times obtain the greatest output.

Storage or primary batteries should be used with make-and-break ignition when the magneto armature has a fixed relation to the crank-shaft of the engine, which practice is generally followed by builders on account of its simplicity. The current supplied by the magneto is alternating, of 100 to 125 volts on open circuit and two or three amperes at the time of break. It is an actual fact that more power can be obtained from an engine with the make-and-break system than with the jump-spark, also that the time of ignition does not need to be advanced so many degrees, as the spark is made instantaneously with the break. The contacts within the cylinder are sometimes made of platinum and iridium, which alloy resists intense heat. There are several other marked advantages in the make-and-break system, namely, freedom of spark rigging from injury caused by soot, excessive oil, or moisture. The wiring in connection with this system is extremely simple, consisting of only one wire leading from the armature, the magneto itself being mounted on the engine. You will note that the voltage is low, so that no unusual insulation is necessary to prevent leakage.

Now let us look into the jump spark system. A current of about 14 amperes, at approximately six volts pressure, is supplied by battery, either primary or secondary, to the primary circuit of an induction or Ruhmkorff coil. A commutator or timer which is operated by the engine makes the circuit between the battery and coil at the instant a spark is desired. The commutator has as many contacts as the engine has cylinders, and serves, not only to economize the electric current, but to cause the spark whenever it is wished.

Timing the spark is accomplished by moving the commutator so as to advance or retard ignition. You probably all know that an induction coil has a vibrator which when it breaks the circuit causes a sudden reaction or magnetic flux in the iron core and produces an induced circuit of very high voltage of perhaps 10,000 to 20,000. Of course, the current of the secondary circuit is almost nothing. The secondary winding of the coil is composed of a great many turns of the finest wire, one end of which is grounded, the other being connected with an insulated plug called a spark-plug. The spark-plug has two points of platinum placed about 1-32" to 1-16" apart and the high tension current jumps across them whenever the commutator causes the primary circuit to be closed.

There are two objections to this system, one, the very great care necessary to prevent leakage of the high tension circuit, the other being batteries which discharge rapidly and are a source of constant trouble.

What is called a high tension magneto may now be used instead of the battery. This consists of a low tension magneto, run by the engine, the current of which flows through the primary coil of a transformer. This induces a current of high tension which is distributed by a special device giving correct timing of the spark for each cylinder. A low tension timer is also necessary. The objection of high voltage exists even with this arrangement.

Materials of Construction

TENSILE AND ELASTIC LIMIT REQUIREMENTS OF MATERIALS FOR MODERN GASOLINE ENGINES

ALUMINUM.	
Maximum Strength	25,000 lbs. per square inch.
Elastic Limit	16,000 lbs. per square inch.
PARSONS MANGANESE BRONZE.	
Maximum Strength	70,000 lbs. per square inch.
Elastic Limit	30,000 lbs. per square inch.
HERCULES GOVERNMENT BRONZE.	
Maximum Strength	44,000 lbs. per square inch.
Elastic Limit	32,000 lbs. per square inch.
MALLEABLE IRON.	
Maximum Strength	40,000 lbs. per square inch.
GEAR CASE METAL.	
Maximum Strength	38,000 lbs. per square inch.
Elastic Limit	23,000 lbs. per square inch.
CHROME NICKEL STEEL (HEAT TREATED).	
Maximum Strength	210,000 lbs. per square inch.
Elastic Limit	155,000 lbs. per square inch.
CHROME NICKEL STEEL (NATURAL).	
Maximum Strength	90,000 lbs. per square inch.
Elastic Limit	65,000 lbs. per square inch.
NICKEL STEEL (HEAT TREATED).	
Maximum Strength	130,000 lbs. per square inch.
Elastic Limit	100,000 lbs. per square inch.
NICKEL STEEL (NATURAL).	
Maximum Strength	85,000 lbs. per square inch.
Elastic Limit	65,000 lbs. per square inch.
NO. 4 STEEL FORGING.	
Maximum Strength	70,000 lbs. per square inch.
Elastic Limit	40,000 lbs. per square inch.

STEEL CASTING (STANDARD MEDIUM).

Maximum Strength	75,000 lbs. per square inch.
Elastic Limit	40,000 lbs. per square inch.

CAST IRON (STANDARD MEDIUM).

Maximum Strength	21,000 lbs. per square inch.

Management and Operation

The best and quickest way to learn the gentle art of operating explosion engines is to get in touch with them from a practical standpoint. If one be of an observing turn of mind, he will quickly acquire knowledge, but he should be careful not to have it *thrust* upon him, as might be the case if an attempt were made to start an engine without first retarding the spark or time of ignition. Not all of us, however, have explosion engines available for experimental purposes, so I will devote a few words to this subject.

It should be explained that when a motor is running at normal speed, the ignition spark is set to occur somewhat ahead of the end of the compression stroke. At such time the spark is said to be "advanced," in other words, moved back against the direction of rotation of the engine. In order to increase the speed still further, the spark is first "advanced," after which the throttle should be opened correspondingly. It should be kept in mind that spark position is a function of speed. In some engines the point of ignition is regulated automatically by governing apparatus depending on engine speed. In explanation of the above attention is called to the fact that an appreciable time is required for a compressed charge of vapor to ignite. The spark and maximum point of explosion pressure are not simultaneous. You will note that at high rotative speeds the spark must be advanced in order to compensate for the higher angular velocity of the crank, which tends to carry the piston farther on its working stroke, before the vapor charge has time to explode. If under these conditions the spark were not advanced, you will readily understand that much power would be lost, since work would be performed through only part of the piston stroke. Care should be taken not to advance ignition too far or the explosion will occur before the piston has reached the top of its stroke, causing loss of power and knocking.

When large power is desired, reasoning backward from the above facts, it is clear that the spark should be somewhat retarded, since the engine speed will be less. At such times the throttle should be well opened.

Beginners sometimes fail to retard the spark before turning the starting crank, and in such cases it frequently happens that a wrist or arm is broken.

When running a motor light with ignition retarded, the mixture should be throttled as much as possible to prevent overheating. A good rule to remember, when there is any uncertainty as to which way to move the spark lever in order to retard ignition is to shift it so that the timer moves in the same direction that the cam shaft rotates.

In hill-climbing the spark should be retarded, but not so far as to cause knocking.

Lubrication is most important, and before starting an engine the operator should make sure that there is a plentiful supply of the right kind of oil and that all passages are clear, so that no part requiring lubrication shall be slighted.

Most engines to-day are water-cooled. Special attention must be given to the water-supply and circulating system. A stoppage of water is likely to cause scoring or tearing of the cylinder walls which will ruin the engine. When an engine has by mistake been run without water, it should be allowed to cool slowly, and under no circumstances should cold water be turned into the jackets. Such procedure would cause a cracked cylinder with attending delay and expense.

Much more data might be added to this subject if time allowed; the above points, however, give a fair idea of the more general features.

Methods of Test

Many kind of tests can be applied to the explosion engine for the purpose of ascertaining or analyzing effects in any of its parts or in the machine as a whole. Of these, two are the most important: one a test to learn what is taking place in the cylinder during complete cycles; the other a test of output or effective work. Both tests are of greatest interest and value to the designer; the latter is of more significance to the purchaser; but if he obtain large power and smooth, economical operation of his engine it is because the engineer has correctly interpreted his tests of conditions of pressure within the cylinder.

What follows is quoted directly from a pamphlet issued by the maker of the Hospitalier-Carpentier Manograph. This is a comparatively new device and is much used abroad by the great automobile companies. It has aroused considerable interest among American engine manufacturers, and our own company has purchased a Manograph for experimental purposes.

"The Manograph has been constructed to furnish indicator diagrams of motors, internal combustion machines, or steam engines of high speed.

"Every one knows the importance of a pressure diagram for the purpose of studying the actual conditions in a heat motor during the cycle of operation. At the time when the first engine was invented, Watt recognized the necessity for some instrument to accurately determine the pressures in the cylinder at all times, and invented one which bears his name to this day. This instrument, while giving satisfactory results on slow-moving engines, is inadequate when those of high speed are to be tested, owing to the inertia of the parts of the instrument.

"To get around this difficulty, Messrs. Hospitalier and Carpentier have invented an indicator (the Manograph) in which the movable parts are of such small weight that inertia is practically eliminated, particularly the index which traces the diagram has no weight, as it is merely a ray of light.

"The ray of light made use of in the Manograph is produced by a small acetylene lamp supported by the apparatus, and traces the outline of the diagram on a plate of roughed glass after having been reflected from a little mirror. This mirror is the soul of the apparatus. Resting on three points, of which two are movable, it receives from the latter motions which show themselves by the displacement of the luminous point on the screen, so that the deflections of the two movable points are at right angles with each other, the three points forming a right triangle the fixed point being the apex of the right angle. One of the movable points is controlled by a diaphragm acted upon by the pressure of the gas from the cylinder; the other is controlled by a device which repeats on a reduced scale the movement of the piston. One can therefore easily understand that the composite displacement on the screen forms the outline of a pressure diagram. This diagram cannot be perceived by the eye in its entire length, except it be completed in less than 1-10 of a second, which is the maximum duration of a luminous impression on the retina.

"Since the diagram of a four-cycle motor corresponds to two complete revolutions of the same, it is evident that the curve can only be observed in a satisfactory manner on motors making more than 20 revolutions per second, or 1,200 revolutions per minute. Below these speeds the diagram ought to be received photographically."

So much for internal phenomena.

The brake horse-power of an engine—B. H. P.—may be obtained by any one of several forms of absorption dynamometer.

The simplest is the Prony brake, with which you are no doubt familiar. Owing to the irregular and intermittent turning efforts met with in the explosion motor, the Prony brake has been found unsatisfactory. Occasionally the rope brake is employed, but each of the above devices is open to the objection that the load cannot be kept constant.

Professor Webb, of the Stevens Institute, suggested a water brake, which is used by the Bliss Company in testing engines of torpedoes for the United States Navy. It consists of a smooth metal disc revolving in a casing partially filled with water. The casing is suitably mounted on bearings having little friction, and is attached to a weighing-scales or spring balance which records the pull or torque. When the disc is rapidly turned by the engine, the water in the casing is thrown outward, forming an annular ring. Work must be done to overcome the skin friction of the disc, and this may be easily measured.

The Standard Motor Company uses a liquid brake which depends on throttling the passage of water between the suction and discharge of a small gear pump.

The pump is connected to a scales so that the effort of the casing to revolve is resisted and measured by a spring balance.

If a metal disc be revolved in a magnetic field, eddy currents are set up tending to restrain it. This effect may be illustrated by reference to the damper disc of the Thomson Recording Watt-meter, which offers a very good example of the phenomenon in question. A dynamometer has been devised along this line, and as the field strength may be easily regulated and the resulting torque measured it should be a very effective piece of apparatus.

Electric generators are frequently used to absorb the energy of explosion engines, but there is always more or less uncertainty as to the efficiency of the generator, which varies with the load. Electric dynamometers have the great advantage over mechanical ones, that the output can be very easily and accurately read by the use of voltmeter and ammeter.

The objection of variation raised against the generator brake is met by the cradle dynamometer used in the Lynn Works, also by the French firm of Panhard-Levassor and others. Here the magnet frame of a generator of suitable size is mounted on anti-friction bearings. The armature is directly coupled to the crank-shaft of the engine; means are provided to mechanically balance the magnet frame and field windings, also to measure the tendency of the frame to revolve. Here the error, due to the use of a generator of standard form, is overcome, and at the same time the method of electrical control is retained.

All the foregoing braking devices, as you will readily understand, will approximate the same results, namely, the useful work that a given explosion engine can deliver. They differ only as to accuracy, ease of observation of results, and cost of apparatus.

Formulas.—Horse Power of Four-Cycle Motor

D = Dia. of Cylinders.

S = Stroke of Cylinders in inches.

N = Number of Cylinders.

R = Revs. per Minute.

$\frac{R}{2}$ = Working Strokes of 4-cycle Motor.

$.7854 = \frac{\pi}{4}$

12″ = 1 Ft.

33000 = Foot Pounds in H.P.

M = Mean Effective Pressure.

E = Eff. of Mech. Parts.

$$\frac{(D^2\times .7854)\times \frac{S}{12}\times \frac{R}{2}\times M}{33000}\times N\times E = \text{B.H.P.}$$

Substituting Constants

$$\frac{D^2\times .7854\times \frac{S}{12}\times \frac{R}{2}\times \overset{\text{M.E.P.}}{80}\times N\times \overset{\text{Eff.}}{.85}}{33000} = \text{B.H.P.}$$

$D^2\times S\times R\times N\times .00007 = \text{B.H.P.}$

Using 80% eff. above formula becomes

$D^2\times S\times R\times N\times .0000635\times \text{B.H.P.}$

Prony Brake

L = Length of brake arm in ft.

N = Revs. per min.

P = Lbs. pull.

$$\text{B.H.P.} = \frac{2\pi L\times N\times P}{33000}$$

Calculation for Compression Space for a Given Compression

PV^k constant.

Assume 80 lbs. compression is desired:

$P_1V_1^k = P_2V_2^k$.

P_1 = Absolute initial pressure in atmospheres.

V_1 = Total volume of clearance plus cylinder volume taken as unity.

k = 1.35 Average value for gasoline, vapor and air.

P_2 = Absolute compression pressure in atmospheres.

V_2 = Compression volume.

When suction inlet valves are used the initial pressure is taken at .75 absolute pressure.

When mechanically operated inlet valves are used .90 of absolute atmospheres is used.

Then P_2 = 80 lbs. per sq. inch (5.45 atmospheres) plus one atmosphere = 6.45 absolute atmospheres.

$$V_2 = V_1\left(\frac{P_1}{P_2}\right)^{\frac{1}{k}} \qquad \frac{1}{k} = \frac{1}{1.35} = 0.74$$

$$V_2 = \left(\frac{0.9}{6.45}\right)^{0.74}$$

Log V_2 = 0.74 Log 0.14

Log V_2 = 0.74 × 0.1461 − 1.

V_2 = 0.234, which in this case is per cent. of volume swept by piston plus all clearance space.

EUROPEAN PRACTICE IN ELECTRIC HOISTING ENGINES

PART II.

By EUGEN EICHEL

The description of some of the plants that have been in actual operation for several years will afford an opportunity to present some additional details of hoisting engine equipments of the flywheel converter type.

A large plant showing interesting features of the development of the improved system, is that at Pit Zollern II. This plant was laid out in 1901 to 1902 as a straight D.C. proposition, and was one of the first German mines to be operated electrically from one central power plant.

The two 1100 kw., 90 r.p.m., 525 volt engine driven D.C. generators, are supplied with superheated steam from the adjacent boiler house, and fuel is furnished as waste gas from the nearby battery of 80 coke ovens. On the other hand, the electric generators furnish the power for the coke oven auxiliary machines and the coal washing and screening plant, which has a daily output of 2200 tons. Furthermore, they supply the two 270 h.p. main fans and the two 420 h.p. air compressors for the operation of the mine. The rear part of the machine room contains the electric hoist, space being provided for an additional hoisting engine unit.

The hoisting engine is of the Koepe Disc type, and the 19.8 ft. disc is direct driven from two 750/1400 h.p. D.C. motors.

For control, it was proposed to use a combination system comprising a slight amount of starting resistance, series-parallel control of the two hoist motors, and voltage control by means of a four group 500 Amp.-one hour discharge storage battery. Assuming that the acceleration required to start the masses is constant during the starting period, the starting losses would be represented approximately by the shaded triangles on the left hand side of Fig. 13. The decrease in rheostat losses during the acceleration period, is graphically shown in the three diagrams as follows:

"A" the energy and speed diagram of a motor driven hoist, the motor in this case being operated with plain rheostatic control.

"B" a similar diagram for a hoist driven by two motors which are operated in series-parallel connection.

"C" the diagram of a hoist the speed regulation of which is effected by means of battery control, the storage battery being divided into four groups in order to obtain four running potentials without energy losses in starting rheostats.

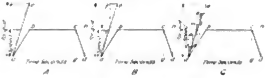


Fig. 13. Energy and Speed Diagrams
(A) Rheostatic Control.
(B) Series Parallel Control.
(C) Potential Control.

Some of the apparent objections to this method of using straight D.C. and series-parallel control are as follows:

The desired flexibility claimed for the electric system is offset, since the cost of the necessary copper in D. C. cables and connections limits greatly the distance between power house and hoist motors. This is proven by a large hoisting engine installed at Grangesberg, Sweden, which is direct driven by two 500 h.p., D.C. motors. Its operation from a power house 17.5 miles distant is made possible only by the use of a high tension A.C. transmission system and the installation of a 7000 volt two-phase, 550 volt D.C. motor generator unit installed near the hoist.

When using series parallel and battery group control, it requires very heavy controlling apparatus for the safe handling of the large main current. This means not only high investment cost, but also high maintenance cost, due to the wear of the large number of main contacts. Furthermore, the speed increase is not effected smoothly, but in steps, which decreases the quiet running as well as the life of the rope.

The original design of the Zollern II hoist included a starter consisting of a large pneumatically operated commutator type contact arrangement for the oil immersed metal resistance. However, this control equipment and the storage battery is now considered as reserve only and is used principally for Sunday, holiday, and such other light service as requires the lowering and raising of a few men and repair gang material. Since 1903 the main

Fig. 14 44 Ton Fly-wheel, Pit Zollern II

service has been operated by means of a flywheel motor generator consisting of a 300 h.p., 350/300 r.p.m. shunt motor, a 44 ton flywheel of 13 ft. diameter, and a 550 volt D.C. generator. The latter is provided with commutating poles, and is able to furnish up to 2000 amperes during the starting of the hoist motors.

Fig. 14 is a view of the flywheel converter, and also shows the very interesting slip regulator. Since the power house main units are D.C. generators, the driving motor of the flywheel converter is a D.C. machine. Therefore it is simply necessary to operate the field rheostat of the motor in order to obtain the decrease in speed which allows the flywheel to give up its stored energy. In order to obtain automatic operation, an adjustable relay is inserted in the main circuit between generator armature and hoist motor armature. This relay energizes one or the other of two electro-magnetic clutches, and these in turn connect a transmission to the field rheostat lever. This transmission is belt driven from the flywheel converter shaft. When one of the clutches is energized, the transmission forces the lever in a clockwise rotation, whereas the other clutch causes its rotation to be reversed.

Fig. 15 shows the current conditions as caused by the use of the flywheel converter. The very smooth and slightly fluctuating curve around the 400 ampere line, shows the amperage input of the motor of the flywheel converter, while the heavily fluctuating curve is the amperage input of the hoist motor. The heavy peaks rising up to 1800 amperes indicate the starting current; the shoulders at about 900 amperes, the free running period; the negative peaks, reaching to 1000 amperes, the retardation, (these indicate the back feeding and storing of regained energy in the flywheel of the converter); the three positive peaks of short duration show the setting of the three floor cage. While this diagram is instructive in showing the high commutating quality of the converter generator it is somewhat misleading regarding the kw. consumption. The upper diagram of Fig. 15 gives simultaneous current and potential conditions during one hoist cycle of a hoist installed at Mine Friedrichshall. Starting from the right hand corner we see the full line rising steeply to almost 800 amperes, after which it drops within a few seconds to 600 amperes, then decreases to

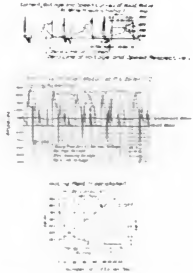


Fig. 15 Operating Curves, Pit Zollern II and Friedrichshall

900 amperes, where it remains for a longer time, this being the free running period. Near the end of this period we notice the heavy negative recuperation peak, [illegible]

lowed by the positive peak indicating the setting of the cage. Following the dotted line which represents both the potential and speed of the hoist motor, we notice that speed and potential are gradually increased while accelerating and remain constant at the free running period; dropping gradually during the retardation and being almost zero at the time of the heavy ampere peak caused by the setting of the cage.

The disadvantage of unsteady load, and its influence on the 24 hours service of hoisting engines is shown in the lower diagram of Fig. 15. While the use of the flywheel equalizes the load factor of the power house, and the application of the Ward-Leonard Control does away with the large rheostatic losses, the following are inherent in the flywheel converter service:—

1) Comparatively high bearing and windage losses, due to the heavy flywheel operated at high speed; noload loss in the continuously operated motor.

2) Rheostatic losses during the operation of the slip regulator.

3) Generator and exciter losses.

The losses under item 1 are of special importance if the mine is operated in such a manner that only a few lifts per hour are required, or that fast hoisting takes place during only part of the 24 hours per day, while little or no hoisting is done during the remaining part of the day. It is evident that during fast hoisting periods, the noload losses represent a small average part of the total current consumed for actual lifting, while on the other hand, when only a few lifts are made per hour, the addition of the noload loss added increases considerably the total current consumption to be charged against these few lifts.

The lower diagram, Fig. 15, representing conditions at Mine Friedrichshall, shows, for instance that it requires a total of 33 kw.-hrs to hoist 10 times per hour, or 3.3 kw.-hr. per lift; while it requires only 70 kw.-hrs. to hoist 40 times per hr., or 1.75 kw.-hr. per lift. To quote another example. The actual steam consumption tests during a 24 hour service in the above mentioned Zollern II plant showed the following conditions:

DESCRIPTION	Morning Shift 6-10 o'clock	Noon Hoisting Miners 2-3 o'clock	Evening Shift 3-10 o'clock	Night Shift 10-6 o'clock
General Power load of Power house; kw.-hr.	9076.33	715.82	7506.75	4770.79
*Hoisting Plant; total kw.-hr	2192.07	83.96	1577.18	552.18
Coal Raised; long tons	1500		700	
Water Consumption, lbs.	167882	12800	137236	97260
Water Consumption per kw.-hr., lbs.	18.59	19.60	18.26	20.42
Eff. h.p.-hr., on shaft	1562.00	13.05	990.13	92.00
Current Consumption per effective h.p.-hr. on shaft, kw.-hr.	1.395	6.42	1.596	6.01
Steam Consumption per effective h.p.-hr. on shaft; lbs.	23.574	114.918	29.143	122.70

*Converter Motor, Input.
Excitation of converter generator.
Excitation of Hoist Motor.
Air Compressor for Brake.

While the steam consumption per shaft h.p.-hr. when hoisting fast (i.e. 1500 tons during the 8 hr. morning shift) amounts to 23.574 lbs., the average steam consumption per effective h.p.-hr. during the 24 hr. service (including power consumed for hoisting men, timber and tools, inspecting the shaft, etc.), amounts to 31.297 lbs.

The 24 hour efficiency in plants operating, say, two 8 hour shifts fast, and the 8 hour night shift very light, can be considerably increased by rendering the flywheel independent of the motor generator. It is the latest practice in such plants to provide flywheels which are supported by two independent bearings and are connected to the motor generator by means of flexible disengaging couplings.

Fig. 16 is such machine comprising a flywheel and a twin motor generator set. During night shift, the flywheel is uncoupled and heavy fluctuations on the power house, when operating without the flywheel, are avoided by decreasing the operating speed and the acceleration about 50 per cent. This is not objectionable on account of the few trips required.

Fig. 17 shows the scheme of the layout of a hoisting engine plant with a detachable flywheel as installed at Pit Tiefbau in Karwin (Austria).

The hoist equipment is installed in a small two-compartment brick building

81 x 34 ft., while the pit house and the structural steel head gear are built separately. The electric drive has replaced steam drive, and a 3000 volt, 30 cycle three-phase current is supplied by means of a lead covered, armored underground cable from a powerhouse located about

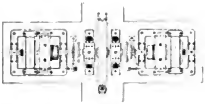


Fig. 16. Two Motor Generator Sets Connected to Common Fly-wheel by Disengaging Couplings

1.24 miles distant from the pit. Fuel is obtained from a nearby coke oven plant.

The operating conditions are as follows:

Ultimate depth of pit......1750 ft.
Present depth of pit....... 990 ft.
Useful output per hour.... 136 tons
Useful output per lift.....6700 lbs.
Hoisting speed, coal......2380 ft. per min.
Hoisting speed, men......1190 ft. per min.

The hoist cycle is made up as follows:

	Time; seconds	Way; ft.
Lifting	2.5	19.8
Accelerating	22.0	514.8
Running	25.2	996.6
Retarding	13.0	237.5
Setting	3.0	0
	65.7 sec.	1768.7
Stop	22.8	
Total	88.5 sec.	

The hoisting engine is driven by a 500 volt, commutating pole shunt wound motor (b) having a capacity of 640 h.p. normal, 1080 h.p. maximum, and a speed of 49.5 r.p.m. The hoist has two cylindrical drums of 15.5 ft. diameter and 4.9 ft. width, one of which is fixed and the other loose. It carries the cages on steel wire rope 1.57 inches in diameter.

Its speed control is effected by means of the operating lever (d), which is mechanically connected with the Ward Leonard field rheostat and the safety device on the depth indicator, thus insuring safe acceleration, free running and retardation speeds, as well as preventing the overwinding of the cage. The air brake is applied either by hand, through the brake lever (e), or in emergency cases, automatically, the hoist motor current being reduced to zero prior to the setting of the brake. Mounted on a column in front of the operator's stand is a gauge for showing the brake air pressure, together with an ammeter for indicating the hoist motor current, and a voltmeter for showing the potential. Since the hoisting speed is proportional to the potential, the instrument has an additional dial indicating simultaneously the momentary hoisting speed in feet per

Fig. 17. Plan of Hoisting Engine, Pit Tiefbau, Karwin

(a)	Bearings	(f)	Exciter
(b)	Hoist Motor	(g)	D. C. Generator
(c)	Drum	(h)	Coupling
(d)	Brake Lever	(i)	Fly Wheel

minute. As is the case in most European hoisting engine plants, a tachograph "System Karlik" is installed. Its operation is based upon the centrifugal principle, the material acted upon being mercury, which in this device performs the functions of the balls in the ball type pendulum governors frequently used for similar purposes. The apparatus is particularly well adapted for indicating and recording such sudden speed changes as are met with in hoisting engine operation, and the log sheet of the recording instrument affords an infailable check upon the daily hoisting conditions.

The flywheel converter (Fig. 18), which feeds the hoist motor, comprises a 420 h.p., 450/437 r.p.m., 3000 volt, 30 cycle, three phase induction motor (h); a 560 kw., 500-0-500 volt, commutating pole D. C.

generator (g); a 12 kw., 190 volt, compound wound exciter (f); and a 27.5 ton cast steel flywheel (i) of 15.8 ft. diameter.

The flywheel is operated at a peripheral speed of 297 ft. per sec., and at 12.5 per cent slip, gives up 25 per cent of its stored energy of 52,220,000 ft.-lbs. It is supported by water cooled bearings which are lubricated by means of oil under pressure, the oil being obtained at a pressure of 118-162 lbs. per sq. in., from two compressors which are friction gear driven from the converter shaft. From the total no-load converter losses a saving of five kw. was effected after reducing the windage losses by enclosing the flywheel in a closely fitting sheet iron casing. As above stated, the flywheel is designed as an individual machine unit which can be connected to the motor generator or disconnected from it by means of a flexible coupling (h). The stored energy of the flywheel is sufficient to make two full load lifts, or five no-load lifts, after the alternating current has been cut off. Since its free running time is about two hours, it is standard practice at Pit Tiefbau to brake by hoisting the last few trips with the A. C. circuit disconnected. This practice is observed in many flywheel converter plants rather than braking by means of emergency band or block brake; although it requires some attention to avoid the stopping of the converter before the cage reaches its landing.

Fig. 18. Fly Wheel Converter at Pit Tiefbau, Karwin

One Three Phase Motor, 420 h.p. 450-437 r.p.m.
One Generator, 300 kw, 500 Volts D. C.
One Exciter, 12 kw, 190 Volts.
One Cast Steel Fly Wheel, 27.5 Tons.

Compressed air for hoist brake operation is furnished by an air compressor which is belted to the converter shaft.

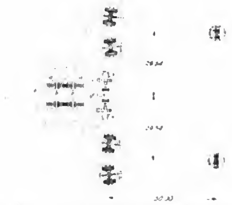


Fig. 19. Lay Out of Hoisting Plant, Pit Matthias Stinnes

(a) Three Phase Motors.
(b) Fly-wheels.
(c) D. C. Generators.
(d) Slip Rheostats.
(e) Exciter Motor-Generators.
(f) Air Compressors.
(g) Switch Table (Armature Current Control).
(h) Switch Table (Exciter Current Control).
(i) Hoisting Engines.
(k) Fans.
(l) Switchboards.

The slip regulator is of the type in which an A. C. relay controls a D. C. motor, which in turn drives a metal rheostat. A special water rheostat is provided for the starting of the flywheel converter from stand still. This operation is effected within from 5 to 10 minutes, the time depending upon the maximum amperage which can be taken from the mains without disturbing the general power and lighting service and the adjustment of the time limit device which prevents the attendant from operating the water rheostat too fast. It requires about 350 kw. to bring the converter up to 300 r.p.m. within 4—5 minutes, while the normal no-load wattage amounts to 25—30 kw. An interesting feature from the operating standpoint, is the employment of only two hoist operators per 12 hour shift. One man operates the hoist while the other one inspects and cleans the electrical apparatus, the engine and the head gear. They change their occupations every two hours, since in addition to their meagre salary, they receive a premium for the amount of coal hoisted.

Double flywheel motor generator sets have a number of advantages which can best be understood by referring to an actual installation, as, for instance, the recently opened mine "Mathias Stinnes at Branck" (Germany), which comprises two shafts with a preliminary depth of 1750 ft. and an ultimate depth of 2640 ft. The shafts have a diameter of about 21.8 ft., probably the largest size that has been built up to the present date.

Each shaft is laid out for double hoisting of a useful load of 10,560 lbs. each. The hoisted coal is transported by means of a rope railway 1.2 miles long, to an older shaft, where it is washed, screened and made ready for shipment.

The entire plant is electrically driven, and current is bought from the Rhenish-Westfalian Electric Works, located about 5.4 miles distant at Essen. This plant represents the first large German mining installation to be fed by an electricity works that supplies current for general use.

The current is three phase, and is transmitted at 10000 volts, 50 cycles over two underground cables with 3 x 0.0525 sq. in. cross section; step-down transformers reducing the potential at the mines to 5000 volts for power, and to 220 volts for lighting purposes.

Fig. 19 shows the layout of the entire plant. The machine house is to ultimately contain two large flywheel motor generator sets, only one of which is installed at the present time, however. In addition to the necessary auxiliaries, two Rateau fans are installed for an output of 2824000 cubic feet of air per minute, while the four electric hoisting engines are located in wings arranged symmetrically with reference to both sides of the motor converter house. Each flywheel motor generator set consists of two identical three-machine units, mechanically coupled. Each of these two sets comprises a three-phase induction motor (a), a flywheel (b), and two D. C. generators of the same size (c). The induction motors are for the purpose of driving the flywheel and the generators, and are designed for the average energy consumption of the hoisting plant, the flywheels equalizing the fluctuations of the load during the hoisting periods. The D. C. generators supply the D. C. hoisting engine motors (i), the voltage and polarity being regulated by Ward Leonard control.

The following details of the flywheel motor generator set may be of interest:

Three-phase Induction Motor:

Voltage—5000.
Current—53 amperes.
Cycles—50.
Output—500 h.p.
Maximum speed—375 r.p.m.

Flywheel:

Weight—44 tons.
External diameter—14.5 ft.
Width of rim—29.5 in.
Highest peripheral speed—292.5 ft. per sec.
Flywheel effect—2,372,000 ft.-lbs.
Stored energy—68,461,500 ft.-lbs.
Speed—320 to 375 r.p.m.
Material—Special cast steel (Krupp).

Two D. C. Generators (with Commutating Poles):

Terminal voltage, each—400 volts.
Current, each—2120 amperes.
Speed—320 to 375 r.p.m.
Output, each—1150 h.p.

When both flywheel motor generator sets are installed, the hoisting service conditions will be as follows:

Four three-phase induction motors taking 2000 h.p. from the net work.

Four flywheels with a combined weight of 176 tons.

Stored energy of flywheels—274-246,000-38 ft.-lbs.

Eight D. C. generators with a combined output of 9200 h.p.

This power is to drive four hoisting engines with a useful load of either of the following:

Coal (eight cars; 1320 lb. load each), 10,600 lbs.

Slate, 12,300 lbs.

48 men of 165 lbs. each, 7,920 lbs.

Hoisting speed:
  Coal—2750 ft. per min.
  Men—1080 ft.
Acceleration and retardation:
  Acceleration when starting 138 ft. per min.
  Retardation when coasting 108 ft. per min.
  Time of one lift from 1750 ft. level—55 sec.
  Rest between two lifts—Normal 68 sec., during fast service 70 sec.
  Time of one lift from 2040 ft. level—70 sec.
  Output of hoist motor—Starting, 2000 h.p.; running, 1120 h.p.

The average energy taken by one hoisting engine has been figured to be 500 h.p. and requires an 88 ton flywheel to equalize the load fluctuations. If all four hoisting engines should start simultaneously, the hoisting engine motors would require 8000 h.p., and it would be necessary to provide 4 times 88 or 352 tons of flywheel weight. The flywheel weight installed in one two unit flywheel generator set at the Mine "Mathias Stinnes", amounts to 2 x 88 = 176 tons, and is sufficient for all four engines. The two flywheels, of the second flywheel motor generator set to be installed, will serve as reserve. The relatively small flywheel weight is allowed on account of the coupling of the D. C. generators, and is based upon the following considerations: The most disadvantageous case would be for all hoisting engines to start simultaneously. This possibility decreases with the increasing number of hoisting engines supplied. The most advantageous case is when the starting time of the various engines is chosen to equalize the starting peak loads. The load fluctuations on the flywheel motor side will decrease with an increasing number of hoisting engines supplied. The actual fluctuations caused by the drive of all four engines, do not differ much from the fluctuations caused by one engine, supplied by one motor generator set only.

In order to make use of this consideration it is only necessary to couple the flywheel motor generator sets supplying the four hoisting engines. This coupling can be effected mechanically, as per Fig. 20 or it can be effected electrically; which is what is intended to be done with the second two unit flywheel generator set to be installed in the future. To effect this electric coupling, the D. C. generators of the flywheel generator sets are divided into two identical machines, so that the two 2-unit flywheel motor generator sets comprise eight D. C. generators. Each one

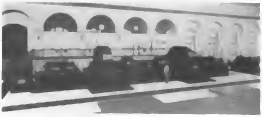


Fig. 20. Twin Fly Wheel Converter, Pit Matthias Stinnes

Two Three Phase Motors [illegible]
Two [illegible] Cast Steel Fly Wheels
Two Double Generators [illegible]

of these generators is sufficient to supply power for driving one hoisting engine at half speed.

Connecting in series of two armatures of two D. C. generators gives the power required as full input of one hoisting engine.

The armature of one D. C. generator of one 2-unit flywheel motor generator set is connected in series with the armature of a D. C. generator of the second 2-unit flywheel motor generator set, so that the shafts of the two 2-unit flywheel motor generator sets are electrically coupled, and the mechanically coupled D. C. generators are electrically connected to supply different hoisting engines. The disadvantage in this arrangement, i.e. the increased number of machines, is compensated for by the advantages due to the possibility of using smaller machine units, and obtaining a larger reserve in case of breakdown.

The following data may be of interest regarding the flywheel motor generator sets. The flywheel converter must be adjusted for a constant energy consumption equal to the average hoisting engine input. This is accomplished by means of a slip regulator, comprising A. C. relays which are affected by the current fluctuations in the induction motor mains, and which control an auxiliary D. C. motor, that in turn operates an oil immersed metal rheostat. A double throw switch,

Fig. 21

Hoisting Engine at Matthias Stinnes Mine, Germany

2 MP-20-550-41-400 Volt A. E. G. Shunt Motor Developing 2000 h.p. when starting

located near the motor which operates the rheostat, is used when the starting is effected by hand control. The change of the slip resistance produces a change of the speed ranging from 320 to 375 r.p.m., and allows practical use to be made of the accumulated stored energy of the flywheels.

In order to avoid the abnormal decrease in the speed of the flywheel converter which might take place when all four hoisting engines start simultaneously, the stroke of the hoisting engine operating levers is limited by an electromagnetic interlock.

The flywheels are provided with band brakes to facilitate bringing them to a standstill, as this would require several hours without this mechanical help.

Special attention was given to the bearings on account of the high shaft speed, amounting to twenty feet per second. The bearings sleeves are fitted with babbit metal linings, and have a length of $21\frac{1}{2}$ in. with $11\frac{15}{16}$ in. bore, and a pressure of 170.6 lbs. per square inch. Oil is forced through the bearings under high pressure by means of centrifugal pumps.

In order to safeguard against total breakdowns of the hoist service, two switch tables (g and h) have been provided in the machine house, and by means of these, the armature of each D. C. generator can be connected to any hoist motor; while the excitation of each D. C. generator can be regulated by any of the controlling devices of the four hoisting engines. Two of the hoisting engines were supplied by the Siemens-Schuckert Works, one by the Allgemeine Elektricitaets Gesellschaft, and one by the Felten-Guilleaume Lahmeyer Works.

The hoisting engines are equipped with Koepe disks of 21.5 ft. diameter, and are driven at a maximum speed of 41 r.p.m. by two commutating pole shunt wound motors having an output of 2000 h.p., maximum, and 1120 h.p. running. An auxiliary resistance can be inserted in the exciter winding while the hoisting engines are at rest, in order to decrease the temperature rise and the energy consumption of the field copper during these stops.

Two brake rims with a diameter of 20.6 ft. are arranged beside the sheave for the rope. The brake shoes of the brake are

Fig. 22

Hoisting Engine at Mine Matthias Stinnes

Direct Driven by Two Siemens Schuckert Commutating Pole D. C. Motors of 550 h.p. normal, 1150 h.p. maximum, 41 r.p.m. 400 Volts.

normally operated by means of a compressed air cylinder. When severe conditions make it necessary, the brakes are capable of destroying 5,750,000 ft.-lbs. within 3 seconds. The cage then having a brake way of 73 feet.

Using Ward Leonard control, the motor speed is proportional to the terminal voltage of the armature of the flywheel convertor generator, and to the stroke of the operating lever by means of which the excitation of the flywheel generator is changed.

The hoisting plant works satisfactorily with regard to smooth performance, easy operation, reliability and average power

Fig. 23. Hoisting Engine at Pit de Wendel

Capacity per 8 Hour Shift, 410 Tons from a depth of 2950 feet

house load factor, and it has caused no disturbances to the service of the Rhenish-Westphalian Electric Works.

A similar hoisting engine installation, which will ultimately include four large hoisting engines and two flywheel motor generator sets, has been erected on the Wendel Pits near Ham, Germany. Fig 23 is an illustration of one of the hoisting engines.

Comparisons with the "Matthias Stinnes" machines, figures 21 and 22, show the space economy afforded by the electric drive. As an early electric installation, the Stinnes plant was designed with the idea of being able to change over to steam engine drive in case the electric drive should prove to be unsatisfactory. In consequence, the engine rooms were built very large, and the shafts of the hoisting engines made of sufficient length to permit of the subsequent installation of steam engines, if this were found necessary.

The following data is taken from the large hoisting engine plant lately built by the Allgemeine Elektricitaets Gesellschaft for Pit Rhein Elbe I/II. This shows the enormous progress which has been made since 1903, the year in which the 300 h.p. hoist for the Donnersmarkhuette, with the first hoist flywheel convertor, was placed in commercial service:

Hoisting Engine Plant for Pit Rhein-Elbe I II.

Hoisting engine data:

Koepe Disc, diam.—23 ft.
Rope diam.—2 3/8 in.
Hoisting speed, coal—3900 ft. per min.
Hoisting speed, men—1980 ft. per min.
Depth of pit—3300 ft.
Useful load per lift in 8 cars—9600 to 10500 lbs.
Direct driven by two commutating pole D. C. motors with a combined output of 1500 h.p. normal, 3170 h.p. maximum.

Flywheel converter data:

Two identical sets, mechanically coupled and consisting each of:

One 1000 h.p., 375 r.p.m., 5000 volt, 50 cycle, three phase induction motor.

One 2600 kw., 800 volt, commutating pole D. C. generator.

One 66 kw., 230/110 volt exciter.

I am greatly indebted to our German friends the Allgemenie Elektricitets Gesellschaft and to the Siemens-Schuckert Works, for the help rendered me in visiting the above described plants, for photographs and other valuable information given in my review of the European Practice in Electric Hoisting Engines.

TYPE SA MOTOR STARTING RHEOSTATS

By W. C. Yates

A new line of motor starting rheostats with no-voltage release is now being put into production by the General Electric Company. These embrace starters for all types of direct current motors from 1/8 h.p. up to and including 35 h.p., 110 volts: and 1/8 h.p. up to and including 50 h.p., 220 and 550 volts.

Fig. No. 1. Type SA Rheostats

In the design of these new rheostats, full consideration has been given to past experience, and a complete series of tests has been made to determine the best possible practice in regard to each particular feature.

The dial switches are of strong and durable construction, and may be roughly handled without affecting the contact between the sliding brushes and the stationary segments. These brushes, which consist of copper shoes or blocks held firmly upon the segments by springs, are self aligning, thus insuring contact of their entire contact surface. On the rheostats for motors above 7½ h.p., 110 volts; 10 h.p., 220 volts; and 15 h.p., 550 volts; carbon blocks are provided, which precede the copper blocks during the period of starting and prevent pitting of the latter. All parts in which there is any liability to roughening or wear may be readily removed and replaced.

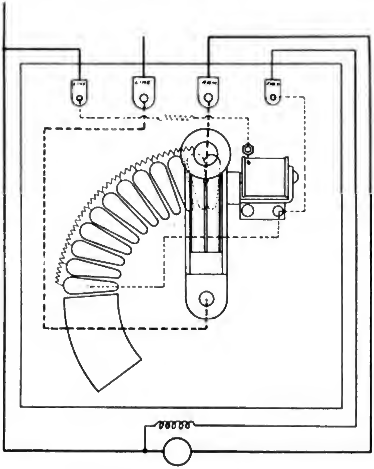
The retaining magnet is placed across the line in series with a resistance. This

Fig. No. 2. Type SA Rheostat with Box Removed

permits the rheostats to be used for shunt, compound, or series wound motors, and also makes the strength of the magnet independent of the shunt field current, which varies in different makes of motors. The magnet is also unaffected by variation of the field current in a variable speed motor.

The motor shunt field circuit is made and broken on the first live segment of the starting switch. When the starting arm passes to the "off" position, the field is discharged through the motor armature and the starting resistance. The resistance, however, is not in series with the field in the running position.

Cast iron grid resistance is employed in the rheostats for motors of 20 h.p., 110 volts; 35 h.p., 220 volts; 40 h.p., 550 volts, and above. In rheostats of smaller sizes the new Form P unit is used, and the copper leads to the switch segments are insulated by glass beads. These units, in boxes above 1 h.p. rating, are mounted on independent supports fastened to the slate base, and the box frame may be removed without disturbing the units or their connections. This construction permits of ready inspection.



Connection Diagram for Type SA Rheostats

The Form P resistance unit, which was described in the "General Electric Review" for May, 1907, is an ideal unit for a starting rheostat, as it employs a low temperature coefficient resistance wire wound on a tube which is ventilated both inside and out. The starting rheostats, therefore, in which the Form P unit is used, possess all the advantages of a ventilated construction, in addition to the advantages of a low temperature coefficient. Furthermore, this unit is absolutely fireproof, and when raised to such a degree of heat as to melt the wire, will open without noticeable arcing, and therefore meets the Underwriters' requirements for rheostats installed in dusty and linty places.

Each rheostat is arranged to receive a cover which will effectively protect the starting switch. The cover, however, is not a part of the standard rheostat, but will be supplied when specified.

Louis J. Magee

Mr. Louis J. Magee, who has been prominently associated with the international interests of the General Electric Company for many years, died very suddenly at his home in New York City upon the night of July 2nd.

Mr. Magee was born at Malden, Mass., in 1862; he was graduated from Wesleyan University in 1885 with the degree of A. B., and shortly after entered the shops of the Thomson-Houston Co. at Lynn.

After completing his shop course, he installed a number of Electrical Plants in this country, and then devoted a year and a half to similar work for the Thomson-Houston Co. in Lima, Peru.

In 1889 he was placed in charge of the Company's office in Hamburg, and it was largely due to his efforts that the Union Elektricitaets Gesellschaft of Berlin was formed in 1892 for the purpose of manufacturing electrical apparatus upon the same lines and in accordance with the methods employed by the General Electric Co.

In 1903 the Union Elektricitaets Ges. was merged with the Allgemeine Elektricitaets Gesellschaft, Mr. Magee remaining until the time of his death, as Director and Consulting Engineer in charge of the international business relations between the consolidated companies and the General Electric Co.

Mr. Magee was a man of wide experience, broad technical knowledge and great business ability; while his sterling character won for him the respect and admiration of his many business associates in the American and German Companies.

NOTES

Dr. Marius Latour of Paris, who is well known in electrical circles as the inventor of a compensated single phase motor and other alternating current apparatus, is visiting the Schenectady Works of the General Electric Co.

* * *

Mr. C. R. McKay, Engineer of the Cincinnati Office, has resigned his position to take the position of Chief Engineer of the Toledo Ry. & Light Co., Toledo, O. Mr. W. S. Culver has been appointed to take up Mr. McKay's work, assisted by Mr. E. H. McFarland, who will give particular attention to turbine installations.

* * *

Mr. A. B. Shepard has resigned his position in the Cleveland Office, and Mr. W. J. Hanley of the Columbus Office has taken charge of the Cleveland Office. Mr. R. W. Palmer of the Railway Department of the Cincinnati Office has been appointed to take charge of the Columbus Office.

* * *

At the recent annual meeting of the National Association of Cotton Manufacturers recently held at Boston, Mr. Charles B. Burleigh of the Boston Office of the General Electric Co., was presented with a medal "for excellence in technical and utility phases of steam turbine work." At Troy, N. Y. on May 25th, Mr. Burleigh delivered a lecture upon "Vertical Steam Turbines" before the Columbia Association No. 20, National Association of Stationary Engineers, and he has lately been elected to honorary membership in that body.

* * *

A. L. Rohrer, H. N. Ransom and J. O. Carr of the General Electric Co., attended the opening of the Ballston-Saratoga electric line on July 3rd. Three special cars were provided by the Schenectady Railway Co., and a large body of railway and city officials were taken over the new electrification of the Delaware & Hudson between Ballston and Saratoga, and participated in a luncheon at the Grand Union Hotel.

* * *

The Employees of the Boston Office of the General Electric Co., recently subscribed $158.50 to the Boston Floating Hospital. This pays the expenses of one day of the Hospital work, and is given by the employees of the Boston Office as a testimonial of their esteem for the late First Vice-President of the Company, General Eugene Griffin. July 9th was set aside for this work, and that day of the year 1907 was known as "General Eugene Griffin Day" of the Boston Floating Hospital.

* * *

H. W. Hillman has recently left the employ of the General Electric Company to accept the position as Manager of the Commercial Department of the Commonwealth Power Co., Grand Rapids, Mich.

Mr. Hillman has been associated with the General Electric Co., for over fifteen years, having entered their employ in the early nineties. He made a special study of arc lighting, and when that Department was created, he was placed in charge. For the past few years, he has devoted his attention largely to the exploitation of electric heating devices, and it is greatly through his efforts that such rapid progress has been made in this branch.

* * *

Recent extensive tests were made at the Schenectady Works upon a Rosenberg type D.C. Generator, rated, REG 2-1-800-50 volts. The machine, which has some peculiar properties, was tested with very satisfactory results for its various applications, such as search lights, train lighting, automobile motors, balancer service, booster service, etc. Further tests were conducted before the Torpedo Board and School of Submarine Defense at Ft. Totten, New York. Upon this occasion Col. Whistler, Commandant of the Fort, took particular pride in calling the attention of the visiting naval officers to the various meritorious features of the machine. We hope to give a description of this interesting apparatus in an early issue of the REVIEW.

The Annual Convention of the American Institute of Electrical Engineers, which was held at Niagara Falls from June 25th to 29th, was well attended by representatives from the General Electric Company; and of the thirty-one papers presented, eight were written by General Electric men, as follows:

- Protective Apparatus Engineering, by E. E. F. CREIGHTON
- Protection of the Internal Insulation of a Static Transformer Against High Frequency Strains, by WALTER S. MOODY
- Notes on Transformer Testing, by H. W. TOBEY
- A New Type of Insulator for High Tension Transmission Lines, by E. M. HEWLETT
- Single-phase versus Three-phase Generators for Single-phase Railway, by A. H. ARMSTRONG
- The Choice of Frequency for Single-phase Alternating Current Motors, by A. H. ARMSTRONG
- The Vector Diagram of the Compensated Single-phase Alternating Current Motor, by W. I. SLICHTER
- Commutating Pole Direct Current Railway Motors, by E. H. ANDERSON

The following delegates and guests were present:

Mr. G. L. Alexander
Mr. E. F. Alexanderson
Mr. & Mrs. E. H. Anderson
Mr. W. C. Andrews
Mr. A. H. Armstrong
Mr. Ernst J. Berg
Mr. S. R. Brown
Prof. E. E. F. Creighton
Mr. W. L. R. Emmet
Mr. G. T. Fielding
Mr. Frank H. Gale
Mr. V. E. Goodwin
Mr. A. W. Henshaw
Mr. E. M. Hewlett
Mr. & Mrs. J. Mason Knox
Mr. E. B. Merriam
Mr. Walter S. Moody
Mr. W. H. Pratt
Mr. H. G. Reist
Mr. L. T. Robinson
Mr. D. B. Rushmore
Mr. & Mrs. W. I. Slichter
Miss Ostrom
Dr. C. P. Steinmetz
Mr. & Mrs. Chas. W. Stone
Mr. & Mrs. H. R. Summerhayes
Mr. & Mrs. John B. Taylor
Mr. H. W. Tobey
Mr. M. O. Troy
Mr. C. T. Wilkinson
Mr. T. A. Worcester
Mr. W. F. Wright

ABSTRACTS OF IMPORTANT TECHNICAL ARTICLES

Illustrated *

Indianapolis & Louisville Traction Company's Line

(Electric Traction Weekly, June 13, 1907, p. 553.)

A brief description of the 41 mile road connecting Sellersburg and Seymour, interlinking the Indianapolis, Columbus & Southern Railway, and the Louisville & Northern Railway; thus completing the 117.8 mile route from Louisville to Indianapolis.

A point of special interest is the use of 1200 volts D. C. as trolley potential. This is obtained by operating two 300 kw., 600 volt generators in series.

The car equipment includes four 75 h.p., G. E. No. 100 motors, which can be operated from a 1200 volt or from a 600 volt D. C. circuit. Sprague General Electric type M control is employed, and the ten passenger and two freight cars are equipped with G. E. automatic air brakes and 24-ft. air compressors.

Electrical Equipment of North Franklin Colliery, at Trevorton, Pennsylvania—Electrically Driven Fans, Centrifugal Pumps and Locomotives

(Mines & Minerals, June 1907, p. 493*)

The North Franklin Colliery at Trevorton, Pa., one of the mines of the Philadelphia & Reading Coal & Iron Co., is located 40 miles from Pottsville, and has lately been equipped with electrical machinery of General Electric make. The power house equipment comprises two 250 volt generators, one of 175 kw., and one 240 kw. capacity. These feed two eight ton 50 h.p. General Electric Mine locomotives, for a daily output of 2500 tons; and one 150 h.p. variable speed General Electric motor for driving a 6 in., 4-stage centrifugal pump having a capacity of 1000 gallons per minute. The pump replaces reciprocating pumps requiring five times the foundation space.

An Alternating Current Coal-Mining Installation "The McKell Coal and Coke Company Employs a Central Power Station with High Potential Transmission and Transformers Where Required"

(The Engineering & Mining Journal, June 8, 1907, p. 1102.)

A map shows the location of the central power station at Kilsyth, which contains 6600 volt 24 cycle three-phase alternators. Three sub-stations with rotary converters for operating the electric haulage in the various pits, are also shown, as well as the location of the three fans. Two of these are 11 ft. in diameter, and are rated to deliver 100,000 cu. ft. of air per min. against a 3 in. water-gauge pressure. They are operated at 230 r.p.m. by means of a General Electric induction motor. The third fan is 9 ft. in diameter, and is to deliver 75,000 cu. ft. of air per min. against a 2 in. gauge pressure. It is to be operated at 200 r.p.m. by means of a General Electric induction motor. Current is supplied at 6600 volts, which is reduced by step-down transformers to 440 volts for the motors. These are started by means of compensators and are provided with large and small pulleys to allow a variation in speed, since the present requirements are much below these ultimately expected.

The System of Fire Protection at the Plank Road Shops of the Public Service Corporation of New Jersey

(Street Railway Journal, June 1, 1907, p. 996.)

High pressure water for sprinkler systems and hydrants is supplied by means of a centrifugal pump which takes water at 25 lbs. pressure from the city main, and has a capacity of 1000 gallons per minute at a pressure of 100 lbs. per square inch. The pump was manufactured by the International Pump Co., after the specifications of the Associated Factory Mutual Fire Insurance Co. of Boston. It is driven at a speed of 920 r.p.m. by a direct connected 85 h.p., 500 volt General Electric motor. The pump also supplys an auxiliary water tank, of 5000 gallons capacity which is supported on a structual steel tower 117 ft. above the ground.

Master Mechanics' Association Committee Reports

(The Railroad Gazette, June 14, 1907, p. 853.)

Abstracts of the committee reports presented at American Railway Master Mechanics Association convention 1907, and pertaining to the "Development of Motor Cars for light Passenger Service". The report includes brief descriptive data on the new 60000 lb. General Electric steel car. The motive power of the car includes an eight-cylinder 150-175 h.p., 550 r.p.m. gasoline engine for direct drive of a 90 kw., D. C. generator, which latter feeds the two 65 h.p. railway motors, one of which is mounted on each truck of the car.

Besides the engine compartment, a baggage, a smoking, and a main compartment are provided, while the toilet and an operating cab are located at the rear end. The car has a seating capacity of 40, and full speed is attained at 50 to 55 miles per hour.

The New Steel Cars of the Hudson Companies

(The Railroad Gazette, June 14, 1907, p. 831*.)

Detailed illustrated description of the cars for operation in the tunnels from Cortlandt St., N. Y., through Jersey City and Hoboken to Christopher St., and thence by Sixth Ave., to Thirty-fourth St., New York.

These fire proof steel cars are equipped with the latest type of Sprague General Electric multiple unit control, and carry two 160 h.p. G. E. No. 76 motors. The lighting is effected by means of 30 continuously operated lamps, and in addition there is provided a storage battery which feeds four emergency lamps, in case the power goes off the line.

Fifty cars have been ordered for the initial operation and it is expected that the line between Hoboken and Sixth Ave., will be opened for passengers this fall.

GENERAL ELECTRIC REVIEW

VOL. IX No. 3 | PUBLISHED MONTHLY BY GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU SCHENECTADY, N. Y. | AUGUST, 1907

2100 Kw. Direct Current Generator with Commutating Poles

(See page 91)

GENERAL ELECTRIC REVIEW

VOL. IX NO. 3

AUGUST, 1907

CONTENTS

Three Car Train on West Shore R. R.

(See Page 110)

VOL. IX No. 3 SCHENECTADY AUGUST, 1907

GENERAL ELECTRIC REVIEW

THE MANUFACTURE OF A LARGE DIRECT CURRENT GENERATOR

By E. B. RAYMOND

A direct current generator consists in its essentials of core, shaft, spider, commutator, fittings, frame, bearings, insulation and the windings of armature and field. The satisfactory production of these various parts at their present standard is the result of years of development and study. The design of today, compared with that of the early machines, embodies a simplicity of armature winding and an economy of dimension hardly conceivable 15 years ago. The designer, with his accumulated experience and data, can predict commutating and heating characteristics with certainty.

Today large generators of usual voltages have symmetrical multiple windings on their armatures. Some of the earlier designs of large direct connected generators not only had series windings on the armature, but interpolated commutator segments as well, with the result that a large amount of testing and experimenting sometimes ensued that consumed much of the profit on new machines. In the production of machines, a proper start in accuracy of engineering dimensions must, however, be followed by similar accuracy and judgment in the construction of essential parts.

The Core

This is composed of many thin sheets of steel, each sheet having on its periphery a series of projections or teeth between which are slot shaped spaces; when the sheets are placed together in the shape of a complete core, these spaces form the slots in which the armature windings lie. When the sheets are assembled, these teeth must coincide with perfect accuracy, so that the sides of the slots will be smooth and will not injure the insulation placed in them. Thus, in punching these slots in the sheet steel, they must be spaced very accurately and cut without burrs resulting from the action of the die, so that when piled upon each other and clamped in position between the flanges of the core, a smooth slot re-

Fig. 1. Armature Punching and Space Block

sults. Subsequent treating of the iron must not distort the shape of the sheets, and in handling the stampings great care must be exercised to avoid bending the teeth or sheets out of shape, for if once bent, it is not possible to get them back into their original form.

The assembling of all these pieces of iron, (each about fourteen thousandths of an inch thick), into a core weighing many tons, is a specific art, as the core must be a solid compact mass, smooth and true in the slots, of minimum hysteresis, maximum resistance between the sheets, and mechanically immovable in relation to the various parts entering into its construction. To secure these characteristics, constant watchfulness is necessary during assembly, and is rewarded by great improvements in the running temperature and life of the apparatus.

Fig. 2. Armature Core

Iron for use in laminated cores must have the lowest possible hysteresis loss and must remain constant, unchanged by time or any of the influences to which it is subjected during the construction and operation of the machine. Such iron cannot be purchased in this country, and it requires accurate treatment to give the commercial metal these necessary qualities.

In addition to the treatment for reducing hysteresis to a minimum amount, each sheet must be insulated from its neighbor by a material which is practically uninfluenced by heat or pressure. In the old days various forms of japan were used for this purpose; this material is now regarded as quite unsatisfactory, and a new substance is used by the General Electric Company, which, when spread upon the sheets, forms a coating only 0.3 of mill in thickness, but which has a high resistance when subjected to heat, pressure and vibration.

The Shaft

On the shaft are assembled the various running parts, some of which are machined to a driving fit, while others are machined to be shrunk into position; both of which operations require the highest grade of machine work with accurate gauges for checking dimensions. Where punchings are fitted directly upon the shaft, all variations in the fit of these must be closely watched, or loose punchings and injured insulation will result after the machine has been in operation for a time. The shafting department must therefore be highly organized and contain properly trained men and efficient tools.

The Spider

Similar accuracy is necessary in the construction of the spider, as the fit between it and the shaft must be exact, as well as that between it and the punchings.

The Commutator

The art of making a commutator is even more difficult than that of making a core, for here, as in the case of the core, we have a whole composed of very many parts; in addition each segment must be thoroughly insulated from its neighbors and from the commutator spider. Moreover, in service, the commutator is often subjected to great variations in temperature, attacks of sparking under overload conditions, and high centrifugal strains. Notwithstanding all this, a compact, smooth and truly round surface must always be presented to the brushes.

The insulation used in commutators is somewhat compressible and it is necessary in sheets composed of small pieces of mica about 2 in. x 3 in. in size and one mill thick, pasted together with varnish until a thickness of about 40 mills is obtained. These sheets after being pasted in this way are heated, subjected to high pressure, and cooled while in the press; this produces a firm material quite similar to a natural sheet of mica, which is unobtainable in pieces of sufficient size in any of the mines of the world today. The sheets are then cut to the desired size and milled to the required thickness, all surface pasting material having been forced out by the very high temperature and pressure to which the sheets were submitted.

The insulation thus produced is assembled with the rough commutator bars into a cylinder, out of which wedge-shaped grooves are turned to receive the clamps which hold the segments against the action of centrifugal force. Great care must be taken when cutting these grooves

Fig. 3. Armature Partly Wound

to make allowance for this. Many departments contribute their services in producing this insulation with its characteristics of high insulating qualities, great compressive strength, correct thickness, and exact shape required by the commutator.

Commutator insulation is manufactured and turning the surfaces, that no copper bridges over from one segment to the next, for a sliver as small as a hair is capable of destroying a whole commutator, so far as operation is concerned. When it is certain that no bridging over exists, mica insulating cones, built up and shaped under pressure as described, are assembled in the grooves, and the spider and clamps are placed in position. These latter are then drawn up, and the commutator bars are thus held rigidly in position, and at the same time are electrically insulated from one another and from the commutator spider.

Fig. 4 Commutator

After the parts have been clamped together, the commutators are placed in ovens and baked; the large ones at a temperature of about 90 degrees C., and the small one at 175 degrees C. Every 24 hours during this process an attempt is made to tighten the clamps with the insulation hot, so that any softness in the insulation can be taken up. This is done three or four times on large commutators to make sure that every segment is receiving pressure from the clamp rings, for if the insulating cones vary slightly in thickness or in hardness, and the clamp consequently bridges over one or more segments without putting much pressure upon them when in its final position, centrifugal force will make these segments come out slightly, causing a rough commutator surface, sparking and much trouble. Hence the clamp must be tightened until every bar receives a firm pressure. After the commutators are assembled on the machines and are in test, if any loosening of the segments or roughening of the surface occurs, as is sometimes the case, the clamps must be tightened still further, until each bar receives its full pressure: heat to soften the insulation being obtained from the current of the machine. As in all other lines of manufacture, the point at which enough has been done to accomplish a given purpose; for example, the amount of heating and clamping necessary, must be judged by those familiar with the special line of work.

There are two constructions of commutators, one called the "shell type", and the other the "arch bound". In the shell type the bars are drawn down on a flange and insulated with white mica about 60 mills thick, and this in turn rests directly on the metal shell of the commutator spider. The bars all "bottom" hard on this insulation and at the same time the insulation between the bars is compressed; in other words a double fit is obtained—an arch fit and a shell fit. This type of construction is commonly used on big commutators. On commutators up to about 25 inches in diameter, the arch construction is

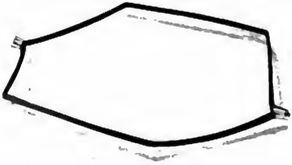


Fig. 5. Armature Coil

often used as it is somewhat cheaper, and works practically as well as the shell type up to this size. With this construction the clamps pull inward on the commutator segments until the arch of the circle prevents any further motion. In actual practice the bars are pressed inward by external means as far as they will go, and then the clamp is forced into position in the V slot so that the segments can go neither out nor in. Amber Mica is used between the segments on commutators; India or white mica, which is somewhat harder, for insulating the cone clamps, as well as between the shell and the bottom of the bar in shell bound commutators.

Fittings

The fittings include brushholders, brushholder studs, cross connections and cables, terminals, etc. The particular feature here requiring accuracy of manufacture is to get the brushes all in line with the commutator segments when they are assembled in position with the brushholder studs, brackets and other fittings. Accurate jigs and fixtures are necessary for doing the machine work on these parts in order that this result shall ensue.

The Frame

Since the air-gap on electrical machinery is small and must be equal throughout the circumference of the machine, the frame, bearings, pillow blocks etc. must all have correct positions relative one to another. Hence the machine operations on these parts must either be layed out accurately, or, if production warrants, be guided by jigs, to give the desired result.

Bearings

One of the important features of machinery is its bearings and the arrangement for ensuring proper lubrication. Poor oil grooves for the distribution of oil will result in misfortune. The anchor holes for holding the babbitt in place must be kept open when the metal is poured in, and the latter must be tightened down properly. In many instances it is necessary to heat the castings to nearly the temperature of the molten babbitt to prevent "cold shot" or shrinkage cracks. Oil grooves must be located properly; oil rings must be free from rough spots, or these will cause oil throwing. In this work also, accurate gauges must be used, as correctness in clearance between journal and bearing sleeve is necessary.

Insulation and Windings of the Armature

At this point in the construction of the machine the greatest care must be exercised; first in the production of a varnish, which is the basis of insulation; second, in placing the insulated coils in the slots. Linseed oil is today recognized as the best insulation; this is sometimes mixed with a gum, boiled down to the proper consistency and other materials added to produce a compound that may be used like a paint, and which will give a film that will stand a high potential, and will not become brittle with age. This varnish is prepared by the General Electric Company, and is held to a very close standard, tests being regularly made of aging and puncture.

All armature coils are wound on forms and are so shaped that after being placed on the armature, each coil is properly locked to its neighbor, without undue pressure and without taking up undue room. The wire is wound directly into the shape it is to assume; the coil is then insulated and heated, which softens the various gums in the insulation, permitting the coil while hot to be pressed to the exact form and dimensions required. On cooling it retains this form and becomes a hard solid body, forming a coil which, when placed in its slot, is free from local pressure, bearing uniformily on the surface of the slot throughout its entire length. A coil thus formed requires a minimum amount of space over the drawing dimension, so that the designer can reduce to a minimum the diameters of his armatures. After being thus insulated, formed and treated, the coils are ready to be placed in the armature slots, where they are held in position either by wooden wedges or by binding wire. The commutator is then put into position on its spider, or on the armature shaft, and connections are made between its segments and the armature winding, a pure tin solder being used for this purpose.

The importance previously mentioned of having the various parts fit accurately, and the necessity for exact dimensions in armature coils and slots, is illustrated by the

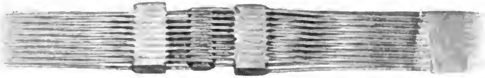


Fig. 6. Sectional Binding of Large Armature

fact that the commutator leads invariably break if any motion of the coils in the slot occurs, or of the commutator on its fit. While in general the American Institute recommendations are used for high potential on direct current armatures, *the armature department gives a greater high potential test before delivering to the testing department; first when the coil itself is put into the slot, and second, after the armature is completely connected up. Thus a brake down by high potential in test is a rare occurance on an armature.

Fig. 7. Rear View of Armature Showing Equalizer Rings

Field Coils

These coils are insulated from their metal spools by similar materials to those used in the armature. It is customary to wind large spools with the wire in uniform layers, for under these circumstances wires have no local pressure on the insulation between the wires, as is the case if the wire is put on at random. The latter is a very much cheaper construction, but is not suitable for large machines. Like the armature, spools are subject to a high potential test before being delivered to the test for assembly on the machine. This potential is considerably greater than the regular high potential that is applied on the machine after it has been run, and when heated by the current. It is rare that a spool breaks down under its Hot Dielectric Stress Test, or in other words, under its hot high potential.

*With the exception of railway generators where same high potential is used as on railway motors.

Test Room

The test room receives the various parts of the machine, spools, armature and frame, and assembles them just as they will be assembled by the customer, thus avoiding any errors in the assembling of the many parts when the machine is set up on the customers premises. Therefore temporary cable and brush holders or "fits" are used during test.

One of the important results to be accomplished in the test is to settle the commutator; that is, to prove that its condition is permanent in regard to the smoothness of its surface, and if running indicates that the surface is not permanent, to make it so. The first step is to get the clamps of the commutator down firmly, so that when the commutator is at normal temperature, no further screwing up on the clamping rings can be done without abnormal effort. This is necessary in order that all the bars may have a direct pressure from the clamp sufficient to render any movement up or down impossible. The second step, after the clamps are properly down, is to obtain a smooth surface.

The method to follow in the first of these operations, i. e., to get the clamps down firmly, is to start the machine on a heat run, or short circuited upon itself with enough field to give full current. If roughness appears, the machine is shut down at the end of about four hours and the clamp rings are tightened up. A four hour heat run is chosen since the temperature during this time becomes practically constant and the consistency of the insulation is normal. If it is then found that the tightening bolts can be screwed up somewhat, the machine is again started up for another heat run of similar duration at the end of which the machine is again shut down and an attempt is once more made to tighten the bolts. When no more can be taken up on the tightening bolts, a surface is put on the commutator, either by turning with a tool, or by grinding. After this the final heat run is made, its duration depending upon the size of the machine, and varying from 24 hours down to 6 or 8 hours. If the clamps are down properly, the surface of the commutator well smoothed, and the mica between bars securely held so that it does not slip; and finally, if the design of the machine is such that bad sparking does not exist, the commutator should go through the final test and be just as satisfactory at the end of the run as at the beginning.

Another important matter covered by the test, is the operation of the bearings. If the machine is fitted out with them, the following points must be demonstrated; first, that the bearings run cool; that is, 35 or 40°; second, that no oil throwing or oil leaking occurs; and third, that end play, (i. e. motion in the direction of the shaft), is of the proper amount. If the machine is of a new type, it is further necessary to demonstrate, in the test room, that the temperatures of all parts are within the usual guarantee of the Company, or within the special guarantee if such exists. In general, it is the custom to put on the actual load that covers the conditions for which the machine was built, and then after running long enough to create a permanent state, to read and record the temperatures.

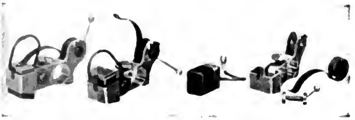


Fig. 8. Parts of CS Brush Holders

Compound

Where the machine is a compound generator, it is the custom to adjust shunt to get the desired compounding, allowing a 2 per cent drop of speed between no load and full load. Where the machine is fitted with interpoles, it is also necessary to adjust these poles to give the best commutation. This commutation is judged with the actual brushes in use that are shipped with the machine. If carbon, they are carefully adjusted to the commutator so that when the customer receives his brushes they fit perfectly.

Efficiency

It is customary to check all guarantees of efficiency by taking core loss by any of the recognized methods and by measuring the resistance of all parts when at normal running temperatures. During the assembly and running of a machine many mechanical matters are carefully considered, such for example, as the true running of all parts, the ease of assembly and the general appearance of the machine. After the heat run is finished, and while the machine is at a normal running temperature, the high potential test is applied, since insulation at a high temperature can stand less potential than when cold; the more severe condition is therefore chosen for this test.

Before starting the test on a machine, the air gap, that is, the distance between the different poles and the armature face, is first adjusted uniformly and afterwards measured and recorded.

A direct current machine will build up, or will not, depending upon the order of connections between the shunt field terminals and the bus rings. Since customers should know the proper connections to be made in setting up apparatus, in order to be sure of a prompt and satisfactory build up, the test room should make a trial of the building up of each machine, with the connections made according to the print furnished the customer, and which will be followed in the final wiring up of the generator. This assures that direct current machines will leave the works without the likelihood of this trouble being experienced.

Among the many other details of operation made note of and put to test by the department, may be named heating; compounding; commutation; condition of commutator; alignment of brushes with insulation between segments of commutator; proper spacing of equalizer taps; polarity of shunt, series and interpole fields, or such as the machine is provided with; true running of all moving parts; condition of bearings; end play; resistance of insulation and its ability to withstand a potential strain considerably in excess of normal; checking of special guarantees, or in any event, the company's normal guarantees, should the first not exist; correctness of air gap, and the like.

Having completed the test of a machine, and noted and recorded the readings and remarks made, it is then torn down, painted and delivered to the shipping department. These operations are likewise under the direction of the Testing Department, which affords a safeguard against any changes being made in the adjustment as effected during test.

Although the testing organization is an expensive one, covering as it does, mechanical assembly, electric testing, making of shunts, etc., yet the knowledge of the operation of the machine, under the same conditions as will be imposed upon it in its future work, is essential for high class production.

THE TREND OF INVENTION AND IMPROVEMENT IN THE ELECTRIC FIELD

By Prof. Elihu Thomson

The electric industry did not reach any considerable development until the beginning of the decade between 1880 and 1890. It was a time when numerous discoveries and inventions were made, following each other in quick succession. Upon these the industry was founded, although some of the early work was not applied in actual commercial form until quite recently. For a long time the open carbon arc alone served in arc lighting. Some ten or twelve years ago the movement towards restricting the access of air to the carbons and thereby saving expense in renewal of carbons and trimming the lamps, took place, and resulted in the enclosed arc lamp. A few years later however, the superior efficiency of the so called luminous arc drew attention to new types of arc lamps, in some of which the carbon in the electrode served only to confer conductivity, while the light was no longer due to the bright positive carbon crater but to the presence in the arc flame of vapors and fine particles of refractory substances.

The comparatively short life of the electrodes, however, as compared with the enclosed arc gave again the disadvantages of the open arc in frequent renewals and trimming.

The present trend of invention is towards securing not only the superior efficiency of the luminous arc, but, by a selection and combination of suitable substances, a long life of the electrode. The inventor has the task of finding the best combination, and constructing a lamp mechanism which will properly take care of the arc adjustment. Work in this field will doubtless continue actively for some years as the possibilities are not yet exhausted in the experiments hitherto made.

Where formerly the constant current arc dynamo with series circuits was universally used, we find its place taken by the constant alternating current transformer, and this may eventually be used in combination with rectifying apparatus such as the mercury arc and a return to direct current arcs thus take place. Invention in this field has been quite active and will probably continue until practical perfection of construction and operation is assured. The tendency in stations is to unify the supply, so that instead of arc machines, constant potential low tension dynamos, railway generators and alternators being found, large generating units of the alternating current type are alone installed, from which current by transformers, rotary converters, rectifiers, motor generators, etc., the adaptation to varied kinds of load is accomplished. Practically today the station supply is alternating except in railway work not involving transmissions at high voltage and transformation.

The various new conditions of regulation and distribution will doubtless continue to furnish a field for the exercise of inventive genius as in the past has been the case.

In the incandescent lamp, carbon, which so long held its own as the best material for filaments, is likely to be eventually replaced by metals possessing high melting point, and, what is of the utmost consequence in this connection, a low or negligible vapor tension when near melting. Carbon, while quite infusible, fails in being too volatile at such temperatures as are necessary to be attained in the incandescent lamp if it is to be efficient. While improved greatly by "metallizing" it cannot be expected to possess a reasonable life if run at an efficiency of only one half of that which can be attained in the latest lamps with metallic filaments, notably in the tungsten lamp.

Beginning with the rare metal osmium, as the first substitute for carbon, we have seen in succession, tantalum and tungsten. We may rest assured that the refractory metals which are not too rare or costly will be scrutinized very carefully in the effort to find whether they are possessed of the properties needed for use in a lamp filament. These are briefly, high fusing point, low vapor tension when near melting, high specific resistance, and capability of being formed into pieces of the lengths and sections desired in the lamps. A new era of incandescent lighting has begun although much work yet remains to be done which will involve great skill in manipulation and perhaps discovery. The advent of a lamp requiring about one watt per candle cannot fail to profoundly affect the progress of electric lighting, and tend, when small units are available, to render electric lighting far more general than is now the case. Existing mains will serve for a much larger output in light, and, with the high economy lamp, day current may be with advantage employed to charge batteries on the customers' premises, which are discharged for lighting at night; thus tending to a relief of the load peak. In a station supplying electric energy for motors and lights, any gain in efficiency of the lamps will make the peak less pronounced.

In the application of electric motors, as in railway or stationary work, the improvements or inventions will naturally relate more and more to details. It is probable that no radical departures from present constructions can be economically made.

The recent revival of the inter-pole for assisting commutation has already had a very important effect on dynamos and motors, leading to increased voltage and capacity, and giving to the continuous current machine an added value. The alternating current dynamos and motors both single and polyphase are at present highly developed machines, and the improvement is not likely to involve any radical departures. Lessened cost, saving of material, ease of maintenance, will continue to be sought by the designer or inventor.

The endeavor to secure variations of speed in motors has led to some ingenious modifications of the machine. In like manner the demand for railway car lighting has led to the invention of dynamos having a nearly constant output notwithstanding great variations of speed as when the driving is from the car axle. This kind of specialization of machines will doubless continue to afford in the future a field for the exercise of inventive talent.

The future progress will probably depend as much upon refined engineering and construction as upon invention, except in special instances similar in character to the examples mentioned. We can see no reason to expect great revolutions in methods or apparatus as a result of new inventions yet to be made. The art is old enough to permit standardization and there is much less danger than formerly that portions of the plant will soon become obsolete.

In the comparatively new field of wireless telegraphy there is perhaps still considerable room for invention and improvement, but it is remarkable what progress has hitherto been made. It is hardly likely however, that this art will be developed to such an extent that it will replace for communication of intelligence existing wire circuits. It will rather tend to supplement such service and occupy fields peculiarly its own, which it does already in furnishing means for communications with vessels at sea.

INSULATORS FOR HIGH VOLTAGE TRANSMISSION LINES

By E. B. Merriam

The insulation and mechanical construction of a high tension transmission line constitute a problem which has been given a great deal of thought by electrical engineers, these being limiting factors of the voltage at which power can be transmitted. To those familiar with the mechanical construction and the insulation afforded by a pin insulator such as is used on high tension transmission lines at the present day, it is quite evident that there are strains present which are both mechanically and electrically objectionable. The problems presented in designing an insulator of this type which shall be of reasonable size, and at the same time properly insulate, suspend and anchor the line, are numerous, and as a result a new form of insulator became necessary.

Fig. 1. Three Unit Link Suspension Insulator

Fig. 2. Three Unit Link Strain Insulator

To meet these requirements a new type of insulator has been designed and is being manufactured by the General Electric Company. There are two forms; one a "link suspension" insulator, (Figure 1), and the other a "link strain" insulator, (Figure 2).

The insulator consists of a solid porcelain piece, having a flanged rim which affords a long creepage surface between live parts, and insures at least some portion of the surface being sheltered from rain. There are two interlinked holes in the center, (Figure 3), through which the cables or guy wires are threaded, thereby bringing a compression strain on the porcelain. The use of cement has been avoided, the entire unit being made from one solid piece of porcelain. It is called "link insulator" because the two guy wires are linked about the porcelain insulation in such a way as to prevent the line falling, even though the insulator be cracked. (Figure 4). An insulator 10 inches in diameter has been found to be suitable for a working strain of 25,000 volts, and a 6-½ inch disc for 12,000 volts. The insulation for higher voltages is obtained by installing several of these units in series, an arrangement which might be termed a "series unit" system. Insulators are spaced at a dis-

Fig. 3. Cross Section of Link Strain Insulator

tance between centers approximately equal to the diameter of the insulator.

There are several schemes under consideration for fastening the insulators together, that of threading a single steel strand through the holes until the desired strength is obtained, being the most promising (see Figures 1 and 2). Other methods which give more or less promise, consist of a loop with bolt; stranded cable, either tied or spliced; cable with special sleeves, etc., but practice will dictate the means most desirable.

The same general design of insulator is used for high tension trolley construction, and permits of many desirable arrangements for this class of work. It is especially good on 6600 volt catenary construction, and has been used with great success. With this construction a more substantial and lasting installation is obtained than that afforded by the use of treated wood or compound. The insulator can be located some distance from the trolley wire, which reduces the liability of its being broken by a blow from the trolley wheel, (Figure 5). It is evident that single units can be used for insulating suspensions, anchors, pull-offs, and a number of other structural details. This type of insulator has been subjected to exhaustive tests by frost, water, smoke and heat, together with mechanical and electrical tests of almost every description, with very satisfactory results.

Fig. 4. Link Strain Insulator which has been broken under a load of five tons.

Fig. 5. Strain Insulator as a pull-off installed on a curve on a 6600 Volt Catenary construction

When discussing the number of insulators required in series, the question naturally arises as to the voltage distribution per unit. Tests show that the voltage necessary to arc over a series of units is in direct proportion to their number. Under operating conditions, the potential distribution across the series is, of course, not uniform; the insulator nearest the line being subjected to the greatest strain; the worst condition being when the line is grounded. Under this condition, the distribution across the three 10 inch insulators, on a 75,000 volt system, will be 43%, 27% and 30% of the line voltage, the insulators being six feet from ground. The maximum voltage per unit in this case is 32,000 volts, or less than 40% of the dry arc over value. It will be seen that the factor of safety is large, when it is remembered that these 10 inch discs are subjected to a dry test of 3-½ times the normal voltage rating, and will withstand a wet test of twice that voltage. When the insulator is wet the potential distribution is evened up by the film of moisture on the outside, and the strain per insulator is approximately the same. Consequently, the question of voltage distribution is not serious, and no trouble should be expected from this source. It is very interesting to note that as the potential is increased the distribution becomes better, and as we approach the arc over point, it is the same for each insulator. The voltage distribution is further influenced by the distance from ground, the greater the distance the better it becomes.

Fig. 6. Transmission Tower equipped with Link Strain Insulators

Figures 6 and 7 show two experimental transmission towers equipped with link suspension and link strain insulators. The link strain insulators serve to insulate and anchor the line at intervals, while the link suspension insulators insulate and suspend the line on the intermediate towers. From observation on this experimental line, apparently no trouble should be expected from swinging or vibration. a group of insulators swaying as a single unit.

These towers were 800 feet apart, and in a certain high wind storm the cables all kept their relative positions, and were deflected, rather than swung, by the wind. There is very little vibration due to the flexible connections, and almost no longitudinal waves.

The particular advantages of this form of insulator are many and may be enumerated as follows:

The material is subjected only to compression strains.

The line construction avoids torsional strains on the cross arm.

Direct pull from the tower, permitting longer spans and necessitating fewer insulators on turns.

A higher electrical and mechanical factor of safety than that obtained by any other known method. The transmission voltage is limited by the number of insulators in series.

Fig. 7. Transmission Tower equipped with Link Suspension Insulators representing a 125000 volt installation

Simplicity of line construction.

Manufacture is simplified by having one type of insulator.

The tower being the highest point in the construction, the line is less liable to damage by lightning.

This design will prevent the line falling away from the tower, even though the insulators be destroyed.

The cost increases directly with the voltage, while it might be said that the cost of the pin insulator, for high voltages, increases as the cube of the voltage.

The suspension being flexible, this minimizes the liability of fatigue in the conductor, which might occur with a rigid support.

INDUCTIVE DISTURBANCES TO TELEGRAPH LINES*

By JOHN B. TAYLOR

Due to the current flowing in a wire, there is an electromagnetic field surrounding this wire, extending to an indefinite distance, and gradually decreasing in strength. If the current in the conductor is alternating, the strength of this field is continually changing, and it is this change which induces electromotive forces in any conductors which chance to be in the field.

Due to the e.m.f., or voltage on the conductor, there is an electrostatic field extending from the conductor to an indefinite distance, and decreasing in strength with increased distance. This electrostatic field attracts charges in neighboring conductors, so that, in general, there is an alternating current in any neighboring circuit, as the result of both electrostatic and electromagnetic induction.

These electrostatic and electromagnetic fields exist about the wires of direct current systems as well as alternating current systems; but it is only the changing strength of these fields that induces disturbing currents in neighboring wires. In other words, a wire has induced in it an electromotive force proportional to the rate at which the strength of the electromagnetic field changes, and similarly, charging currents flow in and out of a wire which are proportional to the rate at which the electrostatic field changes. For this reason inductive disturbances are always of an alternating character, although we may have inductive disturbances from a direct current system if the value of the current changes rapidly.

Considering the matter, then, from merely the mathematical and physical standpoint, any conductor, wherever placed, will have currents induced in it as a result of currents in other circuits, no matter what distance there may be between them.

From the practical point of view, however, it is only when the magnitude of these induced currents is sufficient to cause interruption or inconvenience to the regular operation of the circuits, that they are classed as "disturbances". Disturbance, therefore, is an entirely comparative term, and depends quite as much upon the apparatus and conditions of operation on the disturbed circuit, as upon the circuit which is ordinarily blamed for the trouble.

In other words, a 60,000 volt transmission line conveying thousands of kilowatts, just as certainly has currents induced in it from a neighboring telegraph line, as the telegraph line has currents induced in it from the power transmission line. However, the extra currents produced in the transmission line as the result of the working telegraph line, are not classed as disturbances, and are therefore ordinarily, and properly, overlooked.

The direction of the electromagnetic stress about a conductor carrying current changes with the direction of the current, so that if we have two wires close together which carry equal currents but in opposite direction, the field, due to current in one of these conductors, will, at a slight distance from the wires, be practically neutralized by the field of opposite direction due to current in the other wires. Similarly, the electrostatic field due to one wire at a certain voltage will be practically neutralized if there is a second wire close to it at the same voltage but of opposite polarity. The neutralization will be more nearly exact the closer together the two conductors are.

*Read before The Association of Railroad Telegraph Superintendents, June 19, 1907.

In a similar manner, the two sides of a metallic circuit in a disturbing field act in opposition, and, if sufficiently close together, partial neutralization may result, even though the two conductors are in a very strong field.

The final resulting disturbance in any telegraph or other circuit, is therefore the residual after taking into account the effect on each side of the circuit of all neighboring wires carrying current at their different voltages.

From consideration of these facts, we can see that it is possible for the telegraph, as well as the more sensitive telephone circuit, to run for miles in fairly close proximity to transmission circuits operating at as high as ten, twenty, thirty, or even sixty thousand volts; and carrying currents up into the hundreds of amperes. This is because the transmission system is balanced; i.e., for every ampere in any conductor of the transmission system, there is a corresponding ampere in another conductor flowing in the opposite direction; and similarly, for the electrostatic field of one sign on or near the conductor, there is a corresponding field of opposite sign on other conductors. On transmission systems, however, this condition holds only so long as everything is normal; an accidental ground on one of the conductors of the transmission system will disturb the electrostatic balance, and a broken conductor, or other unusual condition, may disturb the electromagnetic balance; usually by allowing some of the current to return by way of the earth.

Favorable and Unfavorable Conditions:

Consideration of the above facts will show that the most favorable condition for sensitive telephone or telegraph systems in proximity to power systems, is to have both systems operated on metallic circuit, with outgoing and return conductors of each circuit as close together as possible, as in such a case the strength of field is a minimum, and the two sides of the signalling circuit affect still further neutralization. Such extreme neutralization is necessary only for the very sensitive telephone.

The most unfavorable condition exists where the outgoing and return conductors of power and signalling systems are widely separated, and a practical case of this is where both power and signalling circuits operate with ground return. In such a case the distance between the two sides of the circuit is at least equal to that between the cross arm and ground, and is practically much greater than this, due to the fact that the return current does not flow entirely in the surface of the ground immediately following the route of the pole line.

Transpositions:

For mechanical reasons it is not desirable in practice to place open air signalling wires closer than ten or twelve inches apart; and the separation of conductors on power transmission circuits may be as much as six or seven feet when the voltage is as high as, say, 60,000 volts. It is therefore always advisable to make transpositions of the conductors forming a metallic circuit system, such transpositions being so located that, considering a given length of line, the average distance of any conductor from all other conductors will be the same.

With a two-wire metallic circuit, transposition involves merely interchanging the positions of the two wires at the regular or proper intervals; while on a three-phase transmission line the three conductors, which are usually on triangular spacing, are spiralled one-third of their turn. A complete transposition section usually consists of three equal lengths of line with a one-third spiral at two points. Many transmission systems have none of these transpositions, as there is little benefit to be derived from them unless telephone or telegraph lines are in close proximity.

Where a system operates with ground return it is obviously impossible to make use of any form of transposition.

Factors Affecting Induction in Telegraph Lines:

I have many times been confronted with the question: "How far must a telephone or telegraph line be removed from an alternating-current system to be free from disturbances"? There are so many different factors that it is impossible to make any general reply. Some of the points having direct bearing upon this question of inductive disturbance are the following:

(1) Voltage of power system.

(2) Current in power system.

(3) Frequency of power system.
(4) Distance from power line to telegraph line.
Distance from power line to ground.
Distance from telegraph line to ground.
(5) Length of telegraph line parallel to power line.
(6) Total length of telegraph line.
(7) Length of cables (overhead or underground).
(8) Number of telegraph wires on pole.
(9) Telegraph system: Single, duplex, quadruplex, printing, high-speed automatic, etc.
(10) Number and resistance of relays in circuit.
(11) Telegraph working current.

Taking up these various points separately:—

(1) Electrostatic induction will be greater the higher the voltage of the power system.

(2) Electromagnetic induction will be greater the greater the current in the wires of the power system.

(3) The electromagnetically induced voltage, and the electrostatically induced charging current, will be directly proportional to the frequency of the power system; i.e., the values will be approximately two and one-half times as great for a sixty-cycle system as for a twenty-five-cycle system. This, however, is not a direct measure of the disturbance to telegraphic apparatus, as a number of the other factors tend to give less disturbance as the frequency increases.

(4) The distances between the wires of the circuits and ground are usually the factors which give the greatest difficulty in figuring or predicting the amount of disturbance that is likely to be experienced in any case. In the field these distances vary from one mile to the next, and frequently from pole to pole. Increased separation between power line and telegraph line reduces the inductive effects in general more rapidly than the distance is increased; that is to say, a separation of 20 feet will reduce the disturbance to less than half of that which exists when they are separated 10 feet. The closer the wires are to ground the less will be the electrostatic disturbance. The difficulty of making any exact calculation, even where the separation is uniform, lies in the fact stated previously, that the return current does not flow in the surface of the ground directly beneath the wires.

(5) The greater the length of telegraph line that is exposed to power line, the greater will be the inductive disturbance. Other things being equal, an exposure of 20 miles will cause twice the disturbing current, both electrostatic and electromagnetic, that is caused by an exposure of 10 miles.

(6) Disturbance also depends upon the total length of the line; e.g., a line 100 miles long with a 10 mile exposure, will not feel the disturbance as much as a 10 mile line the entire length of which is exposed. This is because the longer line will have greater resistance, and the electrostatically induced voltage will not cause as much alternating current to flow through the instruments as the same induced voltage would cause in a shorter line. Furthermore, the capacity to ground of that portion of the telegraph line which lies outside of the disturbing field will furnish some of the charging current caused by electrostatic induction, so that less will flow through the instruments at the end of the line.

(7) Underground cables, or those with metallic sheaths, have a much greater capacity than open wires, so that sections of cable may cause marked modifications in the effect of electrostatic induction.

(8) In general, the disturbance to an individual wire will not be so great where there are a number of lines on the same pole, since the wires tend to shield each other to a greater or less extent. For example, in the case of two wires on a pole; the current which is induced in one of these wires through proximity to power line, sets up its own field in opposition to the field from the power wire; and similarly, the electrostatic charge which is attracted by electrostatic induction to one wire, also exerts a shielding or neutralizing action upon the other wire.

(9) It should be obvious that the various types of relays used on single wires for such systems as the duplex, quadruplex, printing, high speed automatic, etc., will have widely different degrees of sen-

sibility to superimposed alternating currents.

(10) A line having a number of way stations with 150 ohm relays all in series, will present a much higher impedance to the flow of induced alternating current than a line with but two terminal stations; and assuming that the working current is the same in both cases, the disturbance will be felt less on the line having the greater number of stations. This effect is more marked than might appear at first sight, since the standard 150 ohm relay chokes back a twenty-five-cycle alternating current as though the coil's resistance were approximately 500 ohms; while, with a sixty-cycle current, the same relay has a choking effect equivalent to 1200 ohms. These figures can be taken as only approximate, since much depends upon the air gap adjustment of the relay, as well as upon the number of turns and the size and magnetic properties of the iron core.

(11) The disturbance due to a given induced current will be less as the direct working current is increased, since it is the percentage variation between the maximum and minimum values of current which determines the chattering of the relay.

Elimination of Disturbance:

In order to prevent the disturbance resulting to telegraph lines from exposure to alternating current systems, we have three general lines of attack:

(a) Increased separation.
(b) Special telegraph instruments not sensitive to alternating current.
(c) Neutralization.

(a) Increasing the distance is obviously so simple a remedy as to require little discussion. Unfortunately in the case of existing lines, this may involve the difficulties of obtaining a new right of way, and also the expenditure of large sums of money, but it should be kept in mind when constructing new lines.

(b) Where the disturbance is not extremely bad, several means may be employed to reduce the effect of the alternating current. As stated previously, the proportion that the superimposed alternating current bears to the normal working direct current is a measure of the disturbance, so that increasing the normal working current in the line will, in general, help matters. Also, since alternating currents do not pass readily through reactive coils, increasing the reactance of the line by inserting, in series, coils wound on iron will tend to reduce the disturbance. Condensers may also be used, as these allow the alternating current to pass, but do not pass the direct current. Thus a relay, shunted by sufficient capacity, will separate the two currents, the direct going through the relay and the alternating through the condenser. Both of these methods will tend to make the line sluggish and may fail where high speed automatic, or machine transmission is employed; since in these cases, the frequency of interruptions or reversals in the telegraph circuit may be as great, or even much greater, than the frequencies of the commercial alternating current systems.

The back contact relay, with reversing sounder, or what is known as the "bug trap" device, may also be of service in some cases.

Various methods have also been proposed for neutralizing or absorbing the effect of alternating current in the relay itself. All of the devices in this class must be considered as palliative rather than curative remedies.

(c) Neutralizing may be accomplished either in the power line, the telegraph line, or in both together. In its simplest form this means a metallic circuit for either the power line or the telegraph line. Where expense, or other conditions prevent the installation of a metallic circuit, various neutralizing connections may be employed. These will divide into two general classes:

First: Those in which the fields of the disturbing power wires are neutralized by other wires.

Second: Those in which currents are introduced into the telegraph lines, these currents being made equal to but opposite in direction to the disturbing currents. The best means of accomplishing such neutralization will naturally depend upon a consideration of all the attending factors, and is not likely to be the same in any two cases.

Advantages of Metallic Circuit:

While I do not wish to give the impression of advocating the addition of wires to change the present grounded telegraph lines to metallic, I wish to point out that against the disadvantages of disturbing an existing system, and the expense of additional wires, there are many marked advantages to be gained by employing properly constructed metallic circuit for telegraph use. Not the least of these is the possibility of simultaneous use of the wires for telegraphy and telephony. Such circuits should be less susceptible to wet weather conditions on account of the two insulators in series between one side of the line and the other; they should be free from inductive disturbances due to neighboring telegraph wires; and free from earth currents.

In many cases a consideration of all the points may show the advisability of using a metallic circuit, and when this is installed it should be done in such a manner as to secure the full benefits to be derived from this construction. It seems not unlikely that satisfactory duplex systems can be developed for metallic circuits, which should give the two wires of the metallic circuit the same capacity that they now possess as single grounded wires.

Telephone Interference:

A number of points that have been considered apply equally well to telephone systems, but in many other respects the telephone requires especial treatment which is not touched upon at all in this paper.

In most cases of inductive disturbances there will be two parties involved, and it should be apparent that these two parties should confer freely as to the best means of eliminating or reducing disturbance. The engineers of the power companies are not likely to be conversant with all the details of the telegraph business, nor are the telegraph engineers any more likely to know as much about the conditions of operation of the transmission system. There is no doubt that in many cases, by consideration in conference, or by interchange of ideas, inductive disturbances could be materially reduced, if not practically eliminated, and at little or no expense to either party. It appears not improbable that the growing number of electrical transmission systems, and the tendency to increase the speed and automatic working of telegraph lines, will make this general question of inductive disturbance a more important matter in the future than it has been in the past.

A METHOD OF COLLECTING CURRENT FROM THE UNIPOLAR DYNAMO*

By EDGAR J. NOE

It is assumed in this article that the reader is familiar with the winding and construction of the unipolar dynamo.

In these machines, especially those of large capacities, the effect of ring reaction is quite considerable; as shown by Mr. J. E. Noeggerath in the Proceedings of the A. I. E. E., January 1905. These ring reactions are caused by the current having two paths in the ring between the conductor and the brush, the current in the

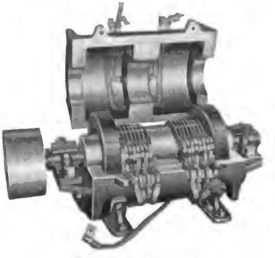


Fig. 1. Unipolar Dynamo

one path aiding the primary flux and that in the other opposing it. This causes the primary flux which passes through the ring to shift to one side, and as the ring revolves, this shifting is continued, producing hysterisis and eddy current losses. In the article mentioned above Mr. Noeggerath shows a means by which the trouble may be overcome. He also shows that a compounding effect may be obtained by running the connecting cables from the brushes part way around the armature before connecting to the frame or return conductor.

The method of collecting current described in this article shows another arrangement for overcoming ring reactions and also giving a compounding effect

*An article by Josf Huppert in the Elektrotechnik und Maschinenbau, March 4, 1906, describes this method for A. C. Machines.

without the addition of any extra material or space. The method is probably more theoretical than practical, as the split ring which is used, would probably not stand the terrific strain to which the rings on large machines are subjected.

Figure 1 shows a unipolar dynamo

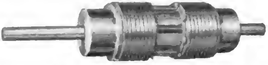


Fig. 2. Armature Unipolar Dynamo

equipped in this manner, while Figure 2 shows the appearance of the armature when removed from the machine.

The rings on each end of the conductors are cut as shown in Figure 3. When the brush is at "A", the current has an immediate path to the brush, and therefore the number of ampere turns is zero; but as the ring revolves and the brush comes to the point "C", the maximum number of ampere turns is produced, i. e. one turn times the current. There being practically no difference in potential between the ends of the ring, the slit may be made very small, and the brushes made sufficiently thick to bridge over the slit, so there is never a break in the circuit. When the armature is revolved in one direction, the ampere turns per ring vary gradually from

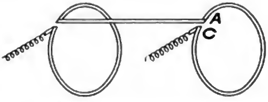


Fig. 3. Diagram of Collecting Rings

zero up to a maximum; and then as the brush short circuits the slot, they suddenly fall to zero, (Figure 4). When the armature is revolving in the opposite direction, however, the ampere turns jump suddenly from zero to maximum, and then gradually die down to zero, (Figure 5). The latter appears to be the better method, as there would not be the tendency to spark at the slot due to self induction.

The conductors are placed equally around the armature, and the slots cut adjacent to each conductor. The brushes being set in a straight line, the length of ring between the brush and the corresponding conductor is different for each ring. This is true for any specific position of the armature, (see Figure 6). For example, if there are eight conductors, and the first brush is directly over the conductor, then the first ring has zero turns; the second ring has 1/8 turns; the third ring 2/8 turns, and the fourth ring 3/8 turns, etc., up to 7/8 turns; making a total number of turns on one side equal to 3½,

Fig. 4. Curve of Ampere Turns

which is the minimum. When the last ring has one complete turn, or 8/8, the first ring has 1/8 turns; in this case the total number is 4½ turns, which is the maximum. The average number of turns is therefore, $(3\frac{1}{2} + 4\frac{1}{2}) \div 2 = 4$ turns.

This variation of the series turns makes a slight change in the total flux. It is probably very small however, being high up on the saturation curve. With eight rings there are eight variations per revolution, and at a speed of 3,000 r.p.m., this gives 400 variations per second. With this high frequency and small variation, the effect on the pressure cannot be detected.

The current always flows around the rings in the same direction, so they can cause no shifting of the flux as in the case of the solid rings, their only effect being a variation in the total flux, which is very slight. Thus, there is practically no eddy current or hysteresis, which, on the contrary, is a large factor in the case of solid rings.

If the armature is to revolve in a specific direction, care must be taken to cut

Fig. 5. Curve of Ampere Turns

the slots on the proper side of the point where the conductor joins the ring, in order to give the compounding effect. For after the slots have been cut, the relation between the series and shunt field cannot be changed without changing the direction of rotation; because to reverse the shunt field, the rotation remaining the same, would reverse the armature current and hence the series field, and the relation would remain the same as before. The connections of the series

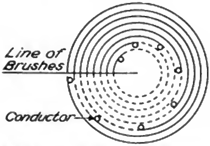


Fig. 6. Diagram of Rings and Brushes

field cannot be changed, as they are built in the armature; but by changing the direction of rotation, the current in the armature is reversed, and thus the current in the series field. This, therefore, reverses the series field with respect to the shunt field.

In case two conductors diametrically opposite on the armature are connected to the same ring, two slots would be cut and two opposite brushes would be used.

The degree of compounding depends upon the number of collector rings and the current. It may be varied, however, by shunting the slots with a resistance, but this increases the ring reactions. In this method of collecting, the brushes must be in practically a straight line.

In the above description I spoke of the ampere-turns varying. Theoretically this is not true, as the actual number of turns, formed by the armature conductors, the rings, and the return or frame conductors, remains constant; and as the load is constant, the ampere-turns must be constant.

What really happens is that as the brushes slide over the inactive portion of the rings, they lengthen out the turn; this increases the area of the magnetic circuit enclosed by that turn, and therefore the total flux increases. When the brushes are at the point "C", Figure 3, the maximum area is enclosed by the turn, which is composed of the armature conductor, the two rings, and the return or frame conductor. The description used to explain the action of the rings seems to be the clearer explanation, and is correct in effect, as the distance, or part of a turn, between the conductor and the brush is directly proportional to the area inclosed by the turn.

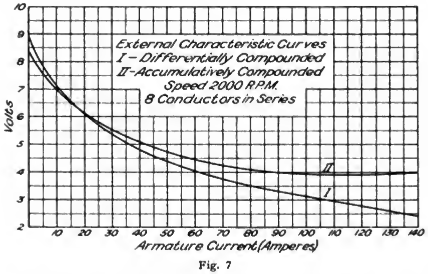


Fig. 7

The curves, (Fig. 7), show the external characteristics of the machine when running accumulatively compounded, and when running differentially compounded. The accumulative is changed to the differential by changing the direction of rotation.

THE ELECTRIFICATION OF STEAM RAILROADS WITH REFERENCE TO THE WEST SHORE ROAD BETWEEN UTICA AND SYRACUSE

By John R. Hewett

When discussing the application of electricity to hauling traffic in densely populated areas, on suburban, and interurban roads, we are on sure ground, being able to state with confidence that no system is capable of dealing with such conditions as efficiently as electricity. We can cite numerous examples of such installations which are giving every satisfaction both from an operating and financial standpoint, and can predict with all reasonable certainty as to the results likely to be arrived at in other localities under similar conditions.

The electrification of large steam road terminals and tunnels, as is being contemplated in many of our more important cities, and has already been effected in the instance of the New York Central Terminal, is of special interest as showing that the art of electrification has developed to a stage where it can handle traffic under the most severe conditions. Up till very recently the concensus of opinion has been that such changes in motive power would, for some time to come, only be compelled by local conditions and ordinances, and that there were no inherent advantages in electrification to warrant its adoption under such conditions, other than the elimination of the smoke nuisance. But that such is not the case is evidenced by the fact that many important steam road systems, after a close analysis of the situation, are contemplating the electrification of their terminals and tunnels in order to secure the economic advantages to be derived by such a change. Experience, with those roads that are operating electrically, is substantiating this contention, and is showing that the increased terminal facilities afforded by electrification is helping to eliminate the congestion of traffic.

A prominent advantage in the adoption of electric traction at terminal depots is likely to be found in the fact that the platform may be arranged both above and below the present platform level, giving three tiers of platforms in the place of one as at present. The importance of this consideration is evident when the cost of real estate in the locality of such terminals is realized. Economy in space is made possible by the ability of an electric train to round a curve, or loop of a curvature, that no steam train could negotiate; by the good grade climbing characteristics of the electric motor; and the ability of the distributing system, which will permit of practically an unlimited amount of energy being transmitted to the train. The smoke nuisance will of course be entirely eliminated.

There is good reason for believing that electrification would relieve the congestion of traffic by permitting the running of trains at more frequent headways, and there is another consideration regarding electric traction which is also of moment, inasmuch as it would greatly reduce the congestion of the terminals themselves; namely, that the signal movements and the train movements are reduced to exactly one-half when individually equipped cars are employed, and in all large electric systems, part at least of the traffic will be hauled in this manner.

With steam locomotives, four-train and eight signals operations are imperative every time a train enters and leaves the terminal station, thus:—

Train entering station—One train operation—Two signal operation:

Locomotive entering to draw train out of depot—One train operation—Two signal operation:

Train leaving depot—One train operation—Two signal operation:

First locomotive leaving track—One train operation—Two signal operation.

With electrical operation, when individually equipped cars are employed, it is obvious that as each car is double ended, the number of trains and signal operations are reduced to exactly half this number. Further, the switching with steam locomotives to bring the engine "head on" is entirely eliminated, and consequently the number of switches, sidings and turn tables are reduced.

However, the electrification of suburban, interurban, and branch lines, together with elevated roads and terminal depots, is an accomplished fact, and the point of greater interest at present is the possibility of electric traction being adopted on main trunk lines which are at present operated by steam.

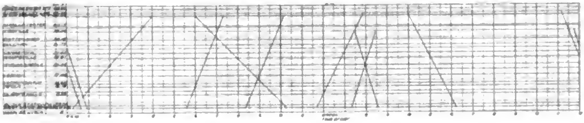
In considering this phase of the question, it is important to determine under the present modes of railroad operation, where heavy fast long distance trains are imperative, if the steam or the electric locomotive is the more efficient form of motive power. In numerous instances where specific examples have been subjected to careful analysis, the balance has been in favor of the electric locomotive. The elimination of the congestion of freight traffic on the present track facilities is the point at issue, and the ability of the electric locomotive to provide faster train movements is a most important feature.

The generally overcrowded conditions of our steam roads throughout the continent is sufficient evidence that the present mode of operation has well nigh reached its limits with the existing trackage and terminal facilities. Another view point of the same subject is, that it seems well within the range of possibility that other modes of operation may be adopted for economic reasons; principally to reduce the heavy maintenance charges incident to the system at present in vogue, and that shorter trains will be run at more frequent intervals. Should this be the case there is little doubt that electric traction would be adopted.

In the electrification of the West Shore tracks, we have another phase of the situation which it is highly probable may lead to similar undertakings. The events which lead up to this electrification are briefly enumerated as follows:—

Numerous trolley lines having sprung up throughout the State of New York, which were built and operated by independent corporations, a keen competition was brought to bear on the steam roads for the local passenger traffic and the light freight business. Certain of these trolley lines were gradually forming a chain of roads between Albany and Buffalo. Consequently it became the policy of the steam roads to absorb the competing electric lines, with the final result that it is the steam roads themselves now that are propagating a campaign to connect these roads together to form an adjunct to their present transportation facilities, and the electrification just completed between Syracuse and Utica forms an important link in connecting a chain of electric lines already existent which run parallel to the steam road tracks. This is an example of especial interest, as it seems reasonable to suppose that the present congestion of freight traffic on the original steam lines may make it advisable to develop the electric roads for high speed passenger traffic, and it is quite within the range of possibility that this may form an important factor in the development of high speed, long distance electric lines operating on highly economical and modernized conditions.

Each new example of electric traction being adopted on railroads formerly operated by steam is of added interest, as it is likely to show the latest development of the art in one or more directions.



Train Sheet of West Shore Road Before Electrification

In the electrification of the West Shore road between Syracuse and Utica, the transmission line operating at so high a pressure as 60,000 volts will attract much attention, and the adoption of the inverted protected third rail on a main line tends to show the course that future development is likely to take, and, futher, it is of interest that the power is supplied from a hydro electric plant.

The new service rendered is also novel, inasmuch as it is largely governed by steam road conditions; and yet the cars run through the city streets after leaving the main tracks, giving a "door to door" service, which is one of the most desirable features of any traction system and one that is entirely beyond the scope of steam road operation to provide.

The electrified portion of the West Shore Road extends from the westerly limit of Utica to the easterly boundaries of the city of Syracuse. This road was formerly double tracked throughout, but to accommodate the different classes of service, a third track has been provided between Clarks Mills and Vernon to enable the faster units to pass the local trains. Between Oneida Castle and Canastota a fourth track has been laid to permit the electrical units to pass the steam trains that may be held in this section, owing to the presence of water stations and freight yards.

The distance between terminals is a little greater than 44 miles. Of these 30.515 miles are laid with two tracks and 8.843 miles with three tracks and 4.582 miles with four tracks, making a total mileage of 105.887. The tracks throughout were relaid with 80 lb. A. S. C. E. Rails.

A point of prime interest is to be found in the different schedules provided before and after electrification. Formerly only two passenger trains were run daily in each direction between Syracuse and Utica, and at night two trains with sleepers passed over the tracks; these latter were of practically no value to the residents of any of the cities served.

Under the newer conditions, three different classes of service will be given.

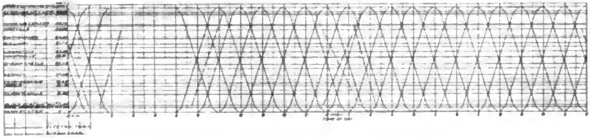
(1) The fast limited cars or trains which will leave each terminal hourly and make but two stops en route. These will complete the journey in 1 hour and 28 minutes, the 28 minutes being taken on the local lines at each end of the system; the run over the West Shore tracks proper taking only 60 minutes.

(2) Local cars or trains with a schedule speed of 24 miles per hour, which will complete the run in one hour and 58 minutes, will also provide an hourly service from each terminal and will make frequent stops, at every highway if necessary.

(3) There will also be the steam service as heretofore.

A comparison of the train sheets for the West Shore tracks before and after electrification will show the difference in the class of service rendered in a most striking manner.

The general scheme of electrification provides for the generation of current at 2200 volts at Spiers Falls, where it is stepped up 60,000 volts and transmitted to the substation. At the sub-station, after this pressure is reduced to 430 volts, it is converted to direct current and fed to the third rail at 600 volts.



Train Sheet of West Shore Road After Electrification

GYROSCOPIC FORCES

Part I

By W. E. Miller

Introduction

The principles involved in the consideration of the gyroscopic actions of spinning bodies have been generally considered to be too abstruse to be understood by any but those of a mathematical turn, and it is somewhat difficult to find simple explanations in any treatises, as either they are too popular, or take up the question by the aid of advanced analysis in a general manner. This article aims at giving certain facts about rotating masses, and also some calculations of the forces involved, taking one or two specific problems as illustrative cases.

The study of gyroscopic forces, until recently, was practically confined to investigations in such phenomena as the precession of the equinoxes, the nutation of the earth's axis, the vortex theory of matter, the apparently anomalous behavior of spinning bodies and other kindred questions. Of late years, however, physicists and engineers realize that the gyroscopic forces of rotating bodies can be usefully applied for the solution of some practical problems, and considerable attention has therefore been given to the subject recently.

Applications

The majority of practical uses to which the gyroscope has been put are based on the fact that a body rotating freely round an axis passing through its mass center, and mounted on gimbals so that its supporting frame can rotate in any direction relative to this axis, will keep its plane of rotation invariable. This principle has already been employed for the mariner's compass, and has been found thoroughly reliable under exacting tests lasting several hours. It has also enabled a true horizon to be obtained by which the altitude of heavenly bodies can be accurately observed in rough weather. In the first case, the rotating element was continuously driven by an electric motor; in the latter case it revolved in vacuo, and was set in motion by a stream of air impinging upon vanes cut in the periphery of the fly-wheel, the vacuum being restored by a pump directly full speed had been obtained. The speed, vacuum, and dimensions of the wheel were such that observations could be taken for 20 minutes to half an hour without the speed falling off sufficiently to allow any noticeable change in the plane of the horizon.

The use of gyroscopes perfected by Mr. Brennan for keeping torpedoes in a straight path, is so well known that it need only be mentioned here as an additional example of their application.

Mr. Brennan has also constructed a model of a monorail car, one-eighth actual size, which was recently shown to the Royal Society of London, and which is a still later adaptation of the gyroscopic forces. That this car can be sufficiently safeguarded for passenger service is open to doubt, but it may find a field of usefulness for conveying freight for military or other purposes. The car was mounted on four wheels; each pair was coupled, and one of each set driven through gearing by electric motors carried on bogies. Two motor driven gyroscopes were used, revolving in a vertical plane in opposite directions at a speed of 7,000 to 8,000 r.p.m. The car was designed to run at seven miles per hour, and could climb gradients of one in five. It steered perfectly, leaning inwards instead of outwards around curves, and if one side was suddenly weighted, it gradually rose to restore the position of equilibrium.

Various experiments have recently been carried out with regard to the steadying effect of large gyroscopes in vessels. The models and calculations were made in Germany by Herr Schlick, and so far satisfied the authorities, that a turbine driven gyroscope was recently fitted in a torpedo boat, in order to see what increase of stability could be obtained in rough weather. The tests proved entirely successful, the angle of heel from the verticle being reduced from about 15 degrees to 1 degree by the gyroscopic forces, the period of swing of the vessel being at the same time increased from about 4 to 6 seconds. Its capabilities were so evident that the naval authorities of more than one country are likely to provide gyroscopes for some of their smaller boats; not for increasing the comfort of the crew, but to serve the more useful purpose of having a steady and level deck from which to fire the guns. The above examples show that the toy of the past has already become a useful instrument for improving existing methods or attacking problems hitherto intractable.

Explanation of Gyroscopic Forces

The theory and behavior of spinning bodies are subject to the same mechanical laws as define the motions of translation without spin, and no mysterious actions need be postulated to explain the observed facts. Newton's three laws of motion, and what are practically their corollaries—the conservation of energy and of moment of momentum—are all that is necessary to give the complete solution of the most general cases. The idea that the ordinary laws of motion are temporarily suspended for rotating masses, has been largely fostered by the necessarily incomplete statements of the motions in popular treatises, which are apt to be misleading when a complete theory of the phenomena is sought.

The forces and movements due to spin are difficult to comprehend at first, and a complete rational explanation is hard to give concisely in words. Understanding can be best achieved by taking a fairly simple example and applying analysis for the solution of the actions involved. In order, however, to form a clear mental picture of what happens, the gyroscopic couples due to rotation are considered below in a simple case, namely, that of a body spinning inclined to the vertical and acted on by gravity only; from which its motions are deduced.

By gyroscopic forces is meant those forces which are called into play by the spin of a body when it is rotated about any axis not the axis of spin. The spin does not affect the forces resulting from a motion of pure translation.

When couples or forces tend to produce rotation about an axis—not the spinning axis—the latter tries to move nearer to the impressed axis of rotation. If the body can move freely around two axes at right angles to the axis of spin, and the impressed couple acts continuously; precessional rotation is set up, which produces a couple in opposition to that impressed.

In order to illustrate the above, take the case of a fly-wheel, (Fig. 1), mounted in a frame as shown, so that the frame can turn round the point X and also round xx; assume the flywheel rapidly spinning about the axis zz¹, and let the pivot X of the whole frame be resting on the floor so that it is inclined to the vertical. Gravity will then pull the frame downward, around the horizontal axis drawn at right angles to the diagram plane through X. Let the rotation of the fly-wheel be upward on the side nearest the observer; then, as the fly-wheel turns under the action of gravity, a particle a, which would have arrived at c if there had been no turning, will be constrained to move to b. But the frame and fly-wheel can turn round the axis xx, and by so rotating will allow the point a to reach c instead of b; therefore it will so turn. The end of the axis marked z¹ moves towards the spectator, and the end z away from him; and the frame and fly-wheel will assume the position shown in the perspective view, Fig. 2. A point lying on the back of the fly-wheel, at the point furthest removed from

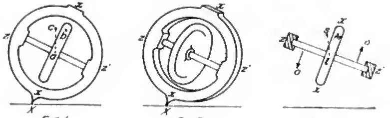


Fig 1 Fig 2 Fig 3

a, is subject to exactly the same forces, also tending to produce a turning of the axis zz' in the same direction.

Now suppose that Fig. 2 be viewed with the fly-wheel end on, Fig. 3. A particle l on the periphery would move to s, due to the second rotation of the frame around xx; but owing to the turning due to gravity alone, it is forced to move to m. It will be seen that the diversion of these particles produces a third couple, OO'. which acts almost in direct opposition to the first, produced by gravity.

From the above it is clear that this third couple does not come into play unless the ring bearing the fly-wheel can turn around an axis xx. The turning due to gravity, which, with the rotation of the frame xx, produces a rotation of the top of the frame axis around a vertical axis, is called the precessional motion of the whole ring and fly-wheel. If this were prevented, no couple could be produced in opposition to gravity, and the case and fly-wheel would fall in the same way as it would do if the fly-wheel were at rest. It is generally true with all gyroscopes that if any one of the rotations around the principal axes is prevented, no couple results in opposition to the impressed couple on the gyroscope.

It will be noticed that when viewed from above, the precessional rotation of the axis xx around a vertical axis is clockwise; and that as the effect of this precession is in opposition to gravity, the frame and fly-wheel try to turn so that the side z' moves upward, trying to bring the axis of the fly-wheel and the direction of its rotation in the same line and sense, respectively, with the axis and rotation of the precession. If the fly-wheel and frame had been supported from points above their mass center so as to be in stable equilibrium when at rest, the precessional motion would have been in the opposite direction for the same rotation of the fly-wheel, since the gravitational couple would then act in the opposite sense.

Take the case of an electric car equipped with geared motors; the motors revolve in a direction opposite to that of the wheels. Suppose the car be moving around a curve; as neither motors nor wheels can move appreciably in a vertical plane, no gyroscopic force results to prevent the car moving around the curve, except a negligible force acting while the outer wheels of the car are being raised, before entering the curve, by the gradually increasing elevation of the outer rail. There is, however, a couple acting about the wheel base, tending to turn the car over. With geared motors, the couple due to the spin of the motors tries to rotate the car around the inner rail, in opposition to centrifugal force; the gyroscopic effect of the wheels, however, acts in the opposite direction; that is, in conjunction with centrifugal force. In other words, the motors try to turn over so that their rotation, when viewed from above, is in the same sense as the rotation of the car around the curve; and as the wheels rotate in the opposite directions, they try to turn over in an opposite sense to the motors. If the motors were mounted directly on the axle, both rotating elements would try to turn the car in the same direction as the centrifugal force, thus producing an upward thrust on the bearing over the inner rail, and a downward thrust on the bearing over the outside rail.

In the example of the fly-wheel given above, the frame and fly-wheel initially move downward under the action of gravity; this immediately brings into play a turning motion of the frame around the axis xx, which in turn produces a couple in opposition to the turning moment of gravity. As the rotation due to gravity increases, so does the precessional rotation, and therefore the opposing or balancing couple. When the frame has fallen through a certain distance depending upon the angular speed and moment of inertia of the fly-wheel, the precessional rotation will have increased sufficiently to exactly balance the force of gravity. The fly-wheel and frame will not, however, stop moving downward, but will be carried further down by inertia, increasing the precessional rotation still more, and thereby producing a couple acting upward, greater than gravity; until a point is reached where the downward movement is completely stopped, when precession is a maximum, and also the upward turning moment. The frame will then rise in opposition to gravity, and precession will decrease until the upward movement of the frame is again arrested at the original starting point, when the spinning axis is momentarily at rest. A vibration, or nutation, of the axis xx of the frame and fly-wheel thus results, which is of small amplitude and short period for a rapidly spinning fly-wheel, and of large amplitude and longer period for one with slower spin. Thus the axis of a quickly rotating top will vibrate up and down as the axis precesses, moving in a slightly corrugated cone, the nutation being generally too small to be perceptible. If, however, the top spins slower, a wobbling movement can be observed which is large just before the top falls.

The example above illustrates a case where the axis of the body was originally at rest. If, however, a precessional rotation had been initially impressed on the frame, in the same direction as that produced by the gravitational couple, and equal to its mean value, no nutation would have occurred, and the end of the axis xx of the frame and fly-wheel would have moved around in a smooth circle. If a greater precessional rotation had been impressed the axis would have risen against the force of gravity, which, if sufficient, would bring the axis vertical. In the same manner, if the precessional rotation were decreased the axis would fall.

The rule that a rotating body will rise if the precession is increased, gives at once the explanation of why an ordinary spinning top, though initially rotating with an axis greatly inclined, will gradually rise against gravity until its spinning axis is vertical, when the top sleeps. This is caused by the friction of the rotating peg on which the top spins helping on the precessional motion, and thus raising the top so that it finally rotates perfectly upright, until friction has sufficiently destroyed the spin to render it unstable.

As a further example of the above, the following may be of interest: take a raw egg between the thumb and finger and rotate it around its short axis; it will continue to so rotate no matter how much effort is used. If the egg, however, be hard boiled, after a few wobbles it will rise up, standing on its end and rotating around its long axis. In the first instance the interior is fluid and therefore cannot transmit the necessary rotational forces through its mass; whereas in the latter case the whole mass is of sufficient rigidity to do so. This also shows that the matter of a rotating body must be rigid, in general a solid, in order that the gyroscopic forces may completely act in such cases as the above.

Stable Rotation

All rigid rotating bodies have three free axes passing through the mass center, which are principal axes of inertia through the mass center at right angles to one another, about which the centrifugal forces equilibriate. Stable rotation, however, can be maintained only around that axis with respect to which the moment of inertia is a maximum. For bodies kinetically symmetrical about the mass center, all these axes are free axes, and the moments of inertia about them are also equal; such bodies will therefore rotate stably about any axis passing through the mass center. For unsymmetrical bodies, or those kinetically symmetrical about an axis only, this is not the case, and the rotation is not always what might be expected. Thus, fasten a string to the edge of a plate hanging vertically downward, and rotate the plate through the string: at first the plate revolves around a vertical diameter. If the rotation is increased, wobbling occurs, and finally the plate moves so that its plane is parallel to the ground and it is revolving about a vertical axis through its center. The gyroscopic forces, due to the rotation caused by the centrifugal forces increasing with an infinitesimal disturbance of the body's original position, finally make the plate rotate around the new and stable axis.

The above shows that an egg-shaped body spinning about its shorter axis is in stable equilibrium with respect to centrifugal forces. If the interior is liquid, and the body is rotating—say on a flat surface—it will not rise; because the greater part of its mass is fluid, and therefore not constrained to rotate about the longer axis by the friction forces at the points of contact with the surface. If an orange-shaped body, however, is revolved about its equatorial axis, the centrifugal forces, and the friction forces at the points of spinning contact, which start and increase precessional rotation, act together; and a body of this shape, with liquid interior, will so move as to rotate stably about its polar diameter.

Examples of Precessional Rotation

In order to illustrate precessional rotation further, take the case of a spinning body whose instantaneous axis revolves in a conical path around a fixed axis. Let the angular velocity about the fixed axis be Ω, and let the body rotate about its instantaneous axis with angular velocity ω: Ω is called the rate of precession. Let θ be the semi-vertical angle of the fixed cone, and let Φ be that of the rolling cone. Then the precessional motions can be completely represented by the three following cases:—

(1): Convex cone rolling on convex—

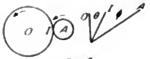


Fig 4

Then $\omega \sin \Phi = \Omega \sin (\theta + \Phi)$

(2): Convex cone rolling inside concave—

Fig 5

Then $-\omega \sin \Phi = \Omega \sin (\theta - \Phi)$
If $\Phi' = -\Phi$

(3): Concave cone rolling outside convex—

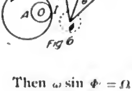


Fig 6

Then $\omega \sin \Phi' = \Omega \sin (\Phi - \theta)$

Cases 1 and 3 give a positive precession. The first case is illustrated by an ordinary spinning top; and the second by a coin spinning on a table where the coin's plane is nearly horizontal.

Case 2 gives a negative precession, as illustrated by a spinning body inclined and supported so as to be in stable equilibrium when at rest. The precessional motion of the earth's axis is also a further example. In this case the period of angular rotation ω is a siderial day, and that of Ω is 25,000 years; the inclination θ of the earth's equator to the ecliptic is 23½ degrees nearly, from which the angle Φ, viz., the angle that the instantaneous axis of the earth's rotation makes with the polar axis of the earth's spin, can be calculated to be 0.0087″. If a circular post of radius, 0.88 ft. is fixed to the earth's axis at the pole, and rolls around inside a circle about 25,000,000 ft. in circumference with the earth's angular speed of rotation, one complete circuit around the center of the circle will be made in 25,800 years, and the precessional motion of the earth will be exactly represented; nutation, however, not being considered. The earth's precession and nutation are caused by the fact that the resultants of the varying attractions of the sun and moon do not pass exactly through the earth's mass center, and thus small couples are produced trying to turn the earth about an equatorial diameter.

Gyroscopic Centrifugal Force

The spin of a precessing body increases the centrifugal force about the axis of precession. Take the case of a disc spinning about a horizontal axis supported at one end which is precessing non-nutationally about a vertical axis through the point of support. Let R be the radius of the circle of precession and r that of the rotating disc. Let v be the peripheral velocity of the disc, and V that of precessional rotation. Let p be the ratio $\frac{v}{V}$, and W the weight of the disc.

Referring to Figure 7, if x is the radius of any particle w, which makes an angle a with the horizontal radius; then $v_x = \frac{x}{r} v \sin a$ represents the horizontal velocity of this particle due to spin. Considering the top part of the disc, it will be seen that the velocity of spin is opposite to the velocity of the body as a whole, due to precession, (this being the case when the rotating mass is acted on by gravity only).

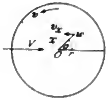


Fig 7

The total velocity of any particle due to both rotations will therefore be represented by $\frac{x}{r} v \sin a - V = V\left(\frac{x p \sin a}{r} - 1\right)$; the centrifugal force due to any particle, w, will therefore be $\frac{V^2 w}{g R}\left(\frac{px \sin a}{r} - 1\right)^2$; and the total centrifugal force $\frac{V^2}{g R}\Sigma w\left(\frac{px}{r}\sin a - 1\right)^2$, equals $\frac{V^2}{gR}\Sigma\left(w - \frac{2pxw}{r}\sin a + \frac{w p^2 x^2}{r^2}\sin^2 a\right)$ the summation being taken between the limits a = 0° and 360°, and x = 0 and r. Now between these limits $\Sigma\, 2p\frac{x}{r} w \sin a = 0$ and $\Sigma \frac{w p^2 x^2}{r^2}\sin^2 a = \frac{p^2 k^2}{2 r^2} W$ where k is the polar radius of gyration and $\Sigma w = W$. Therefore, the formula reduces to $\frac{WV^2}{g R}\left(1 + \frac{k^2 p^2}{2 r^2}\right)$, which equals the ordinary centrifugal force $\frac{WV^2}{g R}$ plus the additional centrifugal force due to spin (gyroscopic centrifugal force) $\frac{WV^2}{g R}\,\frac{k^2 p^2}{2 r^2}$.

If p is large, $\frac{k^2 p^2}{2 r^2}$ is large compared to 1. and the total centrifugal force can be taken as that due to spin only, and equal to $\frac{WV^2}{gR}\,\frac{k^2 p^2}{2 r^2}$ which can be expressed as $\frac{W k^2 v^2}{2 g R r^2}$.

If, therefore, the spin is rapid, the gyroscopic centrifugal force of the body is very large compared to that due to the rotation of the body as a whole, though if the latter were nothing, the total centrifugal force would also be nothing.

If the ratio p is unity, that is to say, the peripheral velocity of spin is the same as the velocity of precessional rotation, the formula reduces to $\frac{WV^2}{g R}\left(1 + \frac{k^2}{2 r^2}\right)$. This formula, can be applied to compute the centrifugal force due to the rotating parts of cars or locomotives, etc., moving around curves, and will be used in calculating the centrifugal forces developed by an electric locomotive.

It follows from the above formula, that the gyroscopic centrifugal force due to rotating parts of locomotives or cars running around a curve, can never be greater than half the centrifugal force due to the weights of the rotating parts moving around the curve without spin. This maximum value only obtains when the whole mass of the wheels and revolving parts can be considered as concentrated in their peripheries so that the radii of gyration equal the radii of the rotating parts.

It will be readily seen from the reasoning used to obtain the above formulae that the latter are applicable to any shape of spinning body, and a disc was chosen for simplicity only. This also applies to what follows.

To be Continued

RAILWAY SIGNALS

PART II

By F. B. COREY

Automatic Block Signals

The highest development in the art of railway block signaling has been reached in the automatic system. Its use is being rapidly extended, and it will, undoubtedly, displace all others; except where unusual traffic conditions render some different system desirable. The automatic system is peculiarly American, both in its inception and its development, and although most roads abroad use the block system in some of its many forms, there are comparatively few *automatic* block signals in use outside the United States.

One reason for this condition is the fact that competent signal operators demand

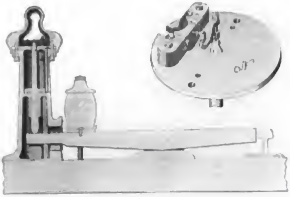


Fig. 1. Track Instrument

higher wages in this country than elsewhere. There is also a greater inclination on the part of Americans, in general, to rely on automatic apparatus of all kinds, than is found among Europeans. This tendency, which has often been noted in reference to other lines of apparatus, undoubtedly has its influence in causing a marked difference between American and European block signal practice.

Automatic block signals were first introduced by Mr. Thomas S. Hall, whose son, Mr. W. P. Hall, is now President of the Hall Signal Co. Mr. Hall began his experiments in 1866, at which time he installed a few signals, for experimental purposes, on the N. Y., N. H. & H. R. R., near Hartford, Conn. In 1871 he had automatic signals operating on sixteen miles of road near Boston, on what is now a part of the Boston & Maine system; these being the first automatic signals in commercial operation. In this installation, as well as in many later ones by Hall, the signals were operated directly by current from primary batteries, the connections be-

Fig. 2. Disk Signal

ing made by wires placed on poles at the side of the track.

The operation of the signal was controlled by an apparatus known as a track instrument. This consists of a simple contact device operated by means of a lever, one end of which is located close to the outside of one of the track rails and projects about ⅜ of an inch above the top of the rail head. The lever is normally held in this position by means of two springs of solid rubber, and the depression of the end of this lever by the wheels of the train, operates to open or close electric circuits, as desired. A track instrument of this kind is shown in detail in Figure 1.

The signals, which were of the disc type, (see Figure 2) were held normally in their proceed position; the passage of a train over the lever of the instrument broke the circuit which energized the signal relay. When this relay was de-energized, the circuit through the "holding clear" magnet was broken, causing the signal to assume the danger, or stop, position; i.e., the red disc was displayed at the opening in the case. The track instrument for restoring the signal to its clear position was located about 2000 feet beyond the entrance to the next block, and when this instrument was acted upon by the wheels of the train, the relay circuit was closed; but the signal circuit was held open until after the train had passed the instrument. The relay being closed, the signal magnet was then energized and the signal assumed the proceed position. As the wheels of the train pass the lever of the track instrument, rapid vibration of the signal contacts is prevented by a dash-pot near the top of the upright part of the instrument, or "nigger head". This arrangement is shown in Figure 1. Such track instruments are still used in many cases for operating crossing bells and other devices of minor importance, but for automatic block signals they have been superseded by more modern apparatus.

The automatic block system, above described, had many objectionable features. In case a train entered a siding to permit another train to pass, it was necessary, after the train had cleared the fouling point, for the train crew to operate a device called a "clearing key"; the action of the clearing key being to energize the signal relay when the switch was thrown normal; so that a following train could enter the block on the main track. A circuit breaker, attached to the switch points, opened the holding clear magnet so as to give the train the necessary protection when re-entering the main track from the siding. Should a rail be broken or removed, or should part of the train be left in the block section, such a signal system could give no indication that a dangerous condition existed.

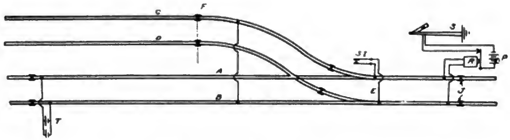


Fig. 3. Elementary Track Circuit

In 1872 a patent was issued to Mr. William Robinson which undoubtedly marked the greatest advance ever made in automatic railway signaling. Mr. Robinson's invention was the simple track circuit which forms the basis of all modern signal systems. He divided the track into sections by means of insulating rail-joints, connected a battery between the rails at one end of each section, and a relay in the corresponding position at the other end of the block. A circuit of this kind is shown in Figure 3. Here A and B represent the rails of the main track, while C and D represent the rails of a spur track or siding entering the main track at switch F.

The track rails are divided at the proper points by the insulated rail joints J. These insulated rail joints include a piece of vulcanized fibre about ¼ of an inch in thickness, and cut to a shape corresponding to the rail section. This piece of fibre, called an "end post", is placed between the ends of two adjacent rails, which are joined together by splice bars of oak properly re-enforced by iron bars and held in place by insulated bolts. A joint most widely known and used for this purpose is the Weber joint, which is shown in detail in Figure 4. As the two rails of each track must be insulated from each other,

Fig. 4. Weber Joint

all switch rods must be provided with an insulated section. A typical insulation of this kind is shown in Figure 5.

At one end of the track section, a track battery T is placed. This battery is usually of the gravity type; two cells being used in multiple to guard against accidental breakage or the failure of one cell or its connections. These batteries are

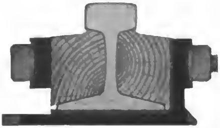


Fig. 5. Insulated Section

usually installed in a cast iron case, called a battery chute, placed in the ground at one side of the track; these chutes are deep enough to prevent serious trouble from freezing. The batteries are raised and lowered by means of a wooden frame to which a rope is attached; this frame being known as the battery tray or elevator. The rope also carries a wooden disc which is normally located inside the chute slightly below the surface of the ground. Such a chute, sectioned to show the batteries, elevator, etc., is shown in Figure 6.

In many instances, storage batteries are used in the track circuit; under these conditions a resistance is placed in series with the batteries so as to prevent a short-circuit when the rails are connected by the wheels and axles of a train in the section. The use of storage batteries for this purpose is rapidly increasing.

Fig. 6. Two Cell Battery Chute

The track battery is connected to the rails by means of wires run in covered wooden troughs, called trunking; these wires being connected to the rails by means of channel pins or riveted bond terminals. Figure 7 shows the sectional view of such trunking, which is usually made of yellow pine; the cover, or capping, is nailed on after the wires are put in place.

Passing to the other end of the section of the track which we are considering, we

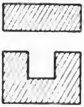


Fig. 7. Section of Wood Trunking

find the track relay (shown at R in Figure 3), the coil terminals of which are connected to the rails in the same manner as the track battery. Such a relay, as manufactured by the General Electric Co., is shown in Figure 8. The resistance of the operating coils of such a relay depends upon the use to which it is put. For long track circuits most roads use coils having a resistance of four ohms, while a few

Fig. 8. Type DN-105 General Electric Relay

roads have adopted the five-ohm relay as their standard for such work. For short track circuits the resistance varies from eight to sixteen ohms; and for other purposes, to be described hereafter, relays of higher resistances are used. For the details of the construction of signal relays reference is made to General Electric Bulletin 4481.

Referring again to Figure 2, it will be seen that when energized the relay R operates to close a circuit through the power battery P and the mechanism of the signal S. The power battery is usually composed of primary cells of the caustic soda type, but storage batteries are being used for this purpose in rapidly increasing numbers. Power batteries are placed either

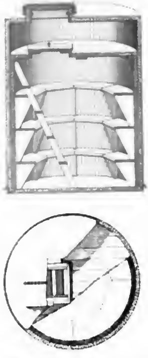


Fig. 9. Steel and Concrete Battery Well

in an iron housing at the base of the signal mast, or in a battery well or vault sunk in the ground near the base of the signal.

Such wells are made of wood, steel, or concrete, according to the railroad's standard specifications; they are provided with water-tight covers for the entrance of the maintainer, and the inside is furnished with shelves for the accommodation of the batteries. Such a vault, made of steel and concrete, is shown in Figure 9. The various methods used for charging storage batteries in these vaults and housings will be considered in a future issue.

In order that the signal shall be held in its clear position, it is necessary for the circuit to remain complete through the power battery and the signal mechanism. The action which is produced upon the signal by a train in the section covered by the track circuit, will therefore be clear from an inspection of Figure 2.

When the train passes the insulated joints, the rails are short-circuited through the wheels and axles, and current is practically cut off from the track relay R. The de-energizing of this relay will break the signal circuit and the signal will return to its stop position by gravity. It is evident, that a failure of the power battery or a break in the signal circuit, will accomplish the same result. Also, any failure on the part of the relay to close its circuit, whether due to burn-out, open circuit in the winding, or other defect, will give a stop indication. Any failure on the part of the track battery or its connections, or an open-circuit in the track, due to broken rail or other cause, will be indicated by a stop signal.

Fig. 10. Exterior View of Switch Instrument

It will be noticed that insulated joints are placed in the rails C and D at the point F, the rails being bonded in such a way that if any part of a train is between the point F and the switch E, the relay R is short-circuited in the same way as if the train were on the main track. The joints are located so that a car or train cannot approach the switch sufficiently close to foul cars running on the main line, without causing a danger indication at the signal. The position of these joints is therefore known as the "fouling point" of the siding.

An apparatus SI known as a switch box, or switch instrument, is connected to the point of the track switch, in Figure 3. The function of this is to short-circuit the main track whenever the switch is moved out of its normal or straight position. These in-

Fig. 11. Interior View of Switch Instrument

struments are usually set to operate with about one-quarter inch movements of the switch points; and, in order to increase the certainty of action of the switch instrument, it is usual to run the *signal* circuit through it in such a way that this circuit is broken at the same time that the shunt track circuit is completed, thus giving double protection. A good idea of the appearance of such a switch instrument is given by Figures 10 and 11, which show the exterior and interior of such an apparatus manufactured by the General Electric Company.

It is manifestly impossible to perfectly insulate the rails from earth and from each other; even with the low voltage used on the track circuit, there is a very considerable loss of current, due to leakage through the track ballast. The leakage factor varies greatly with different locations, as well as changing weather conditions. With good rock ballast kept clear of the rail the ballast resistance is usually high, and consequently the leakage is very small; but even with the best quality of ballast, the dropping of salt water from refrigerator cars upon the ties, or a local accumulation of dirt or cinders; may cause considerable difficulty in maintaining the track circuit. In certain locations, especially on heavy grades, accumulations of brake shoe dust frequently cause trouble by reducing the ballast resistance to such a degree as to cause failure.

The adjustment of the track relay is a matter of great importance and of considerable delicacy. According to the specification of the Railway Signal Association, all track relays shall operate as follows:—

"Four (4) ohm track relays shall be adjusted to release at not less than thirty (30) mil-amperes, after an initial charge of one hundred and ten (110) mil-amperes has been given for one minute. After relay has been adjusted to release as specified, the current through coils shall be reversed; when armatures shall pick up at not more than sixty-five (65) mil-amperes." "Sixteen (16) ohm track relays shall be adjusted to release at not less than fourteen (14) mil-amperes, after an initial charge of fifty-five (55) mil-amperes has been given for one minute. After relay has been adjusted to release as specified, the current through coils shall be reversed; when armature shall pick up at not more than thirty-six (36) mil-amperes."

Under these conditions, it is evident that the length of the track circuit that can be successfully operated depends largely on local conditions. Track circuits are in successful operation 1¼ miles long. These, however, are exceptional, and many instances occur in which it is impossible to operate them at a length of 2000 feet.

When the distance between signals is longer than can be successfully worked with a single circuit, the difficulty is overcome by the use of what is called a cut-section. A simple track circuit with cut-section is illustrated in Figure 12. In this case protection is required between the points A and C, which is too great for a single circuit. It is therefore necessary to divide this circuit at the point B, where the relay R^1 and the track battery T^1 are installed. It will be noted that the relay R^1 is provided with both front and back contacts; so that when it is de-energized, either by the presence of a train in the section A B, or by some other dangerous condition, the track circuit between the points B and C is opened at the front contact, and at the same time the rails are short-circuited through the back contact; this latter being a precaution against foreign currents that might act to clear the relay R.

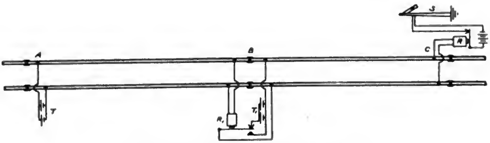


Fig. 12. Track Circuit with Cut Section

Having considered these elementary track circuits, we will, in the next issue, call attention to various modifications of these circuits which are used to meet some of the conditions that exist in the practical operation of automatic railway signals.

To be continued

ELECTRICALLY OPERATED RATCHET DRIVEN FIELD RHEOSTAT SWITCHES

Among recent interesting developments in electrical science may be classed the General Electric Company's new type of field rheostat switching apparatus for the remote control of generator voltage. It is interesting to note the different stages of improvement through which this class of apparatus has passed.

Generator panels, when first built, were provided with field rheostats attached directly to the front of the board.

The next step of development introduced the design of rheostat suitable for location on the back of panels. The switch shaft in this arrangement extends through to the front of the board and there receives the hand wheel.

As electrical business increased, the requirements of electrical machinery demanded the manufacture of rheostats in larger sizes. Many field rheostats became too large to be placed on the board, with the result that banks of resistence were located away from the panels, and connected to their dial switches by means of leads.

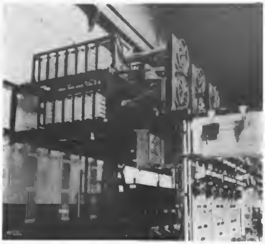


Fig. 1. Ratchet Driven Field Rheostats, Chicago Edison Co.

In order to do away with the large, heavy and likewise expensive mass of leads necessary in this form of construction, the sprocket and shaft driven rheostats were developed.

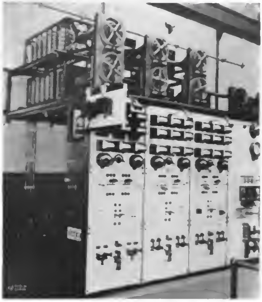


Fig. 2. Ratchet Driven Field Rheostat, Showing Panels

Following this, small motors were made use of for controlling the rheostats from the panel. This arrangement has given complete satisfaction, though it is quite expensive in the end, and requires considerable space for installing. Bearing these facts in mind, the engineers of the General Electric Company have produced a simple, compact, electrically operated remote control switch, which retains all of the advantages of the previous types, and possesses many desirable features in addition. While these remote control ratchet driven switches were designed primarily for varying the field strength of generators, their use is not necessarily limited to this service, as any apparatus, in which automatic "no-voltage and overload release" features are not essential, may be provided with these switches for cutting resistance in and out from a distant point.

Figs. 1 and 2 show these switches, complete with rheostats, as installed in one of the Chicago Edison Company's large generating stations. They are operated by means of the small single-pole double-throw switches shown on the central slab of these panels, which are closed in an upward or downward position, depending upon the desired direction of rotation of the switch arm. The solenoids of the switch have a common plunger which acts on the switch arm, through pawls, and so long as the knife switch remains closed, the proper solenoid is energized intermittently, and a continuous step by step rotation given to the switch.

The solenoids of the standard switch are wound for 125 volts D. C., and require less than 1 ampere for operation. The dial switches are designed for standard voltages up to and including 500 volts, and are built for the following capacities:

50 amperes with 70 divisions;
100 amperes with 65 divisions;
200 amperes with 46 divisions.

Special switches of larger capacities can be furnished when necessary, with solenoids wound for any standard voltage up to 600 volts.

With this type of electrically operated switch, a perfect adjustment of the resistance can be obtained at a minimum cost for apparatus and operation. It is evident from the construction of the switch that there are no high speed revolving parts which will continue cutting in or out resistance after the main control circuit has been opened. In other words, the resistance can be adjusted with great precision. The simplicity of all the moving elements makes the device exceptionally reliable and durable.

MOTOR DRIVEN ASH SIFTER

By Miss O. L. Brown

The question is sometimes raised as to whether members of the electrical fraternity, who so enthusiastically recommend the widespread use of electricity to their customers, utilize the services of this swift and willing agent themselves as freely as they might. This question becomes quite pertinent in connection with the growing adoption of electrical contrivances for the home. As the shoemaker's children were frequently minus footwear, so also is the

Fig. 3. Motor Driven Ash Sifter

electrician often the last to harness the electric current for his own aid.

In vindication of the seeming accusation, we here illustrate an outfit, unique of its kind, found in the home of one of the General Electric Company's engineers, who devised this method of employing electricity in an otherwise unpleasant, but necessary service.

A casual inspection of the ash heaps and ash barrels, which are placed in front of city residences in the early morning, will impress anyone interested in household economics, with the large quantity of good coal and cinders thrown away. This waste is especially striking where servants attend to the fires, in which event very little regard is shown to the amount of coal used. Now, King Coal, at his present high price, would best not be extravagantly used. Moreover, the wages of servants are high, and a very material saving may be effected by the use of sifted ashes from which the clinkers have been removed, for banking fires, or for mixing with new coal.

Sifting ashes is usually a dirty and tedious operation, and is not taken to kindly by helpers. Therefore, consideration of the present high price of coal, and of the amount which could be saved from sifting all ashes, including those from the kitchen stove, as well as the large quantity from the furnace, led to the construction of the motor driven ash sifter shown in the accompanying view, which is largely self explanatory.

The machine is very simply constructed, and is built on the revolving screen principle, being driven by a standard belted General Electric 1S-4-1/15 hp-1800 r.p.m.-KG 4-110 volt, 60 cycle motor, connected to the lighting circuit. The outfit is conveniently located with respect to the coal bin and furnace door. The ashes are dumped in the hopper at the right, the cinders falling into the bin, and the waste going into the can. The device is suspended from the rafters so that the ash can may be easily removed by raising the cloth which confines the dust during sifting, and sliding the barrel horizontally along the floor.

It is estimated that in an ordinary household from a ton to a ton-and-a-half of coal can be recovered from the ashes in a year, and this, mixed with the new coal, effects a saving which is represented by dollars and cents. Aside from this, some consideration may be given to the cleanliness, and to the quick handling of the ashes when being taken from the furnace, and when carrying out the filled waste barrels from the basement.

The present outfit was comparatively inexpensive to construct. Its yearly current consumption is not over three kilowatt hours, and it has been in successful operation for two winters.

THE CHICAGO FIRE BOATS

By J. H. Clark

The General Electric Company has received an order through the Manitowoc Dry Dock Company, of Manitowoc, Wis., for the equipment of two fire boats for the City of Chicago.

The apparatus is to be used not only for pumping water for fire purposes, but also for propelling the boats.

Each boat will be equipped with two 660 h.p. steam turbines, which will be supplied with steam at a pressure of 160 lbs. and operate condensing with 26 to 28 in. vacuum. A centrifugal pump of sufficient capacity to deliver 4500 gallons of water per minute, against a pressure of 150 lbs. per square inch, will be mounted on an extension of the bed-plate of the turbine. A 200 kw. D. C. Generator will also be mounted upon the same bed-plate and direct connected to each turbine, the generator being wound for a normal full load voltage of 220 volts and operating at 1700 r.p.m.

The ship will be equipped with twin screws, and each propellor shaft will be direct connected to a 250 h.p., 250 volt, D. C. motor operating at 200 r.p.m. A 25 kw. Generator, and an exciter of equal capacity, will also be installed and will be driven by steam turbines. The apparatus will be controlled by the Ward Leonard system of field regulation, and may be operated from a controller in the pilot house, or one in the engine room, suitable arrangements being made to prevent any interference from the latter when the pilot house controller is being manipulated.

It will be possible for the operator in the pilot house to run one propeller in the forward direction at full speed while the other is operating at equal speed in the opposite direction; or either propeller may be run at any speed desired. With this control, the propellers can be made to assist the rudder in steering the boat, and it is possible that the rudder may be found to be unnecessary except for use as an auxiliary in case of emergency.

This, we believe, is the first equipment consisting of a generator and motor that has been installed for the operation of a ship's propeller.

It will be appreciated that with electric control arranged in the manner described above, racing of the screws due to the propellers being out of water when a ship is pitching in a heavy sea would be obviated. The fact that the controllers are located in the pilot house has the following advantages over the methods used in the past.

First; the effort required by the pilot to manipulate the controlling switch is no more than that necessary to signal the engineer in the engine room.

Second; it provides a much more prompt response to any decided change in speed or direction.

Third; the liability of an error being made through a misunderstanding of the signals from the pilot house is entirely eliminated.

QUESTIONS

This section is open to inquiries upon engineering subjects. The questions will be submitted to the respective departments and such as are of general interest will be answered in this column, while those of less importance will be answered by letter.

Q. How may the accuracy of a Thomson Recording Watt-hour meter, or Thomson Induction Watt-hour meter be checked?

A. The test may be made in two ways: first, by the use of indicating instruments and stop watch; second, by the use of rotating standard or test meter.

The first method consists of a direct comparison between the energy indicated by the instruments and the rate at which the meter is recording. The latter factor may be determined by the formula:

$$\frac{3600 \times K \times R}{T} = \text{Watts}$$

in which 3600 is the number of seconds in an hour (to reduce watt hours, the unit in which the meter records, to watt seconds).

K is the calibrating constant, marked on the dial face of "non-direct" reading meters, and on the disk of "direct" reading meters.

R is the number of revolutions during T, the time in seconds of the observation, as determined by the stop watch.

To obtain the percentage of accuracy, the result secured above must be divided by the watts, as read on the indicating instruments. When testing on direct current circuits, the indicating instruments should consist of voltmeter and ammeter. For A. C. testing, an indicating wattmeter and voltmeter are required, and, if possible, an ammeter should also be included to determine the power factor.

For the second method, when using a rotating standard, the accuracy of the meter under test is determined by the ratio of watt hours as recorded by it, to the watt hours recorded by the standard during the same interval of time.

$r \times k$ = Watt hours recorded by meter under test, when
r = number of disk revolutions
k = calibrating constant.
$R \times K$ = watt hours of rotating standard, when
R = number of disk revolutions
K = constant for the coils in use.

$$\frac{r \times k}{R \times K} = \text{percentage of accuracy of meter under test.}$$

F. G. V.

• • •

Q. If two single phase wattmeters are connected on a 220 volt, three wire, three phase circuit, and if, during certain periods of the day the power factor of the circuit falls below 50 per cent, but is for the greater part of the time above that value, will the arithmetical sum of the readings, at the end of thirty days, register the correct amount of power used? If not, how can correct readings be obtained?

A. If power factor and condition of load are such that neither meter ever runs backwards, then the sum of the two readings is the true power. Should one of the meters run backwards part of the time, the sum of the meter readings will still be the true power, neglecting an insignificant error, due to the effect of the light load compensation. This compensation always produces a positive torque, thus causing a meter, when running backwards, to under record slightly on light loads. The polyphase meter will always give the true reading.

F. G. V.

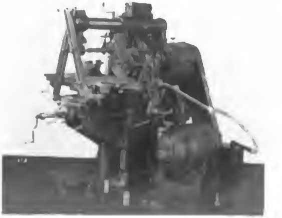
MOTOR DRIVEN No. 2 UNIVERSAL CINCINNATI MILLER

By H. H. MEYROSE

The following illustration shows a No. 2 Universal Miller built by The Cincinnati (Ohio) Milling Machine Company, and driven by a General Electric Company Type CR, 3 h.p., 500 to 1500 r.p.m., 230 volt, totally enclosed direct current shunt wound motor.

The motor is mounted on an extension, which is cast to the base and forms a part thereof. The motor, friction clutch and chain drive are all at the rear, occupying space that must be kept clear for table travel, and is therefore not available for other purposes.

The friction clutch between the motor



Universal Miller Driven by Type CR Motor

and machine enables the operator to control the spindle very conveniently for making a partial revolution when adjusting arbors, cutters, etc. The clutch lever is at the front of machine within easy reach, and the spindle can be started and stopped as required, without stopping the motor. The duty imposed upon the motor when it is started under full load, i.e., when a machine is started with the cutter in the work, is very severe as compared to that required when the motor is running at full speed and picks up the load gradually, as is the case when the machine is started through the friction clutch.

The equipment is provided with a separate starting rheostat of the underload and overload release type, mounted above the table, to be used for bringing the motor up to its normal speed. A separate field rheostat for obtaining the variation is mounted on the side of the column.

The advantages claimed by the manufacturer for this method of control are, that the operator may determine the cutting speed, and further, that if it is necessary to leave the machine at any time, he may return and complete the work without regulating the speed of motor. The motor is always started under no load conditions, due to the friction clutch arrangement described above.

GOOD SERVICE

As evidence of the varied uses to which the mercury arc rectifier may be put, and of its great length of life and general satisfaction afforded in service, we here print an extract from a letter written by the electrician of the Woronoco Paper Co., of Woronoco, Mass.

"This Rectifier is of the type usually installed in garages for the charging of storage batteries, and has a rating of 30 amperes. It is operated on a 220 volt, 40 cycle, alternating current circuit, and gives 110 volts on the direct current side.

The novelty of this installation lies in the fact that this Rectifier replaces a direct current dynamo which operated continuously, and supplies current for the magnets on our paper machines. These magnets are used to extract the small particles of iron from the paper stuff previous to its entering the machine. These machines are operated without stop, for 130 hours a week. Twenty-seven amperes are consumed in the 3 magnets, and about 3 amperes more are required for charging the ringing battery of our telephone system.

The Rectifier was installed in May, 1905, but was only used for a total of about 200 hours up to Feb. 4th, 1907, when it was then put in continuous operation. At this time the tube that was first installed was in use, and it was kept in service until June 3, 1907, when the side of the tube became so coated with mercury, between the starting anode and cathode, that it would not start, and it had to be removed. This tube shows very little wear at the carbons, and no indication that the vacuum was impaired. The records we have show that this tube was in operation about 2400 hours. The present tube, at this writing, has been in operation 800 hours.

When first installed, there was some doubt as to the possibilities of the Mercury Arc for this service, but we are now satisfied that for simplicity of operation, and for cheapness, it is far ahead of a motor generator, and as it is not affected by sudden changes in load, it requires absolutely no attention."

SAMUEL McCLINTOCK HAMILL

Samuel McClintock Hamill was the son of Rev. Samuel M. Hamill, D.D. and Matilda Green; he was born in Lawrenceville, N. J., March 27, 1858, and gained his earlier education at the Lawrenceville school, of which his father was principal for over fifty years. Mr. Hamill received his college training at Princeton University, and was graduated in 1880 with the degree of Bachelor of Arts. He devoted the next three years to teaching and to further study, and in 1883 was granted the degree of Master of Arts.

At this time, having completed his post-graduate studies, Mr. Hamill entered the employ of the Chicago, Burlington and Quincy Railroad, and remained with that Company in the office of the 2nd Vice President until 1886; when he accepted the position of Secretary of the Brush Electric Company, of which concern he later became Vice President and General Manager. He continued in this capacity until the Brush Company was absorbed by the General Electric Company, with which he has since been associated.

Mr. Hamill was a man of rare business acumen and foresight; and showed unusual ability in the promotion of business enterprises, and marked capacity as an organizer.

He was public spirited in the broadest and best sense; the interests of the City of Schenectady, where in later years he made his home, were very near to his heart, and it is due to his initiative that many improvements, both municipal and social, were secured to the city. Among these was the Schenectady Trust Company, which was organized in 1903, Mr. Hamill and his associates purchasing the interests of the Schenectady Bank for this purpose. He was President of the Trust Company from the time of its organization until his death.

His active interest and generous contributions to the Mohawk Golf Club did much to insure its success. He was elected to life membership and was President of the Club for four years. He was a member of the Board of Governors at the time of his death.

The City Hospital, of which he was a trustee, the Old Ladies' Home, and many other charities and public institutions, will miss the ever ready assistance and earnest cooperation which he has always extended.

Throughout his life he kept in close touch with his college associates and had an exceptionally large circle of friends among prominent men of the day.

On any subjects in which he was interested, he held strong convictions, but was fair minded withal, and ever ready to acknowledge a mistake. Tenacity of purpose, with courage to pursue the right as he saw it, and his natural leadership of men, were among his most prominent attributes.

NOTES

We have recently received a very interesting little pamphlet published by the Fitchburg Gas & Electric Light Co., of Fitchburg, Mass. This publication gives a complete list of the various uses to which electric motors are put in their city. It is made up in a very attractive form, with numerous illustrations of the apparatus and installations.

The right-hand pages have on their inside margin the list of motor applications, and on the balance of the page, opposite each item, the name of the concern operating the equipment. The left-hand pages are devoted to illustrations of the apparatus or plants, together with short notices pointing out the advantages to be derived in each case by the use of the motor drive.

The following are a few of the less common motor applications enumerated:

Making Paper Stoppers, Novelties,
Medical Apparatus,
Making Ginghams,
Cancelling Stamps,
Sawing and Splitting Wood,
Making Candy,
Mixing Dough,
Operating Carbonator,
Grinding and Roasting Coffee,
Grinding Meats,
Cutting Leather,
Making Combs,
Making Curtains,
Blowing Organs,
Washing Bottles,
Making Brooms,
Operating Cash System,
Hoisting Coal,
Making Cotton Yarn,
Compressing Waste,
Horse Clipping,
Saw Manufacturing,
Making Shoes,
Massaging.

* * *

An attractive set of blotters has been received by us from the Boston office, advertising the General Electric Company's line of small motors. The blotters are each tinted in one of three delicate shades, and in the upper left-hand portion is a rectangular space of different color, serving as a background for the illustration of the special motor advertised. The printed matter gives the range of capacity in which the motors are manufactured, and sets forth some of the special merits and various uses that may be made of them. A blank is provided at the bottom of the card for the firm name of the motor agency to whom the blotters are sent for distribution.

* * *

CONTRAST OF ACCIDENT HAZARDS

By SIDNEY N. MOON *

A reference to the dangers incident to the steam engine and shafting which are foreign to the electric motor will be self-explanatory.

(a) Set screws, whether close to the ceiling or within reach, are a constant source of danger. Statutes and ordinances exist in many states requiring that set screws shall be guarded or countersunk, but the laws are not enforced.

(b) Revolving shafts, while more often out of reach, and connected with the shafting by belting, frequently involve the loose "jumpers" of the employes, while cleaning; with the result that the body is whirled around the shaft until the engineer receives the signal to stop the machinery.

When the revolving shaft is brought within reach, it is, of course, a greater danger, and sometimes the end of the moving shaft extends beyond the wall of the factory, where it fascinates the ubiquitous small child, sometimes resulting in serious injuries; while the courts, when appealed to, have held that it constitutes legal negligence to so expose moving machinery as to be an invitation to children to investigate.

(c) The existence of the overhead shafting necessarily implies the use of ladders for oiling, cleaning and repairing, with the dangers incident to defects therein and risk of slipping.

(d) Machinery, as a rule, must be cleaned while in motion in order to reach the various parts, and, even with a lose pulley and convenient shipper to throw off the belt from the fixed to the loose pulley, there is liability of the machinery not stopping as intended.

With the individual electric motor we have:

(a) The machinery of the motor is completely covered.

(b) The button, or switch, at each machine by which to shut off the power immediately.

(c) The facility of regulating the speed of the motor.

(d) The saving of space in the factory.

(e) The loose pulley is rendered unnecessary.

(f) By the introduction of the automatic circuit breaker, any overload upon the machinery breaks the current, saving the machinery from damage and the operatives from possible injury.

(g) The machines that are not in use are shut down, thus saving the wear and tear incident to shafting and belt machinery.

(h) The complete shutting down of all machines not actually in use, eliminates all possibility of accident to employes in passing around such machines.

*From Insurance Engineering, March, 1907.

ABSTRACTS OF IMPORTANT TECHNICAL ARTICLES

Illustrated *

New Wrecking Tool Car at Oakland, Cal.

(Electric Railway Review, June 29, 1907, p. 866)

A wrecking tool car with a body 30 feet long, 8 feet wide, and 8 feet high, mounted on a floor structure 46 feet in length over buffers, is used for accident work on the city system of the Oakland Traction Co., and the high speed interurban system of the San Francisco, Oakland & San Jose Railway Co. The electric equipment consists of two G. E. 66 motors, with Sprague General Electric multiple-unit control, and the total weight of the car, including the electrical equipment, is 70,000 lbs.

The article gives a complete list of the various tools and appliances provided with the car, which includes emergency supplies and instructions, and the contents of a First Aid Package.

General Concrete Machine-Shop Equipment
"Equipment of Buildings other than those devoted to Manufacturing Purposes, in Plant of United Shoe Machinery Co., Beverly, Mass."

(American Machinist, July 18, '07, p. 78*)

The article describes the drop forging department, hardening department, power station, and the very interesting foundry. The power station is equipped with two 500 and one 1000 kw., 600 volt 60 cycle three phase Curtis steam turbine alternators, induction motor driven exciters and an extensive switchboard, all of which are General Electric make.

Recent Advances in Artificial Lighting

(Engineering News, July 25, 1907, p. 92*)

Brief illustrated article, giving recent advances in artificial lighting, dealing particularly with incandescent and metal filament lamps, and describing the metalized carbon filament, tungsten and tantalum lamps made by the General Electric Company and their licensees.

Electric Sewage Pumping Plant at Salem, Mass.

(Western Electrician, June 29, '07, p. 509*)

A very nicely illustrated description of the Electric Sewage Pumping Plant at Salem, Mass., which has been previously described in the GENERAL ELECTRIC REVIEW, of August 1906, page 63.

Industrial America

(Cassier's Magazine, July, 1907, p. 250*)

Some comments upon American Machine shop conditions by a British workman, including illustrations of General Electric Co's. restaurant for employees, and dining room for Foremen and Assistant Foremen.

The Besly No. 40 Plain Motor Driven Grinder

(The Iron Age, August 1, 1907, p. 291*)

The No. 40 grinder is equipped with 26 in. disk wheels and is direct driven by a 20 hp., 1,200 r.p.m., variable speed General Electric Direct Current Motor

A. C. Electrification on the Illinois Traction System

(Street Railway Journal, July 6, '07, p. 4*)

A map of the present and proposed lines of the Illinois Traction System facilitates greatly the understanding of the very interesting amount of technical data given by Mr. J. R. Hewett, of our Railway Engineering Dept., on the immense system which operates at present 381.5 miles of D. C. & A. C. railways from a number of power houses, most of which are equipped with General Electric apparatus.

For a detailed and profusely illustrated description of the latest, the Peoria, Ill., power station, see the "Street Railway Journal" of July 20, '07, p. 86. It is equipped with the following General Electric machines:

Two 2000 kw. Curtis turbine driven alternators.

One 75 kw. Curtis turbine driven, and one 75 kw. induction motor driven exciter.

Two 750 kw. rotary converters; and a bank of 750 kw., 23,000-33,000 volt step up transformers.

Wellman-Seaver-Morgan Mine Hoists

(The Iron Age, August 1, 1907, p. 285)

Description of two double reel hoists of different sizes, for the mines of the Compania de Real Del Monte, Pachuca, Mexico, which are electrically driven by means of a 250 hp., 429 r.p.m. 1040 volt, 50 cycle, three-phase induction motor and a similar motor, operated at 600 r.p.m.

These motors, as well as the controlling apparatus, are of General Electric make.

The New York Central Electric Lines

(The Railroad Gazette, July 19, 1907, p. 67*)

A very interesting account, showing the New York Central's Auxiliary Electric Lines, including a map and table of mileage of the same. Most of the traction equipment is of General Electric make and supplied from power houses containing General Electric machinery.

The Electric Hoist and Its Applications

(The Iron Trade Review, July 18, '07, p. 101)

A very interesting and profusely illustrated account of small electric and traveling hoists as manufactured by the Sprague Electric Co.

The Steam Turbine

(Cassier's Magazine, July, 1907, p. 226*)

A brief interesting account, by Prof. Steinmetz, descriptive of the fundamental principles of steam turbines.

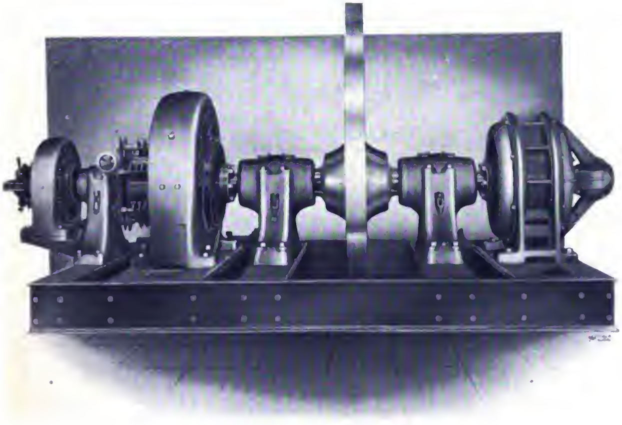
The Power Plant of the Norfolk & Portsmouth Traction Co.

(The Engineering Record, July 6, 1907, p. 4*)
(Street Railway Journal, July 13, 1907, p. 52)

Modern General Electric steam turbine power-house practice.

GENERAL ELECTRIC REVIEW

VOL. IX No. 4 | PUBLISHED MONTHLY BY GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU SCHENECTADY, N. Y. | SEPTEMBER, 1907



Flywheel Motor-Generator Set for Mine Hoist

(See page 140)

GENERAL ELECTRIC REVIEW

VOL. IX NO. 4

SEPTEMBER, 1907

CONTENTS

Iron-clad Portable Wattmeter. Type P-3

(See page 168)

VOL. IX No. 4 SCHENECTADY SEPTEMBER, 1907

GENERAL ELECTRIC REVIEW

FUNDAMENTAL PRINCIPLES OF CENTRIFUGAL FANS

PART I

By MAXWELL W. DAY

In the January 1907 number of the GENERAL ELECTRIC REVIEW, a description of blowers and exhausters was given, having special reference to the navy standard line, and including a short account of the test requirements of the Bureau of Construction and Repair, Navy Dept. Mention was made of 136 blower sets for the equipment of most of the recent naval vessels; and since that time, 79 additional sets have been sold for the U. S. S. "Oregon", "Massachusetts" and "Wisconsin", which are being refitted; and 78 for the new 20,000 ton battleships Numbers 28 and 29. These sets include fourteen forced draft fans on each of these last two ships.

Quite a number of these fans have been ordered for ventilating turbines and other apparatus, many being of the double inlet type because they can be run at higher speed than the single inlet type. A double inlet fan will take in twice the quantity of air that a single inlet fan will admit at the same speed.

The object of the following article is to explain the fundamental principles that apply to these fans. In the first part general formulæ will be given showing the relations that exist between head, pressure, velocity, &c., and which apply to either liquids or gases, assuming that the variation in pressure is so small that the compressibility of the latter need not be considered.

The second part of the article will explain the principle of the fans themselves.

Fundamental Principles

Fig. 1 represents a tank of water with outlet near the bottom through which the water escapes in a horizontal direction, having a velocity depending upon the height of the water above it. Representing the height or head of water by H and the velocity in feet per second, by V we have:—

$$V = \sqrt{2gH}$$

$$H = \frac{V^2}{2g}$$

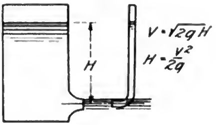


Fig. 1

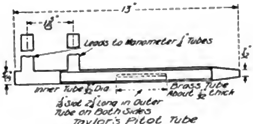
The bent tube at the right is called a Pitot tube, from the name of one of the earlier experimenters. If the lower end is turned directly toward the stream of water, the water will rise in the tube to the same height as the water in the tank, except as the velocity may be slightly affected by the friction of the orifice. This tube provides a convenient means of measuring the velocity of the stream of water when it is not confined in a pipe or closed vessel.

On the other hand, if the Pitot tube be moved through still water with the end pointing ahead, the water will rise in the tube to a height depending upon the velocity with which the tube is moved, that is:—

$$H = \frac{V^2}{2g}$$

This apparatus is also applicable for measuring the velocity of other liquids or fluids. With a pipe connecting it to a suitable water gauge, or other measuring device, it may be used for the measurement of air velocity.

Fig. 2 shows a double Pitot tube as adopted by the Navy Department for fan



Taylor's Pitot Tube
Fig 2

tests. This consists of an inner tube open toward the approaching air and closed at the back end, but provided with a branch leading to a manometer. The outside tube is closed at both ends, but provided with slits in the side and a branch leading to another manometer. The inner tube measures the total impact pressure of the air, which consists of its velocity head and the static pressure; the outside tube is assumed to measure the static pressure only.

Fig. 3 shows the relation of velocity and static heads in a pipe of different sections discharging a liquid or fluid from a tank. Air, being a compressible gas, is subject to different conditions from water, which is practically incompressible; but we may represent the pressure of air by a column of air of uniform density, and this figure may, in that case, represent air under pressure equivalent to the head as shown. In the figures given, friction is disregarded. At the beginning of the discharge tube the area is assumed to be such that the velocity of discharge is 32.08 ft. per second. The tube then enlarges gradually to four times the area in which the velocity is 8.02 feet per second, and then contracts gradually to an effective opening of 1 square foot.

The pressure is assumed equivalent to a head of 100 feet, which should give a velocity at the end of the tube through the 1 foot opening of:—

$$V = \sqrt{2gH} = 80.2 \text{ ft. per second.}$$

There is no side pressure at this point, and the entire pressure is due to the velocity head.

At the beginning of the tube, with a velocity of 32.08 feet per second, the velocity head is again equal to:—

$$\frac{V^2}{2g} = 16 \text{ ft.}$$

leaving a static pressure of 84 feet head. In the large part of the pipe, where the velocity is only 8.02 feet per second, the velocity head is only 1 foot, leaving a static head of 99 feet.

The head or pressure of water is conveniently measured by the height of column of water which it will sustain.

The weight of 1 cubic foot of water is taken as 62.36 pounds, and weight of air, under standard conditions of 30 inches barometer, 70° F temperature and 70% humidity, is 0.07465 lb. A volume of water 1 foot square 1 inch high will weigh 5.2 pounds, and the height of a column of air of standard density, which would just balance the 1 inch column of water, is 69.7 feet; so that in the diagram, the total head of 100 feet of air is represented by 1.434 inches of water.

In passing from one section of the pipe to another, in order to get the advantage of the increased static pressure due to the reduced velocity head, it is desirable to make the change gradually, so as to avoid eddies, which are wasteful of energy.

It should be noted, that the loss of head due to friction in the pipe is proportional to the square of the velocity, and inversely proportional to the diameter of the pipe. Therefore, double diameter of the pipe, which gives a quarter of the velocity, will have only 1/32 of the friction, and it is therefore desirable to use as large sizes as possible for ventilation pipes. In using small pipes for the distribution of air, the velocity head is considerable, and therefore the static pressure is much reduced and the friction very greatly increased.

To determine the loss of head due to friction, it is customary to refer to tables giving the size of pipe, the velocity of air in the pipe, and the loss in head, (measured in inches of water, or ounces per square inch pressure, for 100 feet of pipe). This loss can, however, be very conveniently calculated in the following way:

The loss in head is proportional to the coefficient of friction and the square of the velocity of the air. The experiments of

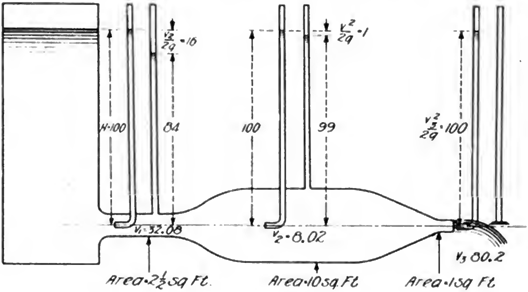


Fig 3

Naval Constructor Taylor at the Washington Navy Yard showed that the coefficient of friction for smooth pipes was about 0.00008, and the loss in head for round or square pipes is expressed by the following formula:—

$$H = 4 \times 0.00008 \frac{L}{D} V^2$$

In which V is expressed in feet per second, H in feet head of the fluid, and L and D are the length and the diameter, respectively, of the pipe in feet. The friction tables in the Sturtevant catalogue are figured on the coefficient of 0.00010 instead of 0.00008. These tables will probably more nearly meet the conditions of ordinary piping, and it is therefore recommended that this value of coefficient be used for calculating the friction loss in piping. The formula then becomes:—

$$H = 0.0004 \frac{L}{D} V^2$$

In the later edition of Kent's Hand-book, a formula for calculating the loss of pressure for distribution of compressed air is given, which can be reduced to:—

$$H = 0.00038 \frac{L}{D} V^2$$

and the table for the loss in friction of water in pipes, as given in Babcock and Wilcox's Book on Steam, reduces to:—

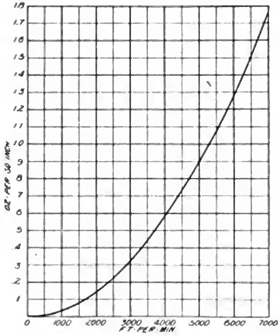
$$H = 0.000375 \frac{L}{D} V^2$$

It is evident, that a sufficient length of pipe will cause a loss of head equal to the velocity head, and as it is generally necessary to know the velocity head in determining the pressure necessary to be developed by the blower, it is very convenient to express the friction in terms of the latter. It can be assumed that the loss of head due to friction of a pipe 39 diameters long is equal to the velocity head.

The velocity head being expressed as follows:—

$$H = \frac{V^2}{2g}$$

If the pipe is of such length as to have a friction loss equal to the velocity head, then:—



$$H = 0.0004 \frac{L}{D} V^2 = \frac{V^2}{2g}$$

$$\frac{L}{D} = 38.8$$

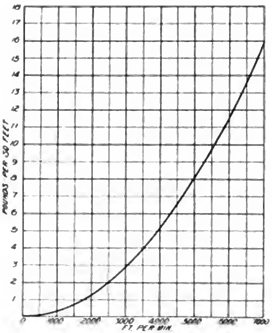
Hence, when it is necessary to calculate the total loss of pressure due to friction, divide the length of the pipe by the diameter (or by the mean of its depth and width if rectangular) divide this quotient by 39 (or 40 for approximate work), and multiply this second quotient by the velocity head; the result will be the loss of head due to friction. This value is also approximately correct for the flow of water in pipes.

The velocity head is generally figured in terms equivalent to the inches head of water, or ounces per square inch pressure, or pounds per square foot pressure, and knowing the velocity head in any one of those three measures, the friction head is very easily calculated.

Curves are attached showing the equivalent head of air corresponding to the different velocities of air. The curve is in the form of a parabola, as the ordinates are proportional to the squares of the abscissæ.

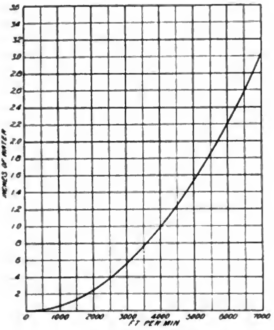
Besides choosing a pipe of suitable size, it is very important, in order to prevent friction and eddy losses, to avoid sharp bends and sudden changes in the size of pipe. It is considered that a square turn will use up the velocity head, and that therefore the pressure of air after passing the square elbow is less than the pressure before the elbow by an amount equal to the velocity head. Curved elbows of very short radius should also be avoided, and it is desirable to use curves of large radius.

In discharging air from the pipe, or in bringing it in from inlet passages, care should be taken to avoid sudden turns, and if they are absolutely necessary, considerable extra allowance of pressure must be made.



Where air is blown from a pipe into a large chamber, or where a fan is used to exhaust air from a room and discharge it into the atmosphere, the discharge should preferably be made through a flaring cone in order not to lose the velocity head.

Suppose a fan used to exhaust from a room into the atmosphere discharges air at the rate of 3,000 feet per minute, a velocity head of 0.56 inch is lost; but if the discharge should be made through a flaring cone of sufficient length, and having an area at the discharge end of four times the area of the fan outlet, the velocity will be reduced to 750 feet per minute, and the loss of head about 1/16 of what it was before, providing the cone operates with an efficiency of conversion of 100%; but even assuming this to be as low as 80%, the gain is three-quarters of the velocity head recovered, equivalent to 0.42 inches of water, which can be utilized



as additional vacuum on the suction side of the fan.

A test on a small fan, working as an exhauster, showed that when a flaring discharge nozzle was used, the suction effect was increased by an amount practically equal to the theoretical difference in velocity head at the discharge.

In the same way, when using a fan to discharge into a pressure pit for transformers, boilers, etc., a gradually enlarging cone will add pressure. The usual formula, as applied to water, for the loss of head due to a sudden enlargement of the pipe, such as when discharging into a larger pipe, or into a large chamber, is:—

$$\frac{(V_1 - V_2)^2}{2g}$$

In which V_1 represents the high velocity of the small pipe, and V_2 the lower velocity in the large pipe. When the difference of these velocities is very great, that is, when the velocity in the large pipe is very small, this loss becomes large, and if the pipe discharges into a large chamber, so that the velocity V_2 is negligible, the entire velocity head is lost.

The complete formula for the increase of pressure, under those conditions, is:—

$$P_2 - P_1 = \frac{V_1^2 - V_2^2 - (V_1 - V_2)^2}{2g}$$

Where V_2 is nearly as large as V_1, the square of their difference is small, but where V_2 practically equals zero, the pressure in the large chamber is no greater than the static pressure in the pipe supplying the water.

I have not been able to actually test this formula as applied to air, but I believe that the law applies in general and it shows the great importance of making the change of pipe gradual rather than sudden.

When air is discharged from one chamber into another through an orifice in a thin wall, the stream of air does not fill the aperture, following the well known law of the vena contracta; and the quantity of air passing through such an opening is only about 60% of that obtained by multiplying the total area by the velocity. If the air passes through a short discharge pipe with well rounded approach, the pipe is filled with the stream, and the loss due to contraction and friction is very small.

For ship work, the distributing pipe, at the beginning, is of the same size as the outlet of the fan; and the specifications require a static pressure of approximately 5 pounds per square foot, and there is about 1½ pounds per square foot due to the velocity head; while for the forced draft fans for the fire-rooms, for pits for transformers, and for other purposes where the air is delivered into large chambers, nearly the full pressure of the fans may be utilized as static pressure, when proper discharge chutes are used.

(To be continued.)

KENDALL GOLD MINING FLYWHEEL MOTOR-GENERATOR SET

By H. H. Clark

The following is a brief description of a unique and interesting electrical hoisting equipment recently built by the General Electric Co., for the Kendall Gold Mining Co., of Kendall, Mont. The requirements which this outfit had to meet were similar to those encountered in most mine hoist installations.

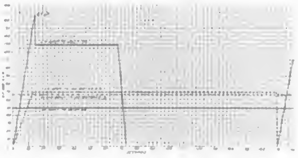


Fig. 1. Horse Power Input. Unbalanced Operation

This hoisting equipment was designed to raise 2000 lbs. of ore from a 1000 foot level every 103 seconds when operating two drums, and every 170 seconds when a single drum only was in operation.

The mine shaft has two compartments, and extends vertically to a depth of 1000 feet. Two cylindrical drums are used, which are provided with the usual clutches for individual and combined running, each drum operating a compartment in which the weight of the rope is always balanced by an individual tail rope, whether the other compartment is working or not. This rope is 1 inch in diameter, and weighs 1.6 pounds per foot, the hoisting speed being 1000 feet per minute. Each compartment is supplied with one skip weighing 1400 pounds, and having a capacity of 2000 pounds of ore.

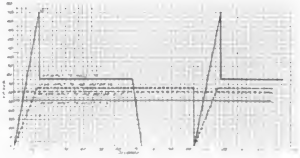


Fig. 2. Horse Power Input. Balanced Operation

Fig. 3. Flywheel Motor-Generator Set for Mine Hoist

Figures 1 and 2 show the theoretical curves of horse power input to the hoist, both when running one compartment, (unbalanced operation), and two compartments, (balanced operation). From these curves the unusual demand which occurs during the period of acceleration is made very apparent.

The capacity of the generating station being somewhat limited, the large rush of current incident to starting and accelerating the hoist tends to produce undesirable voltage fluctuations in the system, and the equipment here described was designed to eliminate this trouble and improve the regulation of the line.

To this end an outfit was supplied which permits of the most perfect speed control, allowing the load to be accelerated as rapidly or as gradually as desired. The equipment was also supplied with a means of equalizing the demand upon the power system, so that instead of being intermittent in character it is practically constant.

The system of control has the further great advantage of electrically braking the load in a manner which not only gives complete control over the retardation of the moving parts of the hoist, but also returns a considerable portion of their kinetic energy to the flywheel.

The hoist equipment comprises a shunt wound direct current motor, arranged to be geared to the hoisting drums, the motor receiving its power from a motor generator set driven from the main power system. This set, as is very clearly shown in Figures 3 and 4, consists of an induction motor, and a direct current generator, with a flywheel swung between them, and a direct current exciter overhung at one end of the set. The function of this latter machine is to excite the field of the generator and that of the direct current hoist motor. The speed and direction of rotation of the latter machine is controlled by varying the field strength of the direct current generator by means of a rheostatic controller, which is conveniently located for the hoist operator.

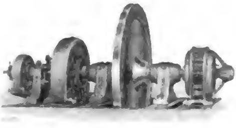


Fig. 4. Flywheel Motor-Generator Set

In this set the induction motor is a three phase, sixty cycle, form M variable speed machine, while the direct current generator is provided with commutating poles, and is designed for operating with a very weak field at all loads.

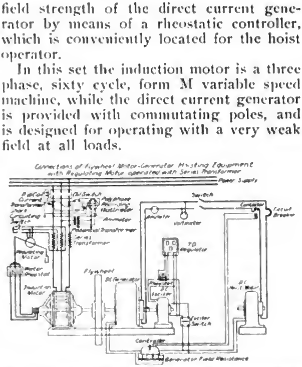


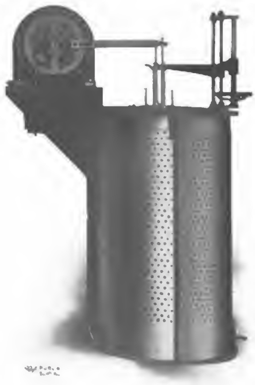
Fig. 5. Diagram of Connections of Flywheel Motor-Generator Hoisting Equipment

Figure 5 shows the diagram of connections of the complete equipment.

The flywheel is a steel casting, machined all over and perfectly balanced; it weighs about 12000 pounds and operates at a peripheral speed of about 18,000 feet per minute. The wheel is used to store energy when the hoist is not in operation, and is called upon to give up this energy when the demand on the line is at a maximum.

In order to obtain this effect on the part of the flywheel of alternately storing and surrendering energy, the induction motor is arranged for variable speed operation; changes in speed being automatically controlled by the variation of the main line current, which is led through a small three phase regulating motor operating a water rheostat in series with the secondary winding of the motor.

The torque which is produced by the full load value of the main line current in the windings of the regulating motor is exactly balanced by the weight of the moving parts of the water rheostat, so that there is no change in the resistance that is in series with the rotor winding of the motor generator set so long as the motor is taking full load current. If, however, it should demand more or less, there is an immediate movement of the water rheostat, tend-



Automatic Slip Regulator

ing to accelerate or retard the speed of the motor generator set to such a point

The voltage of the exciter is maintained at a constant value during the speed variation of the motor generator set by means of a Tirrill Regulator.

Referring once more to Figures 1 and 2, attention is called to the curve which shows the kilovolt-ampere input to the induction motor when a flywheel generator set is used. In these curves the undesirable starting peak has entirely disappeared; it was to secure this result that this equipment was designed.

Figure 7 shows the curves of current input to the hoist motor and induction motor that were obtained from actual test, carried on at the works of the General Electric Co. under conditions of load approximating, as nearly as possible, those which the set would be required to meet after installation at the mine. This figure shows very clearly indeed, how well the automatic devices perform the duty required of them, keeping the demand on the line practically constant, while the hoisting motor was called upon for several times its full load capacity.

This equipment has now been installed for several months, and is operating to the complete satisfaction of the purchasers, as evidenced by letters received from their engineers commenting upon the behavior of the outfit, from one of which we quote as follows:—

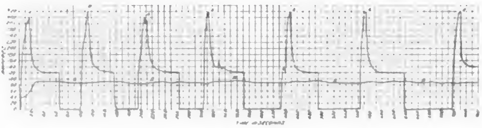


Fig. 7. Curve A, Current Input of Hoist Motor; Curve B, Current Input of Induction Motor of Motor-Generator Set

that the induction motor once more takes full load, and the movement of the water rheostat is stopped.

Figure 6 gives a very good idea of the regulating motor and the water rheostat which it operates.

"We are pleased to inform you that we now have our new hoisting equipment operating in tip top condition, and will be glad to have you and your friends make us a visit at any time."

(Signed) Kendall Gold Mining Co.

GYROSCOPIC FORCES

PART II

By W. E. MILLER

Gyroscopic Couple

Take the case already considered with reference to the calculation of the gyroscopic centrifugal force, and consider the expression

$$\frac{V^2}{gR}\Sigma\left(w - \frac{2\,p\,x\,w\,\sin a}{r} + \frac{w\,p^2\,x^2\,\sin^2 a}{r^2}\right)$$

giving the total centrifugal force of the body. Referring to Fig. 8, consider the forces acting on the top half of the circle, and those acting on the bottom half of the circle, separately. It will be seen that the first and third terms under the summation sign are additive for both the top and bottom halves, but that the second term $\frac{V^2}{gR}\Sigma\frac{2\,p\,x\,w\,\sin a}{r}$ is negative for the top half and positive for the bottom half. These forces, in fact, form a couple PP, trying to turn the rotating disc (represented by the circle) about the line AB: the forces in the upper half acting towards the observer, and away from him in the lower half. The moment of all the forces acting on the upper half of the disc about the diameter AB is $-\frac{V^2}{gR}\Sigma\,2\,p\,y^2\,w$ where $y = x\sin a$, which equals $-\frac{V^2}{gR}\frac{W\,p\,k^2}{2r}$ the symbols having the same significance as in the previous part of the article. In a similar manner, the moment of all the forces acting on the lower half of the disc is $\frac{V^2}{gR}\frac{W\,p\,k^2}{2\,r}$ the total couple therefore acting on the disc is $PP = \frac{V^2}{gR}\frac{W\,p\,k^2}{r}$ or $\frac{V\,v\,W\,k^2}{g\,R\,r}$ which is proportional to the precessional velocity V and the spin velocity conjointly.

If the spinning body, supported as shown in the figure, is initially at rest, it will begin to fall vertically downward. Divide the disc into two halves by a vertical diameter. Consider the total centrifugal force on each half separately, caused by the vertical components of the velocities due to spin and the vertical velocity of the disc as a whole. It will then be seen from reasoning similar to that given above, that a couple results, acting about the vertical diameter, which moves the spinning disc towards the observer. If the spin had been in the opposite sense, the disc would move in the opposite direction. This couple which is of value $\frac{V_v\,v\,W\,k^2}{g\,R\,r}$ and is proportional to the vertical velocity V_v and also the spin velocity v, produces a horizontal precessional velocity whose mean value was assumed above to be initially impressed on the rotating disc.

Thus two gyroscopic couples result, acting in planes at right angles to one another. The first is brought into play by the vertical velocity due to the impressed force (gravity) and is proportional thereto. The second is produced by the horizontal velocity resulting from the first, being proportional to that velocity and acting in opposition to the impressed force (gravity).

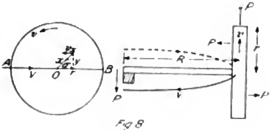


Fig 8

Since the two gyroscopic couples always act in planes at right angles to the plane in which the motions of the spinning particles of the disc lie, they can have no effect on the amount of spin, which is therefore constant.

The above argument suggests a rule for discovering the direction in which the gyroscopic couple acts when the spinning body is rotated in a given direction. Think of the body as divided into two halves by a plane through the axis of rotation and parallel to the body's motion. If the velocities of the spinning particles in one-half of the body, resolved in the direction of the rotation, are in the same sense as the rotation of the body as a whole, the force of the couple will act outwards in that half (with centrifugal force) and inwards in the other half (in opposition to centrifugal force). Though this method may seem complicated from the statement above, which is necessarily somewhat general, it will probably be found simpler in a specific case than the rule given in the first part of this article. It is also easily remembered, being only based on the familiar idea of centrifugal force.

If $p = l$, that is, if the peripheral velocity of the disc and the precessional velocity are equal, the expression obtained for the moment of the gyroscopic couple becomes:— $\frac{V^2 W k^2}{g R r}$

If B is the moment of inertia of the disc about its axis, Ω the angular velocity of precession, and n the angular velocity of spin, it will be readily seen from the above formula that this couple equals $B\,n\,\Omega$.

The gyroscopic couple $B\,n\,\Omega$ represents a couple acting contrary to that due to the impressed force in spinning bodies, and gives the moment of the righting effect. Thus, in the case of a disc spinning at the end of a horizontal axis which is supported at one end and acted on by gravity only, we have the expression $B\,n\,\Omega$ equal to mgR when the disc's weight is balanced, from which the angular velocity of precession can be immediately calculated as $\Omega = \frac{m g R}{B n}$. More generally $\Omega = \frac{m f R}{B n}$ where $m f$ is the force of the gyroscopic couple acting in opposition to the forces impressed.

Vertical Gyroscopic Forces

In the case of a car or locomotive running around a curve, the gyroscopic couple (due to the wheels) tries to turn the car over about the outside rail, and therefore produces a vertical thrust on the outside rail equal to $\frac{V^2 W k^2}{g R x r}$ where x is the gauge of the track.

There is also an additional gyroscopic vertical force acting which can be directly derived from the third term of the expression given for the total centrifugal force. Taking the moment of this force, which acts through the mass center of the rotating parts, about the rail, we directly obtain the expression $\frac{V^2 W k^2}{2 g R r}$. The moment of this force can be regarded as a couple QQ when the reaction of the wheel tread on the rail is considered. In order to obtain the vertical force on the rail due to the above, consider the couple turned through a right angle and acting with the track gauge as its arm; then dividing the moment of the couple by the width of the gauge, x we obtain the expression $\frac{V^2 W k^2}{2 g R r x}$ which represents in the case of the wheels, an upward force over the inside rail, and a downward force on the outside rail. The total vertical downward force on the outside rail, due to gyroscopic action, will

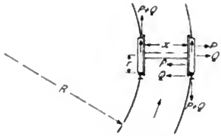


Fig 9

therefore be $\frac{3}{2}\;\frac{W}{g}\;\frac{V^2 k^2}{R r x}$

Path of the Mass Center of Spinning Body Supported at One End

Consider a circle rolling with uniform speed on a straight line. Let the angle through which a point on its circumference has turned in time t be represented by pt, this point will trace out a cycloid whose equations can be represented by $x = \frac{n}{2}(pt - \sin pt)$ and $y = \frac{n}{2}(1 - \cos pt)$

Where n is the diameter of the rolling circle.

The vertical and horizontal velocities and accelerations of the tracing point of the circle revolving uniformly will be represented by $\frac{dy}{dt}, \frac{dx}{dt}, \frac{d^2y}{dt^2}, \frac{d^2x}{dt^2}$ respectively.

In the case of the cycloid given by the above equations:—

Vertical velocity, $\frac{dy}{dt} = \frac{n}{2} p \sin pt$ (1)

Horizontal velocity, $\frac{dx}{dt} = \frac{pn}{2} (1 - \cos pt)$ (2)

Vertical acceleration, $\frac{d^2y}{dt^2} = \frac{np^2 \cos pt}{2}$ (3)

Horizontal acceleration, $\frac{d^2x}{dt^2} = \frac{np^2}{2} \sin pt$ (4)

Therefore the vertical velocity $\frac{dy}{dt} = \frac{1}{p} \frac{d^2x}{dt^2}$ (5)

and the vertical acceleration $\frac{d^2y}{dt^2} = p\left(\frac{pn}{2} - \frac{dx}{dt}\right)$ (6)

The two last equations show that the vertical velocity of the tracing point of the curve is directly proportional to the horizontal acceleration, and also that the vertical acceleration is equal to a constant minus a quantity proportional to the horizontal velocity.

The formula $\frac{B\ n\ \Omega}{R} = m\ f$ already obtained, shows that a force m f is produced when a spinning body precesses with angular velocity Ω which is proportional to that angular velocity. This force has also been shown to act at right angles to this velocity. The total vertical force acting on the body will therefore be at any moment the gravitational force minus a force proportional to the horizontal angular velocity. As the only horizontal force acting is that due to the vertical angular velocity, the horizontal acceleration is proportional to the vertical velocity, and depends upon it only. This is what the cycloid equations state, and they will therefore completely represent the position and motions at any instant of the mass center of the spinning body when the constants of the equations of the cycloid are properly determined. In other words, the body moves in a cycloidal path.

In order to determine the constants n and p it must be noted that, initially, the spinning body is at rest, and therefore commences to fall vertically, under the influence of gravitational acceleration only. Thus, from (3) we have $\frac{d^2y}{dt^2} = \frac{m\ R\ g}{A} = \frac{np^2}{2}$.

A being the moment of inertia of the spinning body about an axis through the point of support at right angles to the spinning axis, R the distance of the mass center of the body from the point of support, m the mass of the body, g the gravitational acceleration, and y the verticle angle through which the body falls. Now obviously, gravity is balanced when $\frac{d^2y}{dt^2} = 0$, and since at that instant the horizontal angular velocity $\frac{dx}{dt}$ is $\frac{mg\ R}{B\ n}$ we have from (6) $\frac{pn}{2} = \frac{mg\ R}{B\ n}$ but $\frac{mg\ R}{A} = \frac{np^2}{2}$, from which we have:—$n = \frac{2A\ m\ R\ g}{B^2\ n^2}$, and $p = \frac{Bn}{A}$

The equations of motion, and those defining the position of the body at any instant, can then be written as follows:— where $\theta = y$ is the vertical angle of fall, and $x = \Psi$ is the angle through which the axis moves horizontally.

$$\theta = \frac{A\ m\ R\ g}{B^2 n^2}\left(1 - \cos \frac{Bn}{A} t\right)$$

$$\Psi = \frac{A\ m\ R\ g}{B^2\ n^2}\left(\frac{Bn}{A} t - \sin \frac{Bn}{A} t\right)$$

$$\frac{d\theta}{dt} = \frac{m\ R\ g}{B\ n} \sin \frac{Bn}{A} t$$

$$\frac{d\ \Psi}{dt} = \frac{m\ R\ g}{B\ n}\left(1 - \cos \frac{Bn}{A} t\right)$$

$$\frac{d^2\theta}{dt^2} = \frac{m\ R\ g}{A} \cos \frac{Bn}{A} t$$

$$\frac{d^2\Psi}{dt^2} = \frac{m\ R\ g}{A} \sin \frac{Bn}{A} t$$

The maximum angular fall, or angle of nutation, is therefore:— $\frac{2m\ A\ R\ g}{B^2 n^2}$ the angular span of the cycloid is equal to:— $\frac{2\pi\ m\ A\ R\ g}{B^2 n^2}$ the mean precessional angular velocity which balances gravity is:— $\frac{m\ R\ g}{B\ n}$ and the period of a complete nutation:— $T = \frac{2\pi\ A}{B\ n}$

The actual velocity of the body at any instant is $\frac{m\,R\,g}{B\,n}\sqrt{2\left(1-\cos\frac{Bn}{A}t\right)}$ from which it follows that the mean centrifugal force equals $\frac{2\,W\,V^2}{R\,g}\left(1+\frac{p^2\,k^2}{2\,r^2}\right)$ or twice that found for a body precessing without nutation. The maximum centrifugal force will be double this again.

In the case considered, the axis of spin makes an angle of 90° with the vertical. If the axis had been inclined at an angle a to the vertical, the equations could have been obtained from considering the equations of a cycloid, the diameter of whose generating circle was u sin a. It would then be found that θ the angle of fall, must be reduced in the ratio $\frac{1}{\sin a}$; but that the horizontal angle was the same as before, though of course the length of the horizontal span of the cycloid would be sin a times the angular value.

Since the moment of the couple $B\,n\,\Omega$ balances the moment of the gravitational couple $m\,g\,R$; nutation would not occur, if the angular velocity $\Omega=\frac{m\,g\,R}{B\,n}$ were initially impressed on the rotating mass.

If precession is prevented, the axis would fall as if the body were not spinning, but a couple will act trying to make the body precess equal to $\frac{B\,n\,d\theta}{dt}$ where $\frac{d\theta}{dt}$ is the vertical angular velocity.

The above reasoning is only true if the spin is rapid, or which is the same thing, if the vertical angle of the body's fall is small, so that the gravitational acceleration can be regarded as constant throughout the motion. This, however, is generally true of gyroscopes. To make the matter quite clear, a short summary of the above is given below.

The mass center of a body, supported at one end and spinning sufficiently rapidly, moves in a cycloidally corrugated circular path, that is, nutation occurs. The downward and upward movements of the spinning axis are zero twice in each complete period of nutation, and the precessional rotation is a maximum when the axis is at the lowest point, and zero at the highest point, the axis being at this instant momentarily at rest. The precessional and nutational velocities are the velocities due to gravity which would be acquired by the body without spin if its mass center slid along the path actually traced out by it.

If the plane of the cycloid Fig. 10 be wrapped round a cylinder whose axis passes through the point at which the body is supported, the curve so found gives the motion of the body's mass center. At the points A and A', the axis is at rest, and will therefore be momentarily vertically accelerated downwards, due to gravity only. At the points B and B', the angular horizontal and vertical velocities of the axis are the same, the horizontal angular velocity being the mean rate of precession which produces an upward force balancing grav-

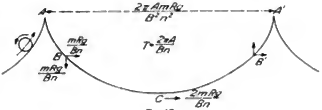


Fig 10

ity. This velocity is equal to the uniform velocity of the center of the generating circle, and is acquired when the axis has fallen through half its total vertical distance, the time taken being ¼ of the whole period of the complete nutation and the direction of motion making an angle of 45 degrees with the line AA'. At the point C, the axis has reached its lowest position, and is moving horizontally with a maximum angular velocity which is double the angular velocity at B and B'. The upward force at this point will therefore be double that due to gravity and therefore sufficient to carry the body again to its original level. The angular velocities, the period of a complete nutation, and the span of the cycloid, are marked on the diagram; the various symbols having the same significance as before.

The following example has been worked out in order to see what quantitative results are obtained in a definite case. The example chosen will be clear from Fig. 11.

A steel disc 1 inch thick and 3 inches in diameter is supported at one end of its horizontal axis at a point 3 inches from its mass center. The disc revolves at 100 revolutions per second. The weight of the disc is 2 pounds.

From the dimensions of the disc, etc., its radius of gyration about its axis is 1.06 inches and 3 inches about an axis through the point of support.

From the above data we have the following:—

The mean precessional angular velocity = 1.64 radians per second.

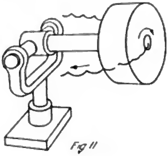


Fig 11

One complete revolution is completed in 3.8 seconds.

The maximum horizontal velocity of the end of the axis = 1 foot per second, nearly.

The maximum vertical angular fall—2½°.

The maximum vertical descent of the end of the axis = 5/32 inch, nearly.

The period taken for one complete nutation = .086 seconds.

The nutational frequency = 11.6 per second.

The number of nutations in one complete precession = 44.

Mean centrifugal force = 772 pounds.

From the above it will be seen that the axis rises and falls through a small angle, that the angular velocity of precession is also small, the frequency of nutation is high, and the maximum gyroscopic centrifugal force extremely large — much greater than that due to the precessional velocity of the mass without spin.

Electric Locomotive Rounding a Curve

The side thrust on the rails, caused by the centrifugal forces due to spin of the rotating parts of a locomotive or car travelling round a curved track, is an interesting example of the effect of gyroscopic action which has recently received some attention. The necessary data for calculating this force has been obtained from one of the General Electric Company's locomotives.

The following are the approximate values of the constants required:—

Total weight of locomotive, 189,000 pounds; total weight of the rotating parts on the driving axles, 46,400 pounds; on other axles, 10,000 pounds; the radius of the driving wheels, 22 inches, and of the other wheels, 17¾ inches; the radius of gyration for the motors and driving wheels with respect to the axle, 12.3 inches, this radius being 12 inches for the other axles and wheels. In order to see what the forces amount to in a special case, let us assume that the locomotive is moving round a curve of 2,000 feet radius at a speed of 100 feet per second (about 68 miles per hour).

Using the formula already obtained, $\frac{W}{g} \frac{V^2}{R} \frac{k^2}{2r^2}$ —where W is the weight of the revolving parts, k their radii of gyration, V the velocity of the car round the curve, R the radius of the curve, and r the radius of the wheels—and substituting the values given above for the electric locomotive, it is found, neglecting the super elevation of the outside rail, that there is a total outward force on the rails of 1130 pounds, due to the rotation of the driving wheels and motors, and a force of 355 pounds due to the other wheels and axles, giving a total outward thrust on the rails of 1485 pounds. The centrifugal force produced by the locomotive taken as a whole, without considering the gyroscopic centrifugal force caused by the rotating parts, is 29300 pounds. The additional force, therefore, occasioned by the gyroscopic effect of the motors and wheels, is almost exactly 5 per cent of the centrifugal force calculated by the usual formula. As both these forces vary as the square of the speed round the curve, this percentage is a constant, and is independent of the speed.

As already mentioned, if the motors had been geared, the gyroscopic centrifugal force due to them would have acted in opposition to the main centrifugal force and that produced by the rotation of the wheels.

Besides the outward centrifugal forces, there will be an additional vertical pressure exerted on the outside rail, which can be readily calculated from the formula already obtained, viz.: $\frac{3}{2} \frac{W}{g} \frac{V^2}{R} \frac{k^2}{rx}$ where x is the track gauge. Using the constants already given, it will be found that the total vertical pressure on the outside rail, owing to the gyroscopic action of the rotating parts and driving wheels, is 1320 pounds, and that due to the other wheels is 350 pounds, or a total of 1670 pounds.

Trolley Car Running Over High Rail

If a car running on a straight track, encounters an obstruction or a high rail on one side which raises one wheel, the front wheels and axle will try and twist round. It is therefore of interest to approximately calculate how much turning torque is produced in a specific case.

If the car's front left hand wheel (looking in the direction of motion) meets the obstruction, the axle of the front pair of wheels will try and twist to the right, but as the motor armature revolves in the opposite direction, it will try and twist the axle to the left. The resultant torque will therefore be to the right or to the left, depending on which of the two revolving factors is of greater importance.

Let V be the velocity of the car; a the height of the obstruction; r the wheel radius; x the gauge of the track; d the distance between the bearing centers of the motor on the axle; K_a and K_w the radii of gyration of the armature and wheels, axle and gear, respectively; n_a and n_w the angular velocities of the armature and wheels, respectively; and Ω the maximum angular velocity about one rail, due to the lifting of the wheel when it passes over the obstruction. This quantity is the same for both armature and wheels and axle, and equals $\frac{\sqrt{2ar-a^2}}{r} \frac{V}{x}$. Let W_a and W_w be the weights of the armature, and wheels and axle, respectively.

The formula $B\, n\, \Omega$, giving the moment of the twisting couple can be readily transformed to $\frac{W_w}{g} K_w^2 n_w \frac{\sqrt{2ar-a^2}}{r} \frac{V}{x}$ for the wheels, axle and gear, and to $\frac{W_a}{g} K_a^2 n_a \frac{\sqrt{2ar-a^2}}{r} \frac{V}{x}$ for the armature and pinion. The total torque (maximum) will be:—

$$\frac{\sqrt{2ar-a^2}}{r} \frac{V}{x} \left(\frac{W_w K_w^2 n_w}{g} - \frac{W_a K_a^2 n_a}{g} \right)$$

which if positive, means that the front wheels and axle will twist to the right, and if negative, to the left.

The above formulæ only refer to the maximum value of the gyroscopic couple, which occurs at the moment when the front wheel first strikes the obstruction. This value of the couple, therefore, only obtains momentarily, and a truer estimate of the forces involved will be made by taking the time integral of the couple. The time integral will be found to be directly proportional to the height of the obstruction a, if the horizontal velocity of the wheel is assumed constant throughout the motion. The total time taken is $\frac{\sqrt{2ar-a^2}}{V}$ and therefore the average couple will be proportional to $\frac{aV}{\sqrt{2ar-a^2}}$, which is practically equal to one-half the initial or maximum value if a is small compared to r.

Thus the various maxima of the couples and forces calculated below must be divided by 2 to give the average value, which can be considered to last through the whole period of action, equal to 0.0066 seconds.

In the case of a single truck car running 50 feet per second (34 miles per hour) along a straight track, and meeting an obstruction ½ inch high, the wheels being 33 inches in diameter, Ω (maximum) will be 2.5 radians per second. If the motors are GE-90, and the wheels of ordinary type, the approximate radii of gyration will be 4.6 inches and 11 inches, and the weights, 690 pounds and 1350 pounds, respectively. The distance d will be 28.8 inches, and the gauge 4 feet 8½ inches. If a gear ratio of 2.90 is used, the angular velocities of the wheels and axles, and motor armature are 36.5 and 106, respectively.

Then the torque (maximum) due to the wheels and axle is 3200 foot pounds, and that due to the armature 830 foot pounds. The resultant torque in this case will be to the right and equal to 2370 foot pounds. The moment of the couple acting at the motor axle bearings will be 3200 foot pounds, and therefore dividing by d, the twisting force on each bearing will be 1340 pounds, and on the axle boxes about 500 pounds. With a greater gear ratio, say 4.73, the latter force would be reduced to about 400 pounds.

Owing to the wheel gauge being slightly smaller than the track gauge, the spring suspension of the car body and the play in the axle boxes, the wheels and axles will slew slightly before the car as a whole is affected, and the edges of the wheel flanges may bear slightly against the sides of the rails.

Size of Gyroscopes

Since the moment of the couple produced by the gyroscopic action of a rotating body is proportional to its weight, square of radius of gyration and angular velocity of spin and precession conjointly, it follows that the linear dimensions of a rotating mass can be chosen so as to give any controlling force between wide limits, without exceeding the strength of the rotating element. For the same reason, it is always possible to proportion the rotating element and determine its angular velocity of spin so that sufficient gyroscopic effect is produced for controlling the motions of a body of practically any dimensions, without making the gyroscope disproportionally large or heavy or straining it beyond a safe limit.

To illustrate the amount of the balancing couple to be obtained from a spinning body, let us take the case of the gyroscope which was actually fitted in the torpedo boat, Seebar: This vessel has a displacement of 52 tons, is 116 feet long, with an 11.7 foot beam. The gyroscope was 3.25 feet in diameter, ran at 1600 r.p.m., and weighed 1100 pounds. The radius of gyration can be taken as 1.25 feet approximately. Then assuming the precessional angular velocity allowed was 1 radian per second, the moment of the gyroscopic couple $= \frac{1100 \times 1.25^2 \times 2\pi \times 1600 \times 1}{32.2 \times 60}$ $= 8900$ foot pounds, which is almost exactly 4 foot tons—a considerable controlling force considering the weight of the gyroscope. The gyroscope used could have been spun at double the angular speed with perfect safety, which would have doubled the moment of the force calculated above.

Steam Turbines

The consideration of the gyroscopic forces due to vertical steam turbines is of great interest, and without going deeply into the question, it would seem from theoretical considerations that the gyroscopic effects could be neglected in all cases which occur in practice. Any slight unbalancing which will obtain in the revolving element tending to bend the shaft is so small as to produce only negligible displacement of the shaft mass center and will not be sufficient to produce a gyroscopic couple of any magnitude. Such forces as are called into play will tend to keep the plane of the rotating wheel horizontal, and thus prevent any rubbing against the intermediates. Were sufficient data available for basing conclusions as to the probable values of the above, and the necessary constants were determined, the calculation of the gyroscopic forces could be made. As, however, the various causes are to a certain degree interdependent, the true resultant action might be difficult to determine.

The gyroscopic problem for turbines in steamships is on an entirely different footing, as the impressed forces are large, due to rolling, pitching, or steering of the vessel; and the base, size of shaft, bearings, etc., must therefore be designed with sufficient strength to take care of the increased stresses. If a horizontal type of turbine be placed with its axis approximately in coincidence with the axis of the rolling of the vessel, that is to say longitudinally, it will exert no force due to heeling. When the steamer pitches, the gyroscopic forces will tend to turn the bow of the vessel to port or starboard; this turning, however, is negligible, owing to the great length of large screw steamers, and therefore pitching will not be affected. If the turbine were of the vertical type, so that its rotating element revolved in a horizontal plane, its action due to rolling of the boat would tend to make the vessel pitch slightly. If the pitching were entirely prevented, due to the length of the vessel, the turbine would have no effect on the rolling, but would try and turn over fore and aft, producing increased stresses on the shaft, casing, base of the turbine, and the scantling of the boat. If pitching occurred, the turbine would make the steamer roll slightly, which motion would tend to reduce the pitching. This type of turbine would have no gyroscopic effect on the steering.

Paddle Wheel Steamers

In paddle steamers it has been found that the paddles exercise some influence on the steering of the vessel when rolling. If the rudder is moved so as to turn the bow towards the starboard side, the vessel will heel over somewhat to port, and in so doing will tend to neutralize the turning due to the steering. On the other hand, if the waves cause the vessel to roll toward the starboard, the gyroscopic effect of the paddle wheels will slightly turn the bow of the vessel round towards the starboard side, from which results a couple tending to prevent the rolling of the vessel. This is one of the reasons why paddle boats roll less than screw steamers. Another effect is when the steamer heels to starboard and the starboard wheel therefore dips further into the water, the vessel turns to starboard and not to port, whereas the increased depth of the starboard paddle wheels in the water tries to turn the vessel to port. Thus the gyroscopic effect of the paddle wheels in this case tends to counterbalance the force exerted by them on the water and helps the steamship to keep a straight course in stormy weather.

Conclusion

In conclusion it should be mentioned that, owing to the interest aroused by Herr Schlick's adaptation of the gyroscopic principle to prevent the rolling of vessels, and also Mr. Brennan's recent inventions in connection with a self-supporting monorail car, a considerable amount of literature has recently appeared in various technical and other papers relating to gyroscopes. Any one therefore who is interested in obtaining further information on these phases of the question can do so by referring to these articles.

POTENTIAL CONTROL OF ALTERNATING CURRENT SYSTEMS BY SYNCHRONOUS MOTORS WITH TIRRILL REGULATORS*

By Ernst J. Berg

To obtain independent potential control of different feeders in a distribution system, some kind of regulator must be used. Frequently such control is obtained by the use of a transformer provided with a number of taps which are connected to a dial switch. The potential is then varied, either automatically or by hand, by connecting the lines to different sections of the transformer. Another and more satisfactory way is that of using a synchronous motor in connection with a Tirrill regulator. This arrangement operates to maintain constant potential in the receiving circuit by virtue of the following well known characteristics of the synchronous motor.

For any given load on a synchronous motor the armature current is at a minimum for a certain critical value of the field excitation. At this point the motor constitutes a load of unity power factor, the current taken by the motor being neither lagging nor leading. For weaker field excitations the current taken by the motor is lagging, and for stronger field excitations the current taken is leading. Therefore controlling the excitation of the synchronous motor is a means of varying the power factor of the local receiving circuit of which the synchronous motor forms a part.

General Discussion

Before attempting to explain the rather complex electrical phenomena involved in this method of control, it may be desirable to recapitulate some of the fundamental principles involved in any electric power transmission proposition.

The general equation giving the relation between EMF's, currents and line constants is:

(1) $E = e + IZ$

where

E = voltage per phase at generator
e = voltage per phase at receiving circuit
I = total current in each line conductor

*Reprinted with alterations from July, 1906 Review.

$= i + ji_1 - ji_2$

j, i, i_1, and i_2 being respectively $\sqrt{-1}$, energy current, and wattless currents: i_1 being lagging when positive and i_2 being leading when positive.

Z = impedance per phase = $r - jx$
r and x being respectively the resistance per phase and the reactance per phase, including, of course, transformers and reactive coils as well as line. Assume that the generator voltage is very constant, and the

ratio $\frac{E}{e} = k$

substituting for I and Z in (1):

$$E = e + (i + ji_1 - ji_2)\ (r - jx)$$
$$= e + ir + i_1 x - i_2 x - j\,(ix - i_1 r + i_2 r)$$

Inasmuch as the imaginary term in this expression is small compared with the real term we may neglect it and write

$$(2) \qquad E = e + ir + i_1 x - i_2 x$$

$$\text{and } i_2 = \frac{e\,(1-k) + ir + i_1 x}{x}$$

The voltage of the generating station is most conveniently kept constant at all loads. The function of the synchronous motor, connected at each receiving center with the regulator for controlling the field excitation, is to maintain the receiving circuit at constant voltage the value of which will be determined by the calculations. Since $k = \frac{E}{e}$ in any particular branch system, the problem is to keep this ratio constant at all loads. It results from this condition that at light load or no load on the receiving circuit a lagging current has to be taken by the synchronous motor to establish an artificial drop, when otherwise there should be none, and at full load a leading current should be taken to help to overcome the drop due to the load proper.

Substituting $k = \frac{E}{e}$, and the full load values $i = C$, $i_1 = C_1$ and $i_2 = C_2$ in (2), and solving for C_2:

$$(3) \qquad C_2 = \frac{e\,(1-k) + Cr + C_1 x}{x} \text{ and}$$

$$(4) \qquad k = \frac{e + Cr + C_1 x - C_2 x}{e}$$

These questions thus give a means of determining the amount of wattless current C_2 necessary to maintain the ratio k between generator voltage and receiving voltage, over a transmission of constants r and x, at full load on the receiving circuit proper, that is with a load of C amperes energy current and C_1 amperes lagging current.

To use the synchronous motor to best advantage it should give full leading current at full load, and full lagging current at no load, on the receiving circuit proper. Thus, at no load, substituting $C = 0$, $C_1 = 0$, and $C_2 = -C_2$ for lagging current, in (4), we get

$$k = \frac{e + C_2 x}{e}$$

Substituting this value of k in (3) and solving for C_2:

$$(5) \qquad C_2 = \frac{Cr + C_1 x}{2x}$$

Again, substituting this value of C_2 in (4):

$$(6) \qquad k = 1 + \frac{Cr + C_1 x}{2e}$$

Since C_2 is the leading or lagging current taken by the synchronous motor, these two equations (5) and (6) give us the rating of the synchronous motor and the ratio of voltages at all loads between generator and receiving end of line.

To find the synchronous motor current for any fractional load of the receiving system proper, substitute the value k, as obtained in (6), in (2), and solve for i_2, obtaining:

$$(7) \qquad i_2 = \frac{ir + i_1 x}{x} - \frac{Cr + C_1 x}{2ex}$$

which is therefore a general equation giving the synchronous motor currents for any loads i and i^1, in the receiving circuit when C and C_1 represent the full load values.

At half load (7) becomes

$$i_2 = 0$$

that is, the synchronous motor runs without wattless current. At less than half load i_2 is negative, that is lagging, and at more than half load i_2 is positive, that is leading.

The total line current is $I = i + ji_1 - ji_2$

or $\qquad I = i + j\ (i_1 - i_2)$

or $\qquad I = \sqrt{i^2 + (i_1 - i_2)^2}$

the line loss is therefore $[i^2 + (i_1 - i_2)^2]r$

and the per cent line loss of the loss if no compensation were used is

$$(8)\qquad 100\,\frac{i^2+(i_1-i_2)^2}{i^2+i_1^2} = 100\left(1-\frac{2i_1-i_2^2}{i^2+i_1^2}\right)$$

There is obviously no reduction in line loss if $i_2 = 2i_1$, but there is gain if $i_2 < 2i_1$. It is also obvious, from (7), that the greater the reactance (x) the smaller is the synchronous motor current (i_2).

As a rule the line and transformer reactance is not sufficient to enable the most economical synchronous motor to be used, but additional reactance has to be installed. There is, however, a practical limit to the amount of reactance that can be used, but it is safe to say that unless the line and transformer reactance amounts to 15 per cent, reactive coils should be installed so as to bring the total reactance to between 15 and 20 per cent.

Application of Tirrill Regulator

This regulator to work satisfactorily should not be called upon to take care of a range of field excitation of more than 100 per cent. Therefore, to utilize the synchronous motor to its full capacity it should have such characteristics that with a change of field excitation of 100 per cent the current changes from full load lagging to full leading. Such synchronous motor must have a close regulation—i. e., should give at least three times full load current when short circuited with normal field.

Motors which have a short circuiting current of from 1.6 to 2 times full load current are therefore not suited for control, except at a reduced rating. These motors, with 100 per cent variation of field excitation, can only be used as compensators to 53 per cent and 67 per cent of their rated outputs, respectively.

It is often desirable to make use of the compensating synchronous motor for power purposes, especially since the synchronous motor lends itself to this double function with very slight increase of heating.

The theoretical relation between mechanical output and output as compensator is as sine to cosine, as given in the following table, or vice versa:

PER CENT OF RATING ENERGY OUTPUT.	PER CENT RATING FOR PHASE CONTROL.
100	0
95	31
90	43
80	59
71	71
50	87

As an illustration, assuming that the calculations indicated a synchronous motor, as compensator, of 310 kw. capacity, and that a synchronous motor of 1000 kw., running at a maximum load of 950 kw., was already installed, the use of the motor for both phase control and power purposes would result in only normal heating.

Numerical Instance

1000 kw. 60 cycle three-phase power is delivered at 10,000 volts over a line 19.2 miles long made of No. 0 B. & S. wires 18 in. apart. The power factor of the load is 89.5 per cent.

$$C = \frac{\text{watts delivered}}{\text{deliv'd voltage} \times \sqrt{3}} = \frac{1{,}000{,}000}{10{,}000\ \sqrt{3}} = 57.8$$

$$C_1 = \sqrt{\left(\frac{C}{\text{Power Factor}}\right)^2 - C^2}$$

$$= \sqrt{\left(\frac{57.8}{.895}\right)^2 - 57.8^2} = 28.9$$

The resistance and reactance are obtained from equations given in the discussion of line constants, as:

$r = 10$ ohms

$x = 11.5$ ohms.

Substituting these values in (5):

$$C_2 = \frac{Cr + C_1x}{2x} = \frac{(57.8)(10) + (28.9)(11.5)}{2\,(11.5)}$$

$= 39.5$ amp.

Substituting in (6):

$$k = 1\,\frac{Cr + C_1x}{2e} = 1.079$$

Thus since full load energy current is 57.8 amp. the synchronous motor must have a capacity equal to 68 per cent of the energy output, and the generator voltage should be kept 7.9 per cent higher than the voltage at the receiving end.

The reduction in line loss by the use of the compensating motor is obtained by substituting these values in (8), as:

$$100\left(1-\frac{2(28.9)+(39.5)-(39.5)\,(39.5)}{57.8^2+28.9^2}\right)=83.$$

i. e., 83 per cent of what it would have been if no compensation were used. Or, putting it in another way, the line copper could be decreased 17 per cent for the same loss.

Calculated Tables

The following tables facilitate determinations of the various constants involved in these problems, and refer to unit energy delivered at the receiving station. Various percentages of resistance and reactance are considered. Resistances of 5, 10 and 15 per cent mean that 5, 10 and 15 per cent of the voltage per phase at the receiving end is consumed in the transmission resistance when full load current is passing. Reactances of 10, 20 and 30 per cent mean reactances of such value that if full load current is passing the drop will be 10, 20 and 30 per cent respectively.

The tables are worked out for various power factors of the load, and give the ratio of generator voltage to voltage at the receiving end of the line. The size of the synchronous motor is given as the ratio of synchronous motor rating to energy output of load, and the relative line losses are given with and without the use of the motor.

The values in Table I are computed for a total reactance of 10 per cent, made up of line reactance proper and any other reactance in series with the line. Table II is computed for a total reactance of 20 per cent, and Table III for a reactance of 30 per cent.

The following example will serve to illustrate the use of the tables.

Assume a line of 10 ohms resistance and such reactance that with energy current flowing there is 10 per cent drop in voltage (referring to the receiving end), and 20 per cent total reactance, consisting of 10 per cent in line reactance and 10 per cent in special reactive coils. The power factor of the load is 89.5 per cent.

Referring to the table: The synchronous motor should have a capacity equal to 50 per cent of the actual load; the generator voltage should be kept 10 per cent higher than the voltage at the receiving end; and the line loss will be 10 per cent, instead of the 12.5 per cent which it would be if no compensating synchronous motor were used.

Compensation for Line Drop by Synchronous Motor

TABLE I

Per Cent Line Drop	Per Cent Power Factor	Energy Load at Receiving End	Volts at Generating End	Volts at Receiving End	Capacity of Synchronous Motor*	Per Cent Line Loss Without Compensation	Per Cent Line Loss With Compensation
Res., 5 React., 10	100	Full	1.025	1.00	25.	5.	5.3
		3/4			12.5	2.8	2.80
		1/2			0	1.25	1.25
		1/4			12.5	0.31	0.39
		0			25	0.	0.31
	89.5	Full	1.05	1.00	50.	6.25	5.
		3/4			25.	3.55	2.80
		1/2			0	1.56	1.56
		1/4			25.	0.39	0.39
		0			50.	0	1.25
	70.7	Full	1.075	1.00	75.	10.	5.3
		3/4			37.5	5.63	3.51
		1/2			0	2.5	2.5
		1/4			37.5	0.62	0.39
		0			75	0	2.8
	50	Full	1.1115	1.00	111.5	20.	6.9
		3/4			56.	11.28	5.56
		1/2			0	5.	5.
		1/4			56.	1.25	0.39
		0			111.5	0	6.2
Res., 10 React., 10	100	Full	1.05	1.00	50.	10.	12.5
		3/4			25.	5.63	6.25
		1/2			0	2.5	2.5
		1/4			25.	0.62	1.25
		0			50.	0	2.5
	89.5	Full	1.075	1.00	75.	12.5	10.6
		3/4			37.5	7.04	5.63
		1/2			0	3.125	3.13
		1/4			37.5	0.78	1.25
		0			75.	0.	5.6
	70.7	Full	1.10	1.00	100.	20.	10.
		3/4			50.	11.28	6.25
		1/2			0	5.	5.
		1/4			50.	1.25	1.25
		0			100.	0	10.
	50	Full	1.1365	1.00	136.5	40.	11.33
		3/4			68.3	22.52	9.41
		1/2			0	10.	10.
		1/4			68.3	2.5	1.25
		0			136.5	0	18.6
Res., 15 React., 10	100	Full	• 1.075	1.00	75.	15.	23.4
		3/4			37.5	8.45	10.56
		1/2			0	3.75	3.75
		1/4			37.5	0.94	3.05
		0			75.	0	8.4
	89.5	Full	1.10	1.00	100.	18.7	18.75
		3/4			50.	10.55	8.68
		1/2			0	4.68	4.68
		1/4			50.	1.17	3.05
		0			100.	0	15.
	70.7	Full	1.125	1.00	125.	30	15.9
		3/4			62.5	16.9	8.08
		1/2			0	7.5	7.5
		1/4			62.5	1.87	3.06
		0			125.	0	21.4
	50	Full	1.162	1.00	161.5	60.	16.7
		3/4			80.8	33.8	12.08
		1/2			0	15.	15.
		1/4			80.8	3.75	3.06
		0			161.5	0	39.2

Compensation for Line Drop by Synchronous Motor

TABLE II

Per Cent Line Drop	Per Cent Power Factor	Energy Load at Receiving End	Volts at Generating End	Volts at Receiving End	Capacity of Synchronous Motor*	Per Cent Line Loss Without Compensation	Per Cent Line Loss With Compensation
Res., 5 React., 20	100	Full	1.025	1.00	12.5	5.	5.08
		3/4			6.3	2.8	2.84
		1/2			0	1.25	1.25
		1/4			6.3	0.31	0.33
		0			12.5	0	0.08
	80.5	Full	1.075	1.00	37.5	6.3	5.48
		3/4			18.7	3.55	3.
		1/2			0	1.56	1.33
		1/4			18.7	0.39	0.33
		0			37.5	0	0.71
	70.7	Full	1.125	1.00	62.5	10.	5.7
		3/4			31.3	5.63	3.8
		1/2			0	2.5	2.5
		1/4			31.3	0.62	0.33
		0			62.5	0	1.85
	50	Full	1.198	1.00	99.	20.	7.7
		3/4			49.5	11.28	6.
		1/2			0	5.	5.
		1/4			49.5	1.25	0.33
		0			99.	0	4.9
Res., 10 React., 20	100	Full	1.05	1.00	25.	10.	10.6
		3/4			12.5	5.63	5.78
		1/2			0	2.5	2.5
		1/4			12.5	0.62	0.78
		0			25.	0	0.63
	80.5	Full	1.10	1.00	50.	12.5	10.
		3/4			25.	7.04	5.78
		1/2			0	13.125	3.125
		1/4			25.	0.78	0.78
		0			50.	0	2.5
	70.7	Full	1.15	1.00	75	20.	10.6
		3/4			37.5	11.28	7.04
		1/2			0	5.	5.
		1/4			37.5	1.25	0.78
		0			75.	0	7.5
	50	Full	1.223	1.00	111.5	40.	13.8
		3/4			56.	22.5	11.1
		1/2			0	10.	10.
		1/4			56.	2.5	0.78
		0			111.5	0	12.47
Res., 15 React., 20	100	Full	1.075	1.00	37.5	15.	17.1
		3/4			18.8	8.45	9.
		1/2			0	3.75	3.75
		1/4			18.8	0.94	1.47
		0			37.5	0	2.16
	80.5	Full	1.125	1.00	62.5	18.7	15.2
		3/4			31.3	10.55	8.5
		1/2			0	4.68	4.68
		1/4			31.3	1.17	1.47
		0			62.5	0	5.8
	70.7	Full	1.175	1.00	87.5	30.	15.2
		3/4			43.8	16.9	10.
		1/2			0	7.5	7.5
		1/4			43.8	1.87	1.47
		0			87.5	0	11.47
	50	Full	1.248	1.00	124.	60.	18.6
		3/4			62.	33.8	15.4
		1/2			0	15.	15.
		1/4			62.	3.75	1.47
		0			124.	0	23.1

TABLE III

Per Cent Line Drop	Per Cent Power Factor	Energy Load at Receiving End	Volts at Generating End	Volts at Receiving End	Capacity of Synchronous Motor*	Per Cent Line Loss Without Compensation	Per Cent Line Loss With Compensation
Res., 5 React., 20	100	Full	1.025	1.00	8.3	5.	5.03
		3/4			4.15	2.87	2.82
		1/2			0	1.25	1.25
		1/4			4.15	0.31	0.32
		0			8.3	0	0.04
	80.5	Full	1.10	1.00	33.3	6.25	5.14
		3/4			16.7	3.55	3.03
		1/2			0	1.56	1.56
		1/4			16.7	0.39	0.32
		0			33.3	0	0.56
	70.7	Full	1.175	1.00	58.8	10.	5.86
		3/4			29.2	5.63	3.86
		1/2			0	2.5	2.5
		1/4			29.2	0.62	0.32
		0			58.8	0	1.71
	50	Full	1.283	1.00	94.6	20.	8.07
		3/4			47.3	11.28	6.21
		1/2			0	5.	5.
		1/4			47.3	1.25	0.32
		0			94.6	0	4.46
Res., 10 React., 30	100	Full	1.05	1.00	16.66	10.	10.28
		3/4			8.3	5.63	5.7
		1/2			0	2.5	2.5
		1/4			8.3	0.62	0.69
		0			16.66	0	0.28
	80.5	Full	1.125	1.00	41.6	12.5	10.06
		3/4			20.8	7.04	5.91
		1/2			0	3.13	3.15
		1/4			20.8	0.78	0.69
		0			41.6	0	1.73
	70.7	Full	1.20	1.00	66.6	20.	11.11
		3/4			33.3	11.28	7.36
		1/2			0	5.	5.
		1/4			33.3	1.25	0.69
		0			66.6	0	0.44
	50	Full	1.300	1.00	10.3	40.	14.9
		3/4			51.5	22.50	11.73
		1/2			0	10.	10.
		1/4			51.5	2.5	0.69
		0			10.3	0	10.6
Res., 15 React., 20	100	Full	1.075	1.00	25.	15.	15.9
		3/4			12.5	8.45	8.68
		1/2			0	3.75	3.75
		1/4			12.5	0.94	1.17
		0			25.	0	0.63
	80.5	Full	1.15	1.00	50.	18.7	15.
		3/4			25.	10.55	8.68
		1/2			0.	4.68	4.68
		1/4			25.	1.17	1.17
		0			50	0	2.5
	70.7	Full	1.225	1.00	75.	30.	15.9
		3/4			37.5	16.9	12.2
		1/2			0	7.5	7.5
		1/4			37.5	1.87	1.17
		0			75.	0	5.6
	50	Full	1.335	1.00	111.7	60.	20.6
		3/4			56.	33.8	16.6
		1/2			0.	15.	15.
		1/4			56.	3.75	1.17
		0			111.7	0	12.5

*This gives synchronous motor capacity as a percentage of the energy output of the receiving circuit, assuming a synchronous motor that has a short circuit current three times as large as a normal full load current.

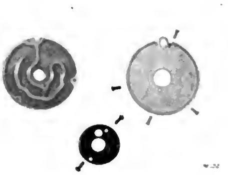
TYPE V LONG LIFE GAS CAP, FOR A. C. SERIES ARC LAMPS

By G. N. Chamberlin

A new gas cap has been designed for the open base enclosing globe type of series alternating arc lamp. This cap is of the well-known spiral groove construction, having a spiral of increased length and cross-section, as compared with the cap heretofore used.

Other conditions being similar, the rate at which carbon is consumed by the arc depends, within certain limits, upon the exclusion of air from the enclosing globe, and this is accomplished in the spiral groove cap by affording the air and gases a long path which is of low resistance as compared with the extremely high resistance path between the ground edge of the globe and the globe seat.

The constant movement of the upper carbon, regulating the arc length, together



Parts of Type V Long Life Gas Cap

with the high temperature gases confined within the globe, cause a continual variation in pressure, or a pumping effect, often sufficient to lift the cap from its seat on the globe, or if tightly held, to break the globe in many pieces.

With a low resistance path available for these otherwise constrained gases, it is obvious, that with increased pressure in the globe, the gases will follow the spiral passage; and then, as the pressure decreases, these hot gases will be drawn back into the globe, thus preventing the entrance of fresh air with its supply of carbon consuming oxygen.

This protection of the arc from the outside air can be carried to such an extent that the carbons will not be sufficiently consumed. This results in the carbon becoming graphitized on the ends (commonly known as mushrooming), the arc length shortened, and the lamp becoming inoperative.

Having in mind the higher potential at all times available on the constant current series alternating system, this improved cap was designed to give the lowest rate of carbon consumption possible without any appreciable sacrifice of stable operation and general efficiency.

For the constant potential lamps of 100 to 120 volts, either direct or alternating current, this cap is not recommended. If used, the lower rate of carbon consumption will materially affect the operation of the lamp, and more than likely make it inoperative.

The service required of an enclosing globe cap is necessarily severe. The finished surface for the globe seat must not rust when exposed to the atmospheric conditions of any section of country, and it must not oxidize or become distorted when subjected to the intense heat of the arc.

To meet these conditions, the cap proper is made of a high grade composition metal casting. The top plate is of galvanized iron, separated from the main casting by a sheet of asbestos. This asbestos forms a packing between the two, and prevents any leaking of air or gases between adjoining spirals, which would thereby shorten their effective length. Iron being less affected by the high temperature of the arc than the composition metal, it is used for the bottom of the cap, and in addition to completing the lower wall of the spiral or passage, it affords protection to the composition metal where the latter is subjected to the direct flame and intense heat of the arc.

While being an advantage to future purchasers of series alternating open base enclosing globe lamps, this cap is especially recommended to the users of about 100 000 lamps that have been furnished during the past ten years. The actual increased life which a purchaser of these caps may expect will depend largely upon the condition and style of the older caps in use. This can be determined by a trial installation. An increased carbon life of from 15 to 30 hours will be obtained.

While the cap is more expensive than those heretofore manufactured, the extra cost is fully warranted by the increased carbon life, which reduces the cost of carbons, globe breakage and general trimming expenses.

RAILWAY SIGNALS

PART III

By F. B. Corey

Automatic Block Signals—*Continued*

All block signals may be classified under two general systems or methods of operation, viz., "Normal clear" and "Normal danger".

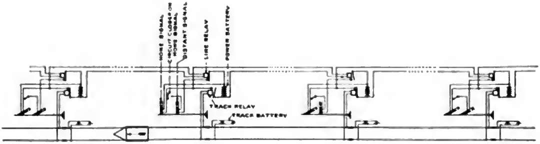


Fig. 1. Circuits for Home and Distant Signals with Line Relay

In the normal clear system all signals are maintained in the clear or proceed position, except when a train enters the block or some other dangerous condition exists, under which circumstances the signals are released and move to the stop or danger position by gravity.

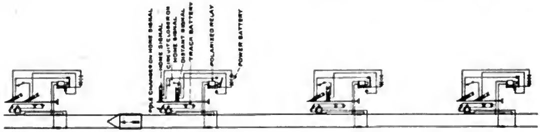


Fig. 2. Circuits for Home and Distant Signals, "Wireless System"

In the normal danger system, all signals stand in the horizontal position, indicating stop, except when cleared by an approaching train; it being so arranged that such a signal cannot be cleared if the block governed by that signal is already occupied, or if the track relay is opened by any of the various danger conditions mentioned in the preceeding chapter.

Where manually operated signals are used, the normal danger system is practically universal. Where automatic signals are employed, however, the practice of the railroads is not uniform. Those who favor the normal danger system contend that such a system involves less liability to signal failures in clear position, i. e., to false clear indications; on account of the fact that, during the greater portion of the time, the signals stand at stop position. This system has a further advantage, in that it requires less battery power for its operation than the normal clear system, on account of the fact that the magnet for holding the signal in its clear position is energized for a much less portion of the time.

The advocates of the normal clear system, on the other hand, claim that the additional complication of the normal danger system is unwarranted, and that the simplicity of the former tends to greater reliability of the signal system as a whole. It is also true that, under certain conditions, derangement of apparatus by lightning troubles can produce a more danger-

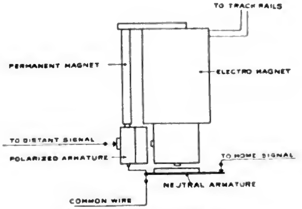


Fig. 3. Diagram of Polarized Relay

ous condition in the normal danger system than in the normal clear. The great majority of signals now being installed operate on the normal clear system, and it is doubtful if the normal danger system is preferable for any conditions, except where trains are so infrequent that corrosion is liable to take place between movements, and thus cause the signal to remain in its normal position after current is cut off. Under such conditions, however, automatic block signals are rare. In order to get a clear understanding of the circuit used in practical railroad signalling, it is best to begin with the consideration of the normal clear system.

Figure 1 is a diagram of the two-arm home and distant system as usually installed. It will be noted that the home signal is controlled directly by the track relay, while the distant signal is controlled conjointly by the line relay and by the circuit closer attached to the home signal. The line relay is controlled by the track relay of the block in advance. It may also be arranged to be controlled both by the track relay and by a circuit breaker attached to the home signal, the latter method being preferable in most cases. These line relays vary in resistance according to conditions under which they are used, the higher resistance of the operation coils being the only feature which distinguishes them from the track relays.

Figure 2 is a similar diagram showing the connections of the so-called "wireless" or polarized system, which has been installed to some extent, but only by one signal company. It will be noted that this system eliminates both line wires and line relays, the relays used being known as polarized track relays. Figure 3 shows diagramatically a relay of this type, and it will be seen that when the relay magnets are de-energized, both of the secondary circuits are open. When these magnets are energized by current flowing in one direction in the track, the home signal circuit is closed while the distant signal circuit remains open; when the energizing current is reversed both secondary circuits are closed, which position on the relay corresponds to the clear position of both signals.

In connection with polarized relays, a pole changer is attached to each home signal. This pole changer is introduced between the track battery and track rails, so that when the home signal is operated, the polarity of track circuit is changed.

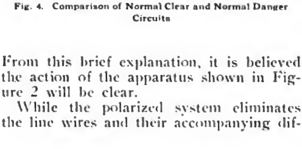


Fig. 4. Comparison of Normal Clear and Normal Danger Circuits

From this brief explanation, it is believed the action of the apparatus shown in Figure 2 will be clear.

While the polarized system eliminates the line wires and their accompanying difficulties of maintenance and lightning troubles, it introduces certain objectionable features on account of the less positive action and complication of the relays and pole changers required. It will be seen, that at the time the pole changer is thrown by the home signal, there is a m.m.f. tending to reverse the polarity of the permanent magnet; the results of such a reversal might be most disastrous.

The diagrams just mentioned refer to the two-arm home and distant signal. It is unnecessary to introduce other diagrams for the three-position signal, as the circuits are the same, with the exception, that in three-position signalling, the track relay controls the movement of the signal from the stop to the caution position, while the and, under certain track conditions, increase the liability of delaying trains from their failure to shunt promptly. Of course the arrangement of circuits for special cases differs greatly from the example given, but the principles of operation are about the same.

An interesting modification of the normal danger system is seen in Figure 5, which shows the circuits now being installed by the Baltimore & Ohio R. R. in connection with General Electric M-110 motor signals. This installation is to extend from Baltimore to Washington on the main line; a large part of this work being already completed and in service. The most novel feature of this installation is the use of electric incandescent lamps

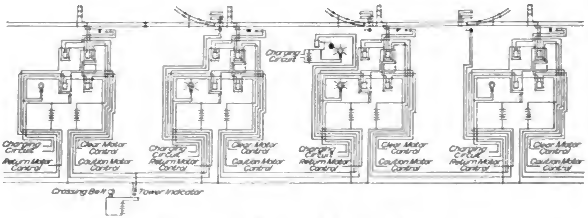


Fig. 5. Normal Danger Circuits, B. & O. R. R. Standard

line relay controls the movement from the caution to the proceed position.

One company which is the chief advocate of the normal danger system has installed a very large number of signals on this plan.

Coming now to the consideration of this system, it is not necessary to make complete diagrams to show its operation, for the difference is most clearly seen by a comparison of the elementary circuits of the two systems. Figure 4 shows two such elementary circuits, which can be easily compared. In many cases additional relays, called clearing relays, are used at the battery end of the block to avoid the use of extra line wires. These relays increase the battery consumption operated from a battery, these lamps taking the place of oil lamps heretofore used. It will be seen from a study of the diagram, that the lamps are only lighted when a train is approaching the signal. By this arrangement, and by the use of special prismatic reflectors with low candle power lamps, the battery consumption will not be excessive.

Having considered a number of different track circuits, as well as the apparatus used in connection with them, we are now in position to take up the various forms of mechanisms used to move the signal arms. A number of such mechanisms will be shown in the next part of this article.

To be Continued

RECENT ADVANCES IN ILLUMINATING ENGINEERING

By W. D'A. Ryan

Illuminating Engineering has made phenomenal progress during the past year and is now generally recognized as a distinct specialized branch of engineering.

Fig. 1. Radial Wave Reflector

Two periodicals are exclusively devoted to the subject, and the technical press in general has, for some time, given this branch of engineering great prominence in this country and abroad.

Fig. 2. Special Wing Reflector Fitted to Arc Lamp

The Illuminating Engineering Society recently formed has a membership of over one thousand, composed in part of influential representatives of industrial and scientific institutions, including Mr. Arthur Williams, ex-President of the National Electric Light Association, Mr. L. A. Ferguson, Vice-President of the Chicago Edison Company, Mr. C. L. Edgar, President of the Boston Edison Company, Professor E. L. Nichols, of Cornell University, Professor H. E. Clifford of Massachusetts Institute of Technology, and Dr. A. E. Kennelly of Harvard University.

Branches of this Society have been formed in New York, Boston, Philadelphia, Pittsburgh and Chicago, and they are being extended to Denver, San Francisco and other centres.

As further evidence of the general interest in the subject, we may note the active work along this line now being conducted in the engineering colleges through-

Fig. 3. Plain Type Diffuser for Plaster Ceilings

out the country. Furthermore, the most prominent electric lighting companies are including illuminating engineers as part of their permanent organizations and we are hardly in a position to supply the demand.

The Illuminating Engineering Society has appointed an International Committee on Standardization, and the results obtained will be far reaching.

Conservative engineers should be particularly careful at this juncture in regard to the publishing of comparisons of illuminants in order to counteract the unfortunate tendency in certain directions to take advantage of the prevailing enthusiasm on the subject and to advance false values and distorted curves for the purpose of commercializing certain lamps and reflectors irrespective of the results obtained.

The science of Illuminating Engineering must necessarily suffer a reverse if this method is pursued without further opposition. It has proceeded sufficiently far to influence people who ought to know better; for example, we note at the present time a tendency in various directions, including the technical press, to indiscriminately discredit the value of the arc in favor of incandescent and other lamps.

Lamps of the Mercury Vapor type, are photometered and candle power values are used in comparison with incandescents and arcs, when as a matter of fact the candle power of certain lamps with strong verticle distribution has been compared to the mean spherical candle power of the arc lamp, thus making a showing for the former.

Many so-called luminometers and candle-foot photometers are also being made and used to obtain illumination data, the major part of which is of questionable value.

Initial vs. Operating Candle Powers

The only logical comparison of candle powers for various illuminants, particularly for interior lighting, is the mean spherical.

Fig. 4. Boston Edison Exhibition Room by Day Light

power values have only a slight relation to the illuminating values of the various lamps compared. Likewise considerable data is being furnished on the vertical candle powers of various illuminants, which is entirely misleading. Elaborate tables for computing wall reflections are in evidence, which only serve to further prevent a clear conception of the relative usefulness of the various illuminants; and in preparing candle power data, costs of operating, etc., lower hemispherical candle whether it be that of incandescent, arc, mercury or other lamp. Suitable reflectors may be used to change the distribution of the light on any of the lamps to meet the conditions, with the possible exception of one which has such a strong vertical distribution that it is difficult to change its direction without serious loss. The common practice of figuring illumination on the initial candle power basis should be discouraged. Some poor examples of illuminating engineering are monuments to this practice, and the arc is frequently discredited by a false conception of this important point.

Briefly, in figuring illumination, about 10 per cent should be added to the initial illumination of the arcs, and about 20 per cent to the incandescents to cover depreciation, globe deposit, etc., thereby representing service conditions.

Over a period of one thousand hours, under all conditions of operation, we can say that the multiple enclosed arc lamps, whether alternating or direct current, will run between two and three watts per mean power is 80 per cent of the initial, the efficiency of the former is 4.5, and of the latter 5.1 watts per mean spherical candle power. If these lamps were frosted to conform with the prevailing demand, the figures would stand nearer 5 for the former, and 5.5 for the latter. Furthermore, it is not customary to immediately remove lamps when they reach 80 per cent of their initial candle power, so it is safe to say that the standard incandescent lamps, of the initial efficiencies mentioned, will average over a period of 800 to 1000 hours, anywhere from 4 to 6 watts per mean

Fig. 5. Boston Edison Exhibition Room Lighted by Selective Ceiling Diffuser System

spherical candle power. This covers a wide range of currents, and also the variations due to carbons feeding, globe deposit, etc. Compare this, for example, with the standard incandescent lamps, of 3.1 and 3.5 watts per horizontal candle power, with clear bulbs. The former has a mean spherical efficiency of 3.76 watts, initial, and the latter 4.24 initial. After the lamps have burned to the limit of their so-called useful life, namely, to the point where the candle spherical candle power, with a renewal cost of from one-half to six-tenths of a cent per kilowatt hour, as compared with 0.2 to 0.3 cents per kilowatt hour for the maintenance of the arc lamp. This gives for the arc lamp practically double the light under service conditions, over the period of time mentioned. Notwithstanding the difference in efficiency, there are many cases where arcs are used, when incandescents would give better results, and vice versa. It is not altogether a question of efficiency and cost, but a question of adaptability to surroundings.

Now, while the GEM lamp with clear bulb, shows initially an improvement of possibly 15 to 20 per cent over the 3.1 watt lamp, this advantage is somewhat offset by a more rapid depreciation.

The tantalum lamp has direct-current limitations, the cost is relatively high, and

Fig. 6. Suspended Type Ceiling Diffuser

under the circumstances the improvement in efficiency is not sufficiently great to warrant its replacing GEM lamps to any considerable extent, especially where the cost of current is low.

The tungsten lamp promises to rival the arc in initial efficiency. We have no evidence as to whether or not it will be its equal or superior under running conditions, that is, the service condition, with the time factor introduced. Furthermore, we know that where a white light is necessary, the tungsten cannot compete with the carbon arc, notwithstanding the somewhat general impression to the contrary, based possibly upon casual observation of exposed lamps, and not on actual color selection test. On the other hand, the light is rather cold for domestic purposes. It promises, nevertheless, to revolutionize commercial lighting, but there is no reason why we should surrender the advantages of the arc lamp for all classes of lighting until we actually have a fair substitute.

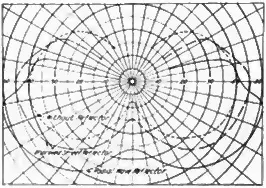
I might state that it is the purpose of the Illuminating Engineering Department of the General Electric Company to disseminate accurate and useful information in connection with the subject, and to be absolutely impartial in specifying apparatus, whether incandescent, enclosed arc, magnetite, tungsten, or other illuminants: it is only on this basis that Illuminating Engineering can properly progress.

New Apparatus of the General Electric Co.

The work of the Illuminating Engineering Department has of late been more along the lines of utilizing to good advantage the existing apparatus, rather than the development of new material. Some improvements of note, however, have been made.

Incandescent Street Lighting—Radial Wave Reflector

Figure 1 illustrates the radial wave reflector designed originally for the lighting of the passenger platforms and standing tracks of the New York Central depots in New York City. Its use has been extended to incandescent street lighting, as a substitute for the present so called improved street reflector. Curve 1 shows the performance of the new 40 c.p. tungsten series incandescent lamp without reflector, with the improved street reflector, and with the radial wave reflector. The increased illumination in the lower hemisphere with the improved street reflector is 16 per cent, and with the radial wave



Curve 1. Mean Distribution of Light in Vertical Plane, Tungsten Series Lamp with Street Reflectors

reflector 39 per cent. It will also be observed that the characteristic is unusually good, a decided maximum occuring at approximately 10 degrees below the horizontal.

New Magnetite Lamp Reflector

There has been some criticism on the light from the magnetite arc as being rather weak in the vicinity of the arc and the shadow of the pan in the globe stronger than desirable. A new reflector has been designed to eliminate these weaknesses without materially cutting down the lighting at a distance from the lamp.

New Street Reflector for Enclosed Arcs

In laying out the lighting for the Dupo Railway Yards at St. Louis, it was found necessary to design a 26 inch inverted concentric reflector with a screening vane attachment for concentrating the light in a given direction (Figure 2). These reflectors have been specified for the Peoria & Pekin Union Railway Yards, and the Altoona Yards of the Pennsylvania Railway, and will be used in future for this class of work. By omitting the vane, it makes a much more efficient street reflector for enclosed arc lamps than the one that has been used for some time, and may be substituted. This reflector is made of steel and has an extra heavy coating of porcelain enamel.

Plain Type Ceiling Diffusers

A plain type is now ready for use in connection with plaster ceilings, (Fig. 3),

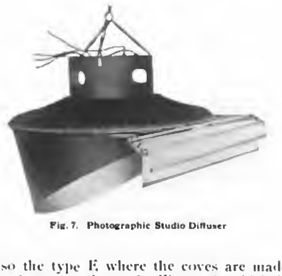


Fig. 7. Photographic Studio Diffuser

also the type E where the coves are made in plaster as shown in Figure 4, which is a daylight photograph taken in the exhibition room of the new Edison Building in Boston. Figure 5 shows the same room as illuminated by the diffusers, by the light of which the photograph was taken. Attention is called to the fact that there are no dense shadows, while at the same time, there are sufficient differences in light and shade to prevent the illumination from being "flat."

Combination Diffuser

There are instances where it is desirable to provide two forms of light, namely white and yellow, and for this purpose a

Fig. 8. Photograph Made by Light of Studio Diffuser

diffuser has been designed so that by throwing the main switch one way the arcs are lighted, and by throwing it the other way the incandescents or tungsten lamps are lighted.

Suspended Type

In the lighting of large areas, such as big power houses, drill halls, etc., it is desirable to reduce the number of outlets as far as possible, consistent with reasonably good distribution. The suspended type diffuser has been designed for this purpose, each diffuser carrying either two or four arcs. For 25 cycle three-phase work, groups of incandescents or tungsten lamps are used, one-third of the lamps being connected on each phase. Owing to the extensive application of 25 cycle current to railway service, it has been found necessary to devise this for the lighting of machine shops and other places where they do not care to introduce an additional frequency.

I might mention the suspended type of diffuser (Figure 6) which can be attached directly to the ceiling or be suspended at any desired height by chains.

Photographic Studio Diffuser

This is shown in Figure 7 and is similar to the suspended type; it has in addition, however, an apron and a diffusing screen. This diffuser contains two lamps, each burning two arcs of 7½ amperes each on direct current, and 10 amperes each on alternating current. The apparatus makes the photographer practically independent of daylight. A perfect Rembrandt can be taken in about one-tenth of a second, as shown by the accompanying photograph, Figure 8, in which the speed is well illustrated by the expression of the subject.

Fig. 9. Six-light Tungsten Incandescent Fixture

A couple of these studio reflectors have been installed in the Winchester Arms' 200 yard rifle ranges to illuminate the targets, and the results have been so satisfactory that it has now been decided to lay out the lighting for fifty ranges from which daylight will be excluded entirely.

Tungsten Fixtures

In the lighting of the department store, for example, it is desirable to reduce the number of outlets to a minimum and maintain the same uniformity on all floors as far as possible. This simplifies the layout, cuts down the cost of conduit and wiring, and makes it possible, at any time, to change from white to a yellow light, or vice versa, without interfering with the outlets.

Generally speaking, it is good engineering practice to equip, say, a seven or eight story department store with three or four floors of white light, and the remaining floors with yellow light. One arc lamp, when properly equipped, can be placed so as to distribute its illumination over the ordinary bays varying from 18 to 30 feet square. It is therefore necessary to have an incandescent unit which can be substituted, particularly on the upper floors where the studding is not so high and where the intensity of the illumination is usually less. For this purpose we have designed the fixtures shown in Figures 9 and 10. These are for either four or six tungsten lamps in series or multiple.

Fig. 10. Four-light Tungsten Incandescent Fixture

MOTOR DRIVEN ICE CREAM FREEZERS

By Miss O. L. Brown

Nearly a half century ago, in 1861, Oliver Wendell Holmes in his observations as the "Professor" in "Elsie Venner", wrote a witty truth that holds almost equally good today:—

"Whatever may be the cause, it is well known that the announcement at any private rural entertainment that there is to be ice cream produces an immediate and profound impression. There is something so audacious in the conception of ice cream that it is not strange that a population undebauched by the luxury of great cities looks upon it with a kind of awe and speaks of it with a certain emotion."

This "defiance of the seasons", as Dr. Holmes well calls it, "forcing Nature to do her work of congealation in the face of her sultriest noon", has now become a prime necessary of life, not only among those of the white race who are aliens in the tropics, in our own hot Southland, and during the Summer days in the North; but it has, furthermore, been long accepted by physicians as indispensable for a light and nutritious food in hospitals among many classes of patients.

Still another field in which ice cream holds dominant popularity and has practically no rival, is in connection with Summer beverages; every druggist, to be up to date and to meet the insistent modern demand, must be prepared to furnish ice cream soda and "college ices". A large supply of ice cream, therefore, is a *sine qua non*.

Motor Driven Ice Cream Freezer with Ice Breaker

Improvements have been steadily made in hand operated and mechanically driven freezers, to meet the requirements of the enormous demand, but it remained for electricity to be applied to this branch of work to provide ideal conditions.

Any improvement which offers to a manufacturer a reduction in the cost of his product, commands instant attention; if, in addition thereto, the product is made superior by this new method and the labor of obtaining it materially lessened, he "waits not upon the order" of its adoption, but adopts at once.

The direct connected, General Electric motor driven ice cream freezer combinations of F. E. Whitney, 65 Sudbury Street, Boston, manufacturer of the standard "Boston freezer", have been widely adopted and are achieving an enviable reputation, as numbers of these outfits with General Electric motors have been in use for over two years, and of these the maker asserts: "I have yet to receive the first complaint".

Motor Driven Swivel Top Ice Cream Freezer

These equipments are very widely scattered, some being in Callao, Peru; Havana, Cuba; (where there are four, two of which are 4½ gallon single freezers, one a nine gallon double, and one a twelve gallon double); Oklahoma, Pensacola, Birmingham, Charleston, Jamestown, La Salle, Milwaukee, and Salt Lake City, as well as in many hotels, hospitals and colleges throughout the country.

The freezers, which are supplied with either direct or alternating current motors are made in a great number of sizes, ranging from 4½ gallons to 20 gallons, in a great many combinations, some of which are illustrated in the cuts.

The entire equipments are compact, self-contained, perfectly stable, require no floor fastenings, and may be located at will and readily changed at any time, as convenience or necessity demands, by merely readjusting the service wires.

The advantages of a direct connected ice cream freezer are readily apparent to those who have suffered the annoyance of belting, pulleys and countershafts. There are no belts with attendant annoyance and expense; no countershaft requiring continued attention and causing vibration to the floor above; nor is there dirt and oil being thrown here and there. In addition to the mechanical advantages secured by the motor driven ice cream freezer unit, there is obtained by its use cleanliness, increased space, light and ventilation. When not actually freezing, all power is shut off

Motor Driven Ice Cream Freezer. Closed

and power savings are effected thereby. When in operation the power is applied direct, with no waste in belts and countershafts, securing the highest efficiency.

Actual experience in daily operation has shown two 20 gallon swivel motor driven freezers, here illustrated, to produce in the same time twice the output of four 10 gallon belt driven freezers, with practically the same expenditure of power; in addition, the quality of the product was superior in the motor driven outfit, being finer grained.

This swivel top type of freezer, here illustrated, will appeal particularly to those who desire to use mechanical refrigeration. The cut will explain itself. The arm that carries the gearing of the motor swivels from one tub to the other, so that as soon as the cream is frozen, the spindle may be raised by means of the lever at the top, and the whole arm swivelled so as to couple on to the other tub. This leaves one tub perfectly clear so that the can may be removed readily without moving the tub. As will be seen, the motor is geared directly to the shaft, a raw-hide pinion being attached to the armature shaft, and the gears thoroughly protected with a gear guard. The cans hold forty quarts, are made of heavy copper with a brass bottom, and are brazed. The tubs are very heavy and are made of cedar. The cut represents a 60 cycle three phase motor and the total weight of the machine is approximately 1100 pounds. Motors of any voltage can, however, be furnished.

Considering the wide variety of the combinations made,—their reputation for reliability,—the popularity of the field to which they apply,—and the fact that their use is practically continuous throughout the year,—these outfits would seem very desirable for the alert central station manager to recommend for connection to his circuits, as a welcome addition to his power load, and a means of thus increasing his revenue.

Tests made under the supervision of the Boston Ice Cream Co. gave the following results:

With the double freezer (as shown in the cut) nine (9) gallons (4½ gallons per can) of frozen cream were produced in 18 minutes with an average power consumption from start to finish of 577 watts.

This at $.10 per kilowatt hour gives a total cost of power at $.0173 (577 watts $\times {}^{18}/_{60}$ hours × $.10 = $.0173) for freezing nine gallons of cream, or a cost per gallon of only $.0019 ($.0173 ÷ 9 = $.0019).

The above are actual results based on an assumed cost of electricity at $.10 per kw. hour. By multiplying the kilowatt hour required by the actual cost of electricity in any given locality estimates may readily be made to govern local conditions.

Motor Driven Ice Cream Freezer. Open

These machines can be furnished with either one or two cans (as shown in illustration) fully equipped with General Electric constant current or alternating current motors.

IRON-CLAD PORTABLE INSTRUMENTS

By W. F. Howe

Considering the various factors that enter into the design and production of a satisfactory portable instrument for electrical measurements, the requirement of first importance is that the instrument shall be accurate—not only must it be accurate as it comes from the manufacturers, but it must also be capable of retaining this quality in continued service.

Type P-3 Portable Wattmeter with Cover Removed

Portable instruments are especially subject to rough usage, and to eliminate as far as possible all likelihood of changes occuring in calibration, due to vibration and hard knocks, the working parts must consist of few pieces, substantially made, and fully protected from injury by a suitable containing case. At the same time the meter must possess a light weight moving element which will not be susceptible to damage in transportation.

A further essential requirement in a portable instrument is that its accuracy shall remain unaffected when the instrument is subjected to the disturbing influences resulting from external magnetic fields, variations in wave form, frequency, etc. Suitable means must be provided in the design for counteracting these influences, if the instrument is to give reliable results under average conditions.

In addition to possessing the above necessary qualities, a portable meter, to be desirable, must be of small weight and size so that several instruments can be carried with ease by one person.

The new portable instruments made by the General Electric Company meet all of these requirements, and are known as the Iron-clad Portable, Type P-3. (See page 134).

The voltmeters and wattmeters of this type are constructed on the direct reading dynamometer principle, while the ammeters depend for their operation upon the well known design of the Thomson inclined coil. The best skilled labor is employed in their manufacture; they therefore excel in mechanical detail, are very substantial, and present a neat and attractive appearance. They are contained in a finely grained, highly polished carrying case, provided with a hinged cover and snap lock.

The entire mechanism may be quickly and easily taken from the case for the purpose of inspection or repairs by removing the inside moulded cover and loosening three additional screws. The fluctuations of the needle are damped by means of Foucault currents set up in a thin aluminum segment attached to the shaft, and which oscillates with each movement of the needle, in the fields of two astatically arranged permanent magnets. This segment also serves the purpose of balancing the pointer, thereby doing away with the necessity of special counterweights. The meters are also supplied with the usual damper, so that by depressing the button, the pointer may be quickly brought to rest when taking readings.

Careful attention has been given to the selection and construction of the jewels and pivots, as the continued accuracy of indicating instruments is dependent to a very great extent upon the perfection of these. The pivots are made from the best grade of steel, specially hardened and highly polished, and are suspended in

Mechanism of Type P-3 Portable Instrument

superior sapphire jewels, which are practically indestructible.

One of the strongest proofs of the reliability of these instruments, is their ability to give accurate indications when used for laboratory or general testing work in the vicinity of external magnetic fields, proceeding from nearby magnets and conductors carrying large currents. The coils of the Type P-3 instruments are entirely surrounded by a laminated iron shield, which completely protects them from such external disturbances when used under circumstances similar to the above, and effectually precludes the possibility of errors arising from this cause, so that the readings of the meters may be entirely depended upon. The shield referred to serves the further purpose of preventing errors which might otherwise be caused by the projected field of the damping magnets, when the instrument is used on direct current circuits.

These instruments may be used on alternating current circuits of any frequency, wave form or power factor, without appreciable error. The voltmeter and wattmeter may be used equally well on either direct or alternating current circuits, but for most accurate results, reverse readings should be taken on ammeters when used with direct currents. The mean of the readings being then taken as the correct indication.

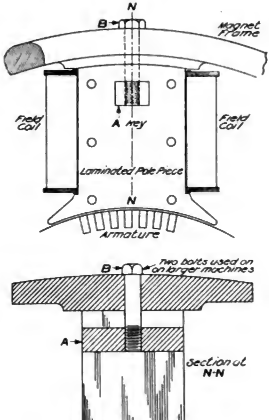
The instruments are made self contained in capacities up to and including the following values: Ammeters, 30 amperes; voltmeters, 750 volts; single phase wattmeters, 30 amperes and 750 volts.

The scales of the Type P-3 instruments subtend an arc of approximately 90 degrees, are very accurately divided, and are very distinct and easily read.

The binding posts are brought out at the top of the instrument, and are provided with suitable thumb screws for securing the leads which connect the instrument to the external circuit.

THE PARCELLE PATENT

One of the General Electric Company's patents that has recently been sustained in litigation against the Bullock Company and users of Bullock apparatus, covers an important detail in the manufacture of dynamo-electric machines which is extensively used by the General Electric Company. This is the patent to Parcelle, dated Nov. 24, 1891, No. 463,704, which covers a



Drawing Showing Application of Parcelle Patent method of firmly fastening a laminated pole piece to a solid yoke.

Before the necessity of laminating the pole pieces was known, solid pole pieces were attached to the yoke by bolts or screws. These pole pieces were readily removable sidewise. But with the laminated pole piece, it became impracticable to do this, because of the difficulty of satisfactorily tapping a bolt directly into the laminations. Prior to the Parcelle invention, the pole pieces were made integral with the yoke and both were then laminated, or the yoke was cast around the laminated pole piece, or the pole piece was secured to the core by bolting through the side plates, which were thickened for that purpose.

None of these methods were very successful. Laminating both the pole piece and yoke was expensive; when the pole piece was cast integral with the yoke, it was difficult to make a firm joint, and besides, the pole piece could not be removed; and the placing of the holding bolts in the side plates made them too thick and gave rise to objectionable eddy-current losses.

By the Parcelle method, the laminated pole piece is secured to the solid yoke by anchoring into the laminated plates a supporting bar, into which the bolt or bolts which hold the pole piece to the yoke are firmly screwed. Figure 1 illustrates the construction. 'A' represents the supporting bar or key extending through the laminated pole piece, and 'B' the securing bolt extending through the yoke and threaded into the supporting bar.

This construction provides a method of fastening a laminated pole piece to a solid yoke so that it can readily be removed sidewise, is firmly clamped against the yoke so as to make good magnetic circuit, and at the same time is so strong that all magnetic and centrifugal forces are successfully resisted.

This construction has been employed by the General Electric Company in upwards of 20,000 pole pieces.

The city of Nashville, Tennessee, has been enjoined from operating Bullock generators which are so constructed as to infringe this patent, and has been given until about November first to remove the apparatus.

EDWARD RUSSELL COFFIN

Edward Russell Coffin, only son of Charles A. Coffin and Caroline Russell Coffin, died on September 2nd from intestinal trouble at the Omaha General Hospital, where he was taken while returning to New York from a business trip in the far West.

Mr. Coffin was born at Lynn, Mass., on July 28th, 1873, and received his early education in the public schools of that place. He was graduated from Harvard University in 1893, and from the Harvard Law School two years later. For several years following his graduation, he practised his profession in the city of Boston, and in 1901 entered the Legal Department of the General Electric Company at Schenectady. In 1904 he became Vice-President and General Manager of the Electrical Securities Corporation of New York City, which position he held at the time of his death.

Mr. Coffin was associated with various electrical interests throughout the country. He was Vice-President of the Asheville Electric Co., the Chattanooga Electric Co., and the Des Moines Electric Light Co. He was a Director of the Animas Power & Water Co., the Central Colorado Power Co., the Duluth Edison Electric Co., the

Grand Rapids Edison Co., and the Omaha Electric Light & Power Co.

Mr. Coffin was a member of the Harvard, Knollwood, University, Calumet, and Metropolitan Clubs of New York City; of the Puritan Club of Boston, and the Fort Orange Club of Albany.

Mr. Coffin, by his ability, integrity and strict sense of fairness, won the highest place in the esteem of those who came in contact with him, while his high principles, his cheerful temperament and his lovable character, endeared him in an unusual degree to those who were fortunate in having his friendship. He was remarkable for his fine perception, for the sincerity of his consideration for others, and for his intense loyality to every friend and just cause. A devoted son, a true and loyal friend, always charitable and thoughtful, his loss is deeply deplored by his many friends and associates.

NOTES

Mr. H. G. Reist, Engineer of the A. C. Engineering Department, General Electric Co., was married at South Hanover, Mass., on August 10th, to Miss Margaret Eaton Breed, daughter of Margaret and Steven F. Breed of that place. Mr. and Mrs. Reist will make their home at 42 Glenwood Boulevard, Schenectady, N. Y.

* * *

Mr. V. L. Benedict has been transferred from the Power & Mining Dept. of the General Electric Co., Schenectady, N. Y., to the Los Angeles office, where he will act as Assistant to the Manager, Mr. A. W. Ballard.

Mr. Benedict entered the General Electric Co., in 1895, and after completing the Test, entered the Power & Mining Department, where he has since remained.

* * *

The midsummer convention of the National Association of Box Manufacturers was held at the Hotel Kaaterskill, Catskill, N. Y., August 28th, 29th and 30th, and was very well attended. At this meeting Mr. L. R. Pomeroy read a paper by Mr. Fred. M. Kimball of the General Electric Company, on the utility of electric motive service in wood working establishments. The paper was prepared at the request of the association management and the managers of wood working plants evinced keen interest in the subject; Mr. Pomeroy being called upon to amplify materially upon the possibilities, details, and result of such equipment.

* * *

The General Electric Company has received orders for the electrical equipment of the two new battleships No. 28 and No. 29. The former is to be built by the Newport News Ship Building Company, and the latter is in course of construction in the Fore River Ship Building Yards at Boston, Mass.

These are the two largest war vessels ever built in this country, and a notable feature of No. 29 is that it is the first battle ship to be propelled by turbine engines. These are of the Curtis type and have a capacity of approximately 25000 h.p. On account of the remarkable steam economy of the Curtis turbine at low as well as high speeds, the one set of turbines can be used for both high speed and cruising, thus obviating the necessity of installing a second set for this latter purpose. In addition to this advantage and the attendant economy in space and weight, the absence of reciprocating parts and consequent vibration and strains is expected to make this battleship the speediest in the Navy.

Four 300 kw. Curtis turbo-generating sets will be installed on each ship to supply the lighting circuits and furnish power for about 100 motors, varying in size from 2 to 75 h.p. These motors will be used to operate the turrets, ammunition hoists, cranes, winches, etc.; to run the forced draft and the hull ventilation fans, and to supply power to the laundry and workshops.

The battleships will be equipped with four 36 inch and four 60 inch searchlights.

* * *

The Schenectady Works of the General Electric Co. recently received a visit from a commission sent by the German government and composed of the following distinguished representatives: Privy Councillor Wittfield, of the Prussian government; Prof. Dr. W. Reichel, of the Royal Technical University, Berlin; Building Inspector Guthrad; Director Frischino, of the Siemens-Schwkert Works; Mr. Pforr, of the A. E. G. Railway Dept.; Director A. Elfes, of the A. E. G. Brunnenster; Director Jordan, of the Lahmeyer Works.

Prior to visiting the Schenectady Works, the commission inspected the General Electric electrification of the New York Central & Hudson River Railroad; the Lincoln St. power house of the Boston elevated line, and the Curtis steam turbine equipment of the Boston Edison Illuminating Co. The subsequent plans of the commission include an inspection of the Niagara power plants equipped by the General Electric Co.; followed by a visit to Indianapolis, the centre of the interurban electric railway systems; the 8000 kw. Curtis turbines at the Fisk St. station, Chicago, and the General Electric 2000 kw. vertical shaft frequency changer sets in the substation of the Chicago Edison Co. will also be examined.

The party will make a study of the transmission systems of Utah, Washington, Colorado, and California; they will visit the 60000 volt transmission plants of General Electric design at Guanjato and Necaxa, Mexico, and will return to Europe via Vera Cruz.

BETTER SERVICE

Under the title "Good Service" we printed a letter last month describing the operation of a 30 ampere mercury arc rectifier which had been in service 2400 hours. Since then we have received a letter from S. H. Lewis and Co. of Binghamton, N. Y., of which the following is an extract:

> "On Jan. 25, 1906, we installed one of your 30 amp. mercury arc rectifiers, the tube that went into commission at that time was used on an average of 18 hours a day, at 20 amperes until Aug. 30th, 1907, 574 days, 10332 hours.
>
> "We have used all manner of charging apparatus for charging electric cars and find the mercury arc rectifier by far the most satisfactory".

The life of 10332 hours is the longest life we have heard of on a 30 ampere tube. In fact, we believe it is the longest on any size rectifier tube made. This rectifier outfit is being used for charging automobiles in the S. H. Lewis Co.'s garage.

ABSTRACTS OF IMPORTANT TECHNICAL ARTICLES

Illustrated *

A Hydro-Electric Power Plant Driven by Pelton Wheels

(The Iron Trade Review, August 15, 1907, p. 271)

A brief illustrated description of the Stanislaus Electric Power Co., located at Velecito, Cal., having an initial machinery equipment of three 6700 kw., 400 r.p.m., Pelton wheel driven General Electric alternators.

Kern River No. 1 Power Plant of the Edison Electric Company, Los Angeles, III

(Electrical World, August 17, 1907, p. 313)
(Electrical World, August 24, 1907, p. 359)
(Electrical World, August 31, 1907, p. 401)

A very interesting article comprising not only a description of the Kern River Power Plant No. 1, with 5000 kw., 250 r.p.m., 2300 volt, 50 cycle, three-phase, water wheel driven General Electric alternators, 75000 volt step up transformers, etc., but giving also a complete description of the steel tower transmission line and receiving station No. 3. The latter is equipped with step down transformers, as well as steam turbines aggregating 10,000 kw., and includes two 2000 kw., Curtis steam turbines of General Electric make.

The Central Station of the Gas and Electricity Co., of Nice, France

(Electrical Review, August 10, 1907, p. 214*)

This plant has been built by the French Thomson-Houston Co., and was the first electric plant in France to use the Curtis type of steam turbines. The equipment includes two 800 kw., 1500 r.p.m., 10000 volt 25 cycle three-phase units, which have a high overload capacity. Excitation is obtained from two 40 kw., 125 volt direct current generators, driven by three-phase induction motors at 750 revolutions per minute.

Instruction of Car and Train Service Men—Boston Elevated Railway Company

(Electric Traction Weekly, August 22, 1907, p. 793)

The article gives brief data describing the instruction car at the Sullivan Square Terminal, which is equipped with a Sprague General Electric multiple unit control system, air brake, etc., and includes also a large wiring diagram with tell-tale lamps, which indicate the switch positions.

Copper-Smelting Practice in the Boundary District, British Columbia

(The Engineering Magazine, August, 1907, p. 715)

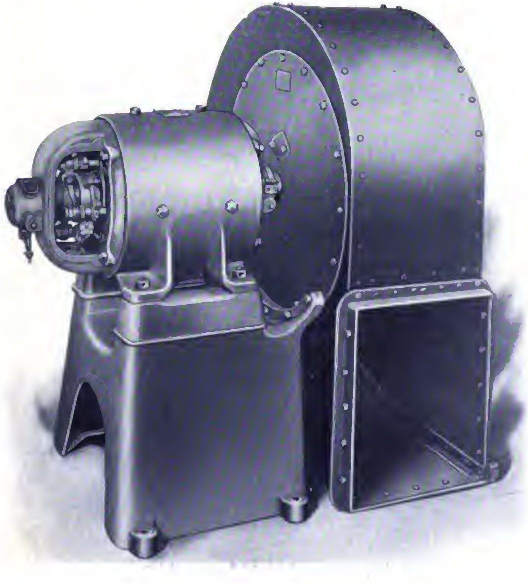
Historical account relating to the copper mining industry in the boundary district of British Columbia, including profusely illustrated description of the equipments of the British Columbia Copper Co.'s plant. The converter power house of this plant contains three rotary blowers and one blowing engine, each driven by a 300 h.p. induction motor, and two induction motor direct current generator sets for furnishing direct current for train and trolley operation. The motors and switchboard are of General Electric make.

GENERAL ELECTRIC REVIEW

VOL. IX No. 5

PUBLISHED MONTHLY BY GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU SCHENECTADY, N. Y.

OCTOBER, 1907



Type EC-26 Centrifugal Fan Direct Connected to open CQ Motor

(See page 153)

General Electric Company

The highest efficency incandescent lamps available at present for commercial use are the

Tantalum Lamps

No. 2—80-Watt—50 c.p.
with Bowl Holophane

The 80-watt regular Tantalum lamp as a lighting unit used in combination with the regular No. 2 Holophane provided for GEM lamps, gives the same candle power values as the 100-watt or No. 2 GEM with 20 per cent. saving in current.

Order Now

For either immediate or future delivery

Tantalum lamps produce the light that is unsurpassed.

1480

New York Office: **44 Broad St.**

Main Lamp Sales Office:
Harrison, N. J.

Sales Offices in all large cities.

GENERAL ELECTRIC REVIEW

VOL. IX NO. 5

OCTOBER, 1907

CONTENTS

Illumination of Road by Magnetite Headlight

(See page 190)

Vol. IX No. 5 SCHENECTADY October, 1907

GENERAL ELECTRIC REVIEW

A MODEL ELECTRIC BAKERY

By Chas. B. Davis, Manager
General Electric Company's Boston Office

The Ferguson Bakery Company's plant, located in Boston, presents an interesting and inviting up to date electrically equipped bakery. By the use of individual motor drive there is an economy of space and the machines are located in that part of the room where they can be worked to best advantage and out of the way of trucks used for conveying the cooked food.

The running of quarter turn and long straight belts is eliminated; as is well known such belts running close to and parallel to the floor above will collect dust even though it is but little that sifts from the cracks above and when the belt is set in motion this dust flies into the air and settles on the food below.

Not many years ago this business was started by two Ferguson Brothers in a small shop near the present bakery, all the work being done by hand; today this bakery is foremost in New England.

The small shop where the business originated soon became inadequate for their output and a new building was constructed where the business could be taken care of. The power for driving the machinery in this building was derived from a steam engine which ran long lines of shafting with belts that ran in every conceivable direction; by this method of drive oil had to be freely used on the many bearings and these were often so situated that it was only with untiring precaution that oil did not do serious damage by getting into the flour or dough and again the flour would stick to the belts and cause slipping and if a belt came off considerable time was lost and the workman was obliged to wash his hands before he could resume his work with the flour.

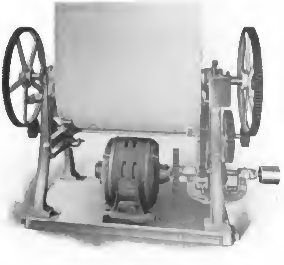


Fig. 1 Day Dough Mixer

This method of drive was the best of its kind at that time, but even at its best it was none too good.

The present bakery was to be enlarged but then came the problem of how to drive the machinery which was located on the different floors and in the adjoining building.

After careful study and investigation it was decided to adopt the electric drive

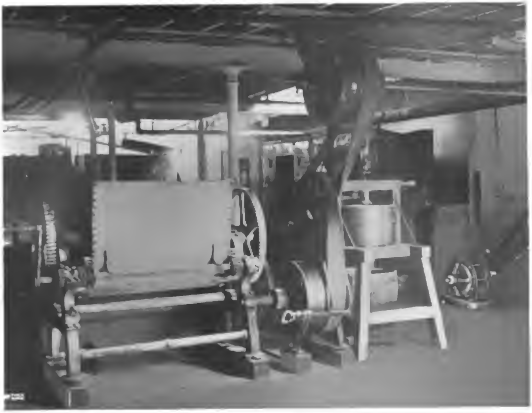


Fig. 2 Brown Bread Room

which at this time was coming into prominence.

By many this was thought to be a serious undertaking as all the present shafting, belts and pulleys which could not be used had to be sold as secondhand, at whatever they could get, or else sold as scrap, but the owners were shrewd and saw that the saving in coal would in a few years not only pay for the scrapped material, but would save money.

Because by the old method of drive in order to work one department overtime it was necessary to run the entire plant where considerable useless energy was consumed in driving the idle shafting which was often badly out of alignment; of course this was very hard to observe and often never detected until a hot box was the result. With the individual drive it is only necessary to run the one machine which is to do the work and should the workman wish to do other work he stops this machine by simply pulling out the line switch and this unnecessary waste of energy driving an idle machine is saved. These motors running from the Edison circuits are each equipped with a recording wattmeter. Now we will suppose that after running one of these motors several months it is noticed that the power taken from the line is gradually increasing month after month, yet the motor is doing the same amount of work and running the same number of hours per day, our first thought would be the alignment of our shafting and without doubt we would be correct. This poor alignment can immediately be remedied but in the case of the steam engine drive this loss went on for month after month, yes year after year, and was never detected unless a hot box or break down occurred,—all the time the coal consumption is growing larger and the owner's pocket book shrinking.

The present installation consists of a 100 k. w. DC generator which lights the building and supplies power to some of the motors.

Most of the motors are now run from the Edison 220 volt AC circuits, and I dare say in due time all the direct current motors will be superseded by the three-phase motors which will run from the Edison circuits

These motors now installed run either individual machines on a short line of shafting and this shafting only used where it is a good safe working distance from the floor or dough whereby all chances of dirt getting into the flour is eliminated.

The flour which is used is shipped by bag in car load lots and carried from the cars to the bakery by teams; it is then unloaded and conveyed by an electric elevator, driven by an I-12-25 h. p.-600 r. p. m. induction motor, to the top floor of the building and there stored; as the flour is needed it is emptied from the bags into the bins where it is blended and from there it is carried by an endless chain of buckets to the screener and thoroughly sifted, from here it is again carried by an endless chain of buckets and deposited in a large bin directly above the dough mixers on the floor below.

After a bag has been emptied it is run through a cleaner. This cleaner is nothing more than a large box with a paddle wheel inside, the paddles simply beat the flour from the bag and this waste flour is sold to foundries where it is mixed with clay and molasses for making the moulds.

On the second floor and directly under the supply bins, are the scales so that the flour is weighed before it is emptied into the mixer. There are three mixers each

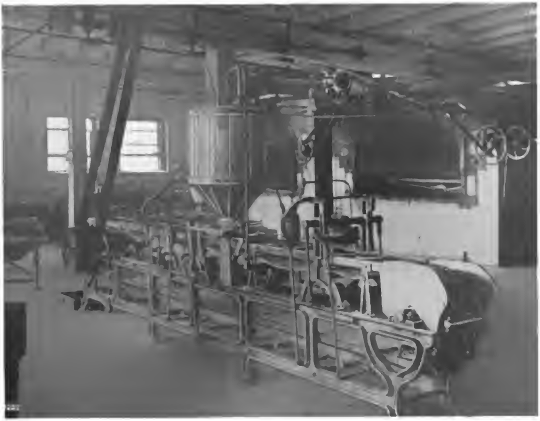


Fig. 3 Pie Machine

capable of holding five barrels of flour at one time. Each of these is direct connected to a 20 h. p. induction motor. The average daily output from these mixers is about 20,000 lbs. Fig. 1 shows a General Electric three-phase motor direct connected to a J. H. Day dough mixer.

After the dough is kneaded it is then removed and put in large trays where it is allowed to stand three or four hours to rise. The next process is to cut this dough into loaf size; this is done by a loaf cutting machine which is run by a small motor. By this machine any size of loaf can be cut.

The chunks of dough are next placed in the shaping machine (Fig. 4) and moulded into the loaf shape. This machine is direct driven by a CE-4-10 h. p.-635 direct current motor.

Two other small shaping machines are used there, being run from a short shaft

Fig. 4 Dough Shaper

driven by a CE-4-10 h. p.-635 direct current motor. From these machines, any desired shape of loaf can be obtained. After the dough is made into loaf form, it is placed in the baking tins and taken to the ovens on the floor below where it is baked and from this floor it is then taken to the next floor and made ready for shipment.

The temperature of the mixing room is maintained at 80 deg. F. and in each end

Fig. 5 Pie Dough Mixer

of the room are placed recording thermometers and by referring to these charts one can at a glance see whether or not the room temperature has been kept constant.

The pie and cake rooms which are in the adjoining building are worthy of special attention because of their cleanliness and economical method of making pies or cakes. By the use of several electrically driven machines the work can be done in that part of the room near the windows where the best results may be obtained by reason of the good light, fresh air and distance from the ovens which are in the same room.

The two machines most worthy of attention are the small dough mixer and the pie making machine. The former, (Fig. 5) is built by the J. H. Day Co. and is driven by the new type riveted frame 2 h.p. General Electric induction motor. This machine is capable of mixing one barrel of flour at a time.

The whole outfit is finished in white enamel paint and makes a very unique appearing set.

After this dough is kneaded it is removed from the mixer and ready to be made into pies. The workman immediately refills the mixer and starts the motor which is mixing the dough while he is busy making the pies.

Fig. 3 shows one of the pie machines which together with three rotary ovens and a crust machine are run by a CE 4-5 h.p.-635 r.p.m. direct current motor fastened to the ceiling.

The pie machine is about fifteen feet in length with a chain of endless dummy cast iron plates which run the whole length in the middle of this machine. As an iron plate comes upright a tin plate is set in it and then a small piece of dough is dropped in this. As this plate passes on a plunger presses down upon this dough and squashes out the bottom crust of the pie. This plate is still passing forward and as it comes under the large tank in the center of the machine the required amount of filling is dropped into the pie, then the top crust put on and the last operation is the trimming. This is accomplished by a die coming down over the pie plate and neatly trimming the edges. The pie is now removed and put in the rack ready for baking.

Two of the three revolving ovens can be seen in the background of the picture. These are capable of holding 320 pies each at one time and resemble a large paddle wheel. The pie plates are simply put on the paddle and the wheel set in motion; in this way all the pies are evenly baked.

Adjoining this room is the room where brown bread is made (Fig. 2). The machinery of this room is run by an I-8-7-1 2-900 r.p.m. induction motor driving a short line of shafting which in turn drives a J. H. Day dough mixing machine and also another machine which is used for screening pie filling. In this room the brown bread is prepared and then put in aluminum tins for baking. The baking is done by steam and the daily output from this room is about 500 loaves but on Friday the output is about 5000 loaves. This large amount called for on that day goes to clearly show that the Bean City must have its brown bread and beans Saturday night.

The basement contains the seven cold storage rooms, the engine room, the small machines used for paring and coring the apples, also the ice refrigerating plant

Fig. 6 Refrigerating Machine

which is driven by an I-6-25 h. p.-1200 r. p. m. three-phase General Electric motor. This refrigerating plant is sufficiently large to supply the seven rooms where eggs and such articles of food are kept. This motor is run both day and night.

The few illustrations which are here given will readily show the reader how far superior, especially for a bakery, the individual motor drive is as compared with steam engine or any other engine, whereby long lines of shafting and belts coming from one floor to the one above would have to be used.

Again when we consider the most vital question of all, that is health, we must confess that the Ferguson Co. have as near an ideal bakery as can be found.

CENTRIFUGAL COMPRESSORS FOR INDUSTRIAL AIR BLAST

By Dr. S. A. Moss

A general description of centrifugal compressors was given in the July issue of The Review—supplementary details are given in this article.

As stated, these units are principally adapted for air blast for burning fuel in oil, gas, or other similar furnaces for various industrial purposes, such as hardening, soldering, annealing, melting, smelting, etc.; for machine shops, factories using gas and oil furnaces, gas works, copper smelters, iron foundries, brass foundries, blacksmith shops, and the like. As compressors, the machines deliver air at pressures from about one to four pounds per square inch. The machines are also arranged as "exhausters" for pressures within 3.25 pounds per square inch, or 6.5 inches of mercury below atmospheric pressure.

It must be emphasized that the machines are not adapted for pressures less than 0.88 pounds per square inch, or 14 ounces per square inch or 24 inches of water; or for ventilating work of any kind using 2 or 3 ounces or 2 or 3 inches of water. The ordinary fan blower should be used for such work.

As stated, the "Centrifugal Compressor" is a modified type of fan blower, and consists simply of an impeller, rotating in a case. The principal feature of the compressor is the design of the passages which conduct the air to and from the impeller, leading to the flanged inlet and discharge openings. This design is such as to maintain pressures and efficiencies much greater than heretofore obtained. The impellers are also of perfected design. They are symmetrical, receiving air on both sides so as to avoid end thrust. There is ample clearance between impeller and case, so as to avoid all possibility of rubbing.

The driver is furnished as an integral part of the apparatus so that there is no belting, gearing or other device requiring maintenance. The unit has two bearings and a single shaft on which are mounted the impeller of the centrifugal compressor and the rotor of the driver. This is the only moving part.

On sizes of 50 h.p. and below, frames and casings carrying feet are bolted together, while the larger sizes have a base or bed-plate on which are mounted the frames, casings and bearings.

The accompanying table gives a list of General Electric Centrifugal Compressors of standard sizes, comprising a number of capacities for each of three pressures. Any size may have as driver, a 220 volt 60 cycle three-phase induction motor, a 125 volt or 250 volt direct current motor, or a non-condensing steam turbine for any gauge pressure above 80 pounds per square inch. The starting characteristics of the induction motors can be made anything desirable. When required, the motors can be especially arranged to start without exceeding full load current. Special voltages, etc., may, of course, be arranged for.

Table of Standard Sizes.
Single Stage Centrifugal Compressors for Industrial Air Blast

Service	Rated pressure lbs. per sq. in.	Nominal capacity cu. ft. free air per minute	Diam. of disch. pipe, inches	Nominal h.p.	Max. pressure D. C. or Turbine Drive, lbs. sq. in.
Foundry Cupola or low pressure air blast	0.88*	2600	12	20	1.5
	0.88*	3600	16	30	1.5
	0.88	7000	20	50	1.25
	0.88*	10000	28	75	1.25
Moderate pressure air blast	1.7	750	8	11	3.7
	1.7	1400	10	20	3.7
	1.7	2000	12	30	3.7
	1.7	3600	16	50	2.5
High pressure air blast	2.7	1200	8	30	4.2
	2.7	2400	12	50	4.2
	2.7	3400	14	75	3.0

*For these three sizes, the figures given are for turbine or direct current motor drive only: for induction motor drive, pressure and capacity are as follows:

PRESSURE	CAPACITY
0.7	3200
0.7	4600
1.2	7400

To get pressures in other units, multiply the pressures in pounds per square inch, by the following factors:

For inches of water, 27.7; for inches of mercury, 2.04; for ounces per square inch, 16; for pounds per square foot, 144.

For an exhauster with atmospheric final pressure, the given pressure P in pounds per square inch is to be multiplied by $\frac{14.7}{14.7-P}$ The result is the vacuum pressure in pounds per square inch below atmosphere. By multiplying by 2.04, and subtracting the product from 29.9, the vacuum in inches of mercury is obtained.

If the barometric pressure differs from normal value, (viz., 14.7 pounds per square inch or 29.9 inches of mercury), the pressures given must be reduced in the ratio of actual to normal barometer.

If the Fahrenheit atmospheric temperature t°, differs from 60°, the pressure must be reduced in the ratio of $\frac{520}{460+t°}$

Special sizes and special air pressures may, of course, be arranged for under certain circumstances, particularly when there is direct current motor or turbine drive. With turbine drive, the rated pressure may be fixed at higher or lower values by the setting of the governor before machine leaves factory. With direct current motor drive, the rated pressure is merely nominal, and the pressure may be altered up to the maximum values given, by hand adjustment of the field rheostat. With induction motors, pressure is usually invariable; however, when special starting apparatus is provided, a slight variation can be secured.

The capacities given are based on measurements of the quantity of air *actually delivered* under normal conditions. In comparing with positive pressure blowers, it should be noted that the rated capacity for positive pressure blowers is usually the "computed displacement." The quantity of free *air actually delivered is much less than the displacement of a positive pressure blower*, owing to the heating of the air and drop of pressure while entering the machine, as well as to leakage around the moving parts. Actual tests have shown a loss of 50 per cent or more in the capacity of a positive pressure blower. In usual cases, centrifugal compressors will deliver as much air as a positive pressure blower with a rating 33 per cent greater.

Large overloads may be put on centrifugal compressors in excess of the rated capacity, at the expense of a slight drop of pressure and of an increased temperature rise of windings, when an electric motor is driver. The electric motors that are supplied with these machines have the usual moderate temperature rise of General Electric motors, for rated capacities.

Centrifugal Compressors for Foundry Cupola Service

The first four sizes on the list are normally arranged for supplying air blast to foundry cupolas, and will be found much superior to either positive pressure blowers or ordinary fan blowers for this service. They are arranged with a driver the speed of which varies automatically with load—either a direct current compound wound motor or a steam turbine with special governor, as induction motors do not have this property.

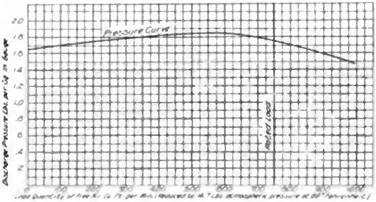
The characteristics of the set are such that the pressure increases rapidly if the cupola chokes up, so that an opening is forced and normal conditions are restored. In this feature the centrifugal compressor resembles a positive pressure blower. This action is considered necessary by many foundrymen. In many cases, however, choking of the cupola never occurs, so that there is constant pressure even with a machine which would give a pressure rise if load decreased due to choking. An actual capacity of about 375 cubic feet of free air per minute is required for each ton per hour melted.

Centrifugal Compressors for Constant Pressure Air Blast, Gas Furnaces, Etc.

All of the groups on the list are adapted for industrial air blast for various services requiring *constant pressure* in the mains, whether low, moderate or high, and for this use the centrifugal compressor is vastly superior to the positive pressure blower. For such service the apparatus is arranged with a constant speed driver, either a direct current shunt motor, a steam turbine or an induction motor. As shown by the accompanying curve, there is a practically constant pressure independent of the load and without waste of air at light loads. This is a distinct advance over positive pressure blowers, which waste air through the safety valves for all loads less than normal load, and give a decrease of pressure for greater loads.

The positive pressure blower, when efficiently installed, has pulleys arranged to give the normal pressure when the average number of furnaces is in use, and with a safety valve just on the point of blowing off. If air is not required on any of the furnaces, the normal amount of air must nevertheless be compressed to full pressure and the air not used blown off through the safety valve. If all furnaces are turned off, as occasionally occurs, the full amount of power is nevertheless absorbed and all that small amount required to keep the machine rotating without load. This automatic regulation of pressure as load varies is accomplished solely by efficient design of the compressor; and no regulation devices, safety valves or other apparatus are used. At very light loads, and at heavy overloads, the pressure is slightly lower than normal, but for all practical purposes the variation cannot be detected at the furnaces.

For gas furnace service, the standard centrifugal compressors are of such capacity as to permit of the use of a single machine in a central location in a factory, rather than a number of small blowers scattered in various places. Even the



Pressure Curve of Centrifugal Compressor for Different Loads

is wasted, while on the other hand, if a few more than the average number of furnaces are turned on, the pressure in the main drops, and each successive addition of a furnace gives a further drop of pressure.

This exceedingly inefficient performance is to be compared with the performance of the centrifugal compressor, which gives practically constant pressure, regardless of number of furnaces,—that is, regardless of quantity of air being used. If furnaces are turned off, the quantity of air passing through the compressor automatically decreases and the power input lessens correspondingly. If no air is being used, the power input is a minimum, and is only smallest machines listed are too large for small gas furnace installations, only comparatively large installations being provided for. Usual gas furnaces require air blast capacity of about ten times the quantity of gas supplied.

For ordinary gas or oil furnaces, the machines rated at 1.7 pounds per square inch pressure should be used, and for furnaces requiring a concentrated or positively directed jet, the machines rated at 2.7 pounds per square inch pressure should be employed.

Pressures

As already stated, no pressure varying device, safety valve, etc., is required, and the pressure remains constant for all loads, if a constant speed driver is used, or varies automatically for foundry cupola service. There is therefore no necessity for selecting sizes of pulleys or varying weights on safety valves, etc., in order to adapt the machine to the requirements of a particular service. However, it is requisite that the desired pressure be properly selected in advance, as this pressure is a characteristic of the machine and is fixed when it leaves the factory. When a direct current motor is the driver, however, the pressure may be altered at any time, by hand alteration of the position of the field rheostat.

The rated pressures given are those at the beginning of the pipe line, and with free inlet, and provision must be made for any pressure drop through the inlet supply pipe or drop in the main. All sizes are provided with inlet pipe which, for most efficient operation, should be led to a cool place out of doors. The pressures given are for air supply at a temperature of about 60° F.; if the supply is hotter than this, or if barometer is abnormally low, there will be a slight decrease of pressure. For an average case, where the inlet air is heated somewhat, and where there is sufficient length of inlet and discharge pipe to give appreciable drop, the three groups listed may usually be depended upon to give, at a distance from the machine, actual pressures in the mains of respectively, about 0.625 pounds per square inch (10 ounces per square inch); 1.25 pounds per square inch, and 2 pounds per square inch. Extremely small pipes would give lower pressures.

The centrifugal compressor delivers air at a constant pressure, and without such fluctuations as occur with a positive pressure blower due to its intermittent action. No tank is, therefore, necessary to steady the pressure, and the machine may be connected directly to the pipe line.

Durability and Ease of Operation and Maintenance

As already stated, the units are remarkably simple and the only moving parts are the rotor of the driver, and the impeller, which are both mounted on a single shaft run in two bearings. These bearings have the usual efficient system of lubrication of the General Electric Company and seldom require renewal. There are no other parts where wear can possibly occur. The bearings are self-oiling, so that the only attention which the machine requires is the renewal of the oil in the reservoirs at intervals. There are none of the belts, gears, sliding parts or other devices which give so much trouble in the usual type of positive pressure or fan blower.

A number of machines have been in service for long periods without renewal or adjustment of any kind and without attention except a monthly renewal of oil.

These machines have replaced positive pressure blowers very successfully. They have avoided the pressure variation previously occurring as load varied, as well as the attention, oiling and frequent repairs previously necessary to keep the positive pressure blowers in good order, so that very enthusiastic testimonials have been received. In these installations the valve in the discharge pipe may be opened or closed, putting on or off full factory load, without appreciable pressure variation or waste of air.

There is no possibility of wear in the centrifugal compressor, so that the efficiency and capacity always remain unaltered; actual tests of machines after long service confirm this. In this respect, the apparatus is vastly superior to the positive pressure blower, which has various rubbing surfaces that soon wear so as to cause serious leakage, and great decrease of efficiency and capacity. As already stated, actual tests of positive pressure blowers have shown a loss in the capacity of 50 per cent from measured displacement.

Blast Gates

A line of blast gates has been developed by the General Electric Co., and one of these should usually be placed in the discharge pipe. It is necessary that a blast gate be used for induction motor drivers, and it is desirable to have one for direct current drivers, in order to remove load when starting. A blast gate will also be found very convenient with steam turbine drivers. As in any fan blower, there is an open passage through the machine when not running.

POWER REQUIREMENTS OF RAILROAD SHOP TOOLS

By L. R. Pomeroy

Generally speaking, the generator capacity for railroad repair shops is equal to approximately 15 kw. per locomotive pit, or space in erecting shops occupied by one locomotive. This includes the requirements for tools, cranes, heating, blower and exhaust fans: i.e., provides for all power required except that needed for lighting.

The tools alone require about 9 or 10 kw. per pit; the heating, and the blower and exhaust fans demand 5 kw. per pit; while 3 kw. per pit will care for the ordinary shop and adjacent yard lighting. If in addition to shop requirements, power is needed for lighting terminal yards, buildings, etc., an increase in generator capacity must be made to cover such demands.

The following curves, Fig. 1 to 8, together with tables V to X, are submitted to cover the horse power requirements of the machine tools generally found in railroad repair shops.

Occasionally certain tools are selected for the purpose of performing extra heavy service, to utilize the full capacity of the new rapid cutting tool steel, as is now done in manufacturing shops. In such cases the power to drive the machine must be figured on the basis of service required, but as these cases are few and exceptional, the curves will be found to meet the majority of conditions, and the exceptions can be taken care of by the following formula:

Horse power to drive = $F \times D \times$ f.p.m. $\times 12 \times N \times C$ (1)

Where:—

F = feed in inches

D = depth of cut in inches

f.p.m. = feet per minute

N = number of tools cutting

C = a constant with the following values, depending on the class of material:—

Table I

Cast iron	0.35 to 0.5
Soft steel or wrought iron	0.45 to 0.7
Locomotive driving wheel tires	0.70 to 1.00
Very hard steel, such as crucible steel driving wheel tires	1.00 to 1.10

This formula is based on Prof. Flather's dynamometer tests, which check up fairly well with actual motor tests, and it is therefore submitted with confidence.

As an example of the accuracy of this formula, the aggregate horse power of 45 tests made with various tools was 247.7, while the calculated aggregate horse power by formula equalled 247.2.

The extensive tests made by Dr. Nicolson of the Manchester Technical School, England, confirm the correctness of the foregoing formula, and form a very interesting contribution to the subject. A careful analysis of the results of these experiments shows the average horse power required at the motor, per pound of metal removed per minute, to be as follows:

Table II

Medium or soft steel or wrought iron	2.4 h.p.
Hard steel	2.65 h.p.
Cast iron, soft or medium	1.00 h.p.
Cast iron, hard	1.36 h.p.

Using the symbols of previous formula the horse power becomes:—

$F \times D \times$ f.p.m. $\times 12 \times N \times W \times K$ (2)

where W equals the weight in pounds of a cubic inch of the metal, and K is the coefficient for that metal as given in Table II above. The value of W for the different metals is as follows:—

Table III

Cast iron	0.258
Wrought iron	0.278
Steel	0.284

The following examples illustrate the more or less heavy cuts to which reference has been made; the larger powers given are exceptional, while the average requirements are far below these, and all are submitted as actual cases which have come under the writer's observation:—

(a) 100 inch driving wheel lathe—(material steel driving wheel tires) 5/16" feed, 5/16" cut, at 18.5 feet per minute—two tools cutting.

Substituting in formula (1) we have:—
5/16 × 5/16 × 18.5 × 12 × 2 × C=40 h.p.
Same lathe, 3/16″ feed, 1/4″ cut, at 16 f.p.m.—two tools cutting
3/16 × 1/4 × 16 × 12 × 2 × C = 16 h.p.

(b) Old 76 inch driving wheel lathe. (material driving wheel tires)
1/16 × 1/4 × 16 × 12 x 2 x C=5 h.p.

(c) Steel tired wheel lathe (material engine truck wheels)
1/7 × 5/16 ×16 × 12 × 2 × C =17 h.p.

(d) Planer (material cast iron)
5/32″× 3/8″× 16′ × 12 × 0.35 (one tool cutting) ....4.5 h.p.
(two tools cutting)...... 9 h.p

(e) Planer (material wrought iron engine frame)
5/32″ × 1/2″ × 16′ × 12 × 2 × 0.5 (two tools cutting)............15 h.p.

(f) 76 inch boring mill (on cast steel driving wheel centers)
1/8″ × 3/4″ × 30′ × 12 × 3 × 0.45 (three tools cutting)............45 h.p.
Same machine boring driving wheel tire
1/8″ × 3/16″ × 28′ × 12 × 2 × 1 (two tools cutting............15 h.p.

(g) 84 inch boring mill (on 62″ cast iron wheel centers)
1/8″× 1/10″× 30′ × 12 × 3 × 0.35 (three tools cutting)............4.7 h.p.
Same mill boring 44″ steel tire
1/4″ × 3/32″ × 26′ × 12 × 2 × 1 (two tools cutting)...........14.5 h.p.

(h) The following is a special test on an extra heavy driving wheel lathe, and gives results representing unusual conditions. The operator was given a heavy bonus to develop the ultimate capacity of the machine.
Average feed 0.4625″, depth 0.0423″, at 12.2 f.p.m. (two tools cutting).

These figures are the averages of 37 tests, and represent a consumption of 40 h.p., while the maximum h.p. required was about 65. The machine was equipped with a 40 h.p. direct current motor with 2.1 per cent speed variation.

The lathe in question was a "special", extra heavy, and of about double the capacity and cost of the standard driving wheel lathe of equivalent size. On average work, the same investment if expended

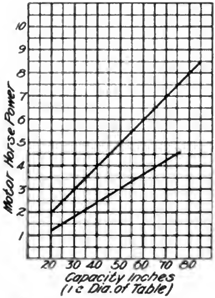


Fig. 1. Drill Press 15 to 20 Ft. per Min.

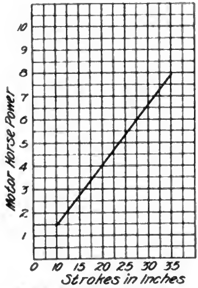


Fig. 2. Shaper 15 to 20 Ft. per Min.

on two lathes will turn out more work in a year than this special machine.

For rapid estimates, where the foregoing data is not available, the horse power required can be obtained by the following formulæ:

$$\text{(Single belt) horse power} = \frac{d \times f \times r.p.m.}{12 \times 400} \quad (3)$$

$$\text{(Double belt) horse power} = \frac{d \times f \times r.p.m.}{12 \times 400 \times 0.7} \quad (4)$$

where:

d = diameter of smaller pulley in inches
f = face of pulley in inches
r.p.m. = revolutions per minute.

These formulæ are very conservative and provide for about as much overload capa-

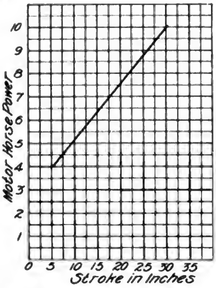


Fig. 3. Slotter Cutting 15 to 20 Ft. per Min.

city for belts as is ordinarily assumed for motors; they also provide a liberal allowance for the influence of centrifugal force, and for the diminishing arc of contact on the pulley when it is driven from a larger one.

They are especially useful in figuring the power required for wood working machines and were arrived at largely from experience with such apparatus.

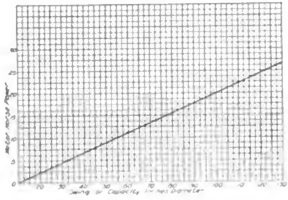


Fig. 4. Boring Mill One Tool Cutting 20 Ft. per Min.

Another formula, adapted from Ruleaux, giving somewhat higher values, is preferred by some as it considers the thickness of the belt. In this case the allowance for centrifugal force and for the arc of contact, being less than 180 degrees, is taken care of in the selection of values for the constant C.

Horse power = t × w × f.p.m. × C, (5)

or if the r.p.m. and not the f.p.m. is known:

$$\text{horse power} = \frac{t \times w \times d \times \text{r.p.m.} \times C}{4}$$

where

t = thickness of belt in inches
w = width of belt in inches
d = diameter of pulley in inches
C = a constant, of following values:

TABLE IV

Leather belt	0.0062 to 0.0098
Cotton belt	0.0036 to 0.0068
Rubber belt	0.0050 to 0.0082

The tool builders do not always discriminate between the requirements of manu-

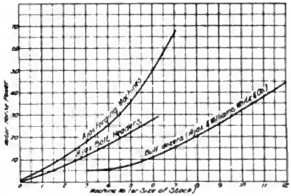


Fig. 5. Forging and Bolt Heading Machines

facturing plants and those of railroad repair shops, and for this reason motors are often recommended that are larger than necessary. For example; the *finished* product of the axle departments of such concerns as the United States Steel, Midvale, Bethlehem, and Cambria Companies, becomes the *raw* material for railroad shops. In the former shops the forging is turned out from the hammer without much regard to finished dimensions, as it is much cheaper to rough out to size on special rapid reduction lathes than to attempt to reduce to size under the hammer.

For such machining high power is required, but for the same lathes in railroad shops, where the work performed is mainly finishing cuts on journals and wheel seats, a smaller and cheaper motor may be selected.

The Bement-Niles lathe which was furnished the Howard Axle Works may be given as an example of extreme requirements, such as mentioned. The capacity of this machine is two cuts, each 5-8 inch by 1-8 inch at 60 feet per minute, and at this rate of cutting the machine will require a 60 horse power motor.

Another machine, built for the same class of work and used largely in axle shops and in many railroad shops, is capable of taking two cuts of 3-4 inch x 1-12 inch, at 24 feet per minute. This requires 18 h.p. and the machine is usually furnished with a 20 h.p. motor.

While this power is all right for the full capacity of the machine, 10 h.p. will cover the requirements of the same tool on average railroad shop work.

Number of pits required =

$$\frac{\text{(Total number of engines)} \times \text{(average number of days in shop)}}{300 \text{ [number of working days in year]}}$$

Examples:—400 engines; average days in shop, 25.

$$\text{Number of pits} = \frac{400 \times 25}{300} = 33.$$

$$\text{Capacity per year} = \frac{\text{(Number of pits)} \times 300}{\text{Average number of days in shop}}$$

In order to reduce to about 20 the average number of days in shop that are re-

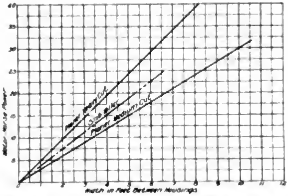


Fig. 6. Planers (Two Tools 15 to 20 Ft. per Min.) Ratio of Cut to Return 1:3

quired for general overhauling, it is estimated that the machine shop adjacent to the erecting shop should contain seven ma-

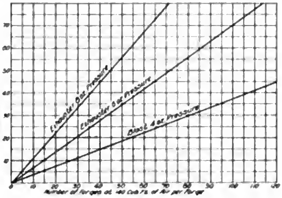


Fig. 7. Fans

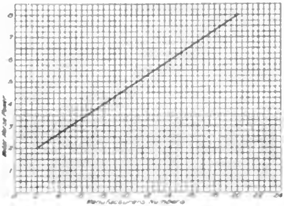


Fig. 8. Pipe Threading and Cutting Machines

chine tools per engine pit, and the floor area in order to accommodate seven tools per engine capacity, should be about 1500 square feet per pit.

Power required for air compressors equals the delivery of free air in cubic feet per minute, at 100 lbs. pressure of the compressor, multiplied by 0.14.

Modern erecting and machine shops, including heating, cranes, etc., cost from \$2.50 to \$3.50 per square foot of inside measurement.

$$\text{Rate per kw. hour to cover fixed charges} = \frac{\text{total fixed charges per year}}{\text{(max. demand)} \times 8760 \times \text{(load factor)}}$$

Illustration:

Fixed charges \$8330.00
Maximum demand .... 500 k.w.
Load factor .... 33 per cent

Then:

$$\text{rate} = \frac{\$8330}{500 \times 8760 \times .33} = 0.0057$$

TABLE V
BOLT AND NUT MACHINERY, HELVE HAMMERS, MULTIPLE DRILLS, ETC.

	Motor h.p. required to drive
1½" single head bolt cutter	1½
Pratt & Whitney No. 4 turret bolt cutter	2
2 spindle stay bolt cutter	2
1½" Acme double head bolt cutter	2½
1½-2½ Acme nut facer	2½
6 spindle nut tapper	3
1½" triple head bolt cutter	3
¾-2½" double head bolt cutter	3
2" triple head bolt cutter	5
4 spindle stay bolt cutter	5
Bradley hammer	7½
Niles 4 spindle multiple drill	7½

TABLE VI
GRINDERS

	Motor h.p. required to drive
Air cock grinder	1
No. 3 Brown & Sharp universal grinder	3
Link grinder	3
Sellers universal grinder for tools	5
Norton 18" x 96" piston rod grinder	5

TABLE VII
MILLERS

	Motor h.p. required to drive
Vertical miller Becker Brainard No. 2	1
Valve miller No. 2	2
Universal miller No. 3 Brown & Sharp	2
Universal miller No. 4 Brown & Sharp	3
Universal No. 6 Becker Brainard	5
Niles heavy vertical	10

TABLE VIII
PUNCHES AND SHEARS

	Motor h.p. required to drive
No. 4 36" throat L. & A. punch	3
No. 9 horizontal flange punch	5
No. 2 Hillis & Jones combination punch and shear	5
Alligator shear (stock 5" x 1")	5
Lenox rotary bevel shear	7½
36" multiple tank plate punch with spacing table	7½
No. 3 Hillis & Jones comb. punch and shear, 12" throat	7½
No. 2 horizontal punch 20" throat	7½
No. 3 Hillis & Jones combination punch and shear, 36" throat	10
No. 3 angle shear 5" x 1" bar	10

TABLE IX
SAWS

	Motor h.p. required to drive
Band saw, 36" wheel	3
Band saw, 42" wheel	5
Swing cut off saw	5
Band saw, 48" wheel	7½
Greenlee 1½ self feed rip saw	10
Greenlee vertical aut. cut off saw	15
40"-46" saws	15
Auto. band resaw	20
Greenlee No. 6 aut. cut off saw	20
Greenlee No. 3 rip saw	20
Woods No. 4 rip saw	20
Ex. heavy aut. rip saw	25

TABLE X
WOOD WORKING TOOLS

	Motor h.p. required to drive
Fay-Egan single spindle vertical boring machine	3
Fay-Egan 3 spindle vertical boring machine	4
Fay-Egan No. 6 vertical mortiser and borer	6
Fay-Egan No. 7 tenoner or gainer	7½
" universal wood worker	7½
" 4 spindle vertical borer	7½
" 5 spindle vertical borer	10
14" inside moulder	12
Fay-Egan universal tenoner & gainer	12
" vertical tenoner	12
Greenlee aut. vertical tenoner	15
Fay-Egan No. 3 gainer, also Greenlee	15½
Greenlee Ex. Range 5 spindle borer & mortiser	15
Greenlee vertical mortiser	15
Fay-Egan Auto. gainer, also comb. gainer & mortiser	20
Fay-Egan No. 8 vertical saw & gainer	20½
Vertical hollow chisel mortiser & borer	20
Fay-Egan 14½" double cyl. surfacer	20½
Heavy outside moulder	20
6 roll D. C. planer & matcher	25
Double cylinder fast flooring machine	30
Double cylinder planer & matcher	30
Fay-Egan No. 8 auto. tenoner	30½
Woods No. 27 matcher	35
4 side timber planer, heavy	60

ELECTRICAL EQUIPMENT OF A LARGE BREWERY

By Wm. Hand

The large breweries of St. Louis have spent a great deal of money in the past year or two in enlarging and modernizing their equipment; the W. J. Lemp Brewing Company alone has spent close to a million dollars in this manner, and the electric drive has been an important feature of these improvements.

The General Electric Company furnished the entire electrical equipment.

Power House

The system is 3-wire, 115/230 volt direct current. The present electric generating plant consists of the following 230 volt engine driven 3-wire generators:—

2—200 kw. 200 r.p.m.
1—100 kw. 250 r.p.m.
2— 60 kw. 280 r.p.m.
1— 30 kw. 300 r.p.m.

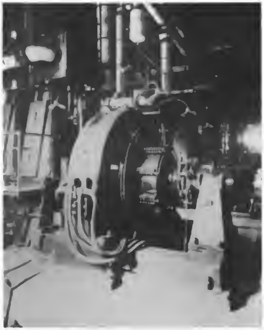


Fig. 1. Engine Room Showing Generators

with provisions for extensions. Figure 1 gives a partial view of the generator room.

One point is worthy of notice and that is the original plant was installed approximately 20 years ago with small Edison belted machines. These machines are still used by the customer but are employed as motors for driving centrifugal pumps and they still have on the original commutators furnished with the motors. This demonstrates the excellent construction of these machines and the durability of electrical apparatus when properly built and operated.

Fig. 2. Motor Driven Water Battery

Malt House

Fig. 2 shows the water battery, centrifugal pumps, and pipe connections, of the new malt house. These pumps handle 250 gal. of water each per minute, at a maximum head of 100 ft., and are driven by 2 CLB 960-1425 r.p.m. variable speed motors. It is essential that the water flow from these pumps shall never fail, and the pipes are therefore connected to the fire pumps. This means that the fire pumps can assist the pumps described above, and in case of fire these pumps can help out the fire pumps, making a very unique and successful method. Fig. 3 shows the wiring connections and speed control of the above motors.

Fig. 4. Barley centrifugal pump operated by one CR 10 h.p. 650 to 1200 r.p.m. variable speed motor. Handles 1500 bu. per hour.

The CR variable speed motor shown in Fig. 5 operates one air compressor, shafting and 3 grain elevators. This equipment is arranged for double duty by being belted to the floor below and relieves the equipment on that floor in case of accident or trouble.

The malthouse proper covers a gronad space of 160 x 100 ft. and the dimensions of the different buildings are as follows:

	Length	Width	Height
Steep House	18' 9"	100' 0"	70' 0"
Germinating House	98' 0"	65' 8"	60' 0"
Altemperator House	78' 6"	34' 6"	60' 0"
Kilns	100' 0"	38' 0"	100' 0"

The plant is constructed of stone, concrete, brick, and iron, is cement plastered

Fig. 3. Starting and Speed Control Mechanism

and has cement floors, and iron staircases throughout. The walls of the compartment rooms are lined with enameled brick, making the entire plant clean and fire proof.

The germinating house is three stories in height. The two lower floors contain the germinating compartments and the top floor is used as a working floor and contains the ventilating fan, centrifugal pump for washing the barley and the piping for unloading the steep tanks, also the air compressor for aerating the barley in the steep.

Compartments

The germinating rooms each contain four compartments, which are each 86′ long by 12′ wide and 4′ deep to the galvanized perforated steel malting floor, and three feet underneath this steel floor is a solid cement floor. The walls of the compartments are made of cast iron frames and steel construction, are lined with hard brick and plastered with cement.

The galvanized steel perforated floor on which the barley is grown, is made in sections to enable it to swing open, so that it and the solid cement floor underneath can be thoroughly cleaned. The water used for cleaning is carried off at the back of each compartment through pipes into the exhaust air pipe, in which is located a bottle trap connecting with the sewer.

Turning Machines

On top of the side walls of each compartment are located the rack bar rails on which the malt-turning machines travel. Each machine consists of a cast iron frame mounted on wheels carrying seven helices or turners, which reach to within a fraction of an inch of the galvanized steel floor, and which rotate continuously in opposite directions while the machine is in motion, thereby thoroughly turning and loosening the growing grain, without injuring kernels or sprouts and leaving the grain perfectly level throughout the compartment. These machines work automatically. On the bottom of each helix or turning screw is attached an elastic steel spring with a brush or scraper, which follows any unevenness of the perforated floor and is always in contact with it, so that each kernel is moved and lifted and makes the closing up of the perforations by sprouts impossible and insures a perfect circulation of air through the grain and consequently an even temperature throughout.

Fig. 4. Motor Driven Centrifugal Pump

The turning machines are propelled with rope drive. The drive sheaves are located on the wall in front of the compartments, and on this wall is also located the power spool for unloading the compartments. The tension sheaves are located on the wall at the back of the compartments. There are also guide sheaves for the ropes attached to the columns in the compartment rooms. Each turning machine has an independent friction clutch and an automatic stopping and reversing device, so that a machine can be stopped at any point in the compartment and reversed.

To insure against breaking, each machine has a safety device in the shape of a breaking pin, which will break if any obstruction is left in the path of the machine, through the carelessness of the maltster leaving implements or thermometers in the grain.

Sprinkling

To the turning machine is attached a brass sprinkling pipe which is connected by a hose to the water mains. These mains are fed by a pump which is fitted with a regulator, so that while sprinkling the grain, an even pressure is maintained, thus insuring a perfect and even sprinkling. The grain is sprinkled while the machine is in motion.

Ventilating

Back of the compartments are located the exhaust air flues which have valves connecting with the space underneath the perforated galvanized steel floors, and are

Fig. 5. Motor Driven Air Compressor

operated from the side of the compartments. There is a pointer showing how far the valves are open, so that any desired amount of air can be let in through the growing barley. The compartments being open on top, their contents are always in view for the inspection of the maltster.

Unloading of Compartments

In front of the compartments there is a gangway underneath which is a conveyor with a feeder over it. A scraper runs back and forth in the compartments and scrapes

Fig. 6. Motor Operated Grain Conveyor

the malt into the conveyor through the feeder, and by this conveyor it is taken to the green-malt elevator (located in the stair and machinery house) which elevates it into the conveyor on the top floor of the kiln house, where it is distributed through revolving sprouts to the upper kiln floor. These revolving spouts distribute the malt evenly on the kiln floor and are closed off by valves when not in use.

Attemperator House

The attemperator house is four stories high, two floors of attemperators to each floor of compartments. The attemperators supply the generating compartments with pure, cool, moist air. They consist of a series of perforated zinc sheet partitions, placed about three feet apart. Between these partitions run horizontal pipes to which are screwed vertical pipes, and on these are fitted atomizers. These atomizers are so constructed that two streams of water of opposite direction, under pressure meet, thus atomizing the water and spraying it on the perforated zinc plates, through which fresh outside air is drawn and is purified, cooled and washed. The surplus water flows to a tank located on the lower floor of the stair house. The tank has an overflow so that all impurities are floated off and the clean water used again, with the addition of fresh water in such amounts as temperature and moisture require. The pumps supplying the atomizers are located in the stair house, and are so arranged that any desired pressure can be maintained. The prepared air enters the germinating room through large openings in the side walls and is drawn downward through the malt into the space underneath the perforated steel floors and then through valves in the back of the compartments into an exhaust air flue, then into the chamber above, from which it is discharged into the open through an exhaust fan. The air being taken from the compartment rooms at the opposite side from which it enters, a perfectly even distribution and even temperature through the growing grain is effected. The temperature as well as the amount of air and degree of moisture, may easily be controlled to a degree during the summer or winter.

Steeping the Grain

The steep tanks are located in a separate building adjoining the germinating house. They are six in number (each holding sufficient grain to fill one half of a compartment). They are square, made of steel and have a hopper bottom, to which valves are attached. The size of steep tanks is 12 x 12 feet, with a depth of 7 ft. and 45 degree hopper bottom. On top of each tank is an overflow, all the water enters the tank from below and overflows at the top, thus bringing all impurities to the surface. The tanks are also provided with perforated air pipes for aerating the grain during the steeping. From the steep tanks the grain is carried with the water through a 4" pipe to a centrifugal pump, where it is given a good washing, thence it is carried through a 3" pipe to the compartments and there distributed by means of a hose, the water draining off through the perforations in the compartment floors. The grain is thus evenly steeped, washed and distributed. There is no steep smell whatsoever.

The barley is brought over from the storage elevator by a conveyor located in a tunnel, then through an elevator located in the steep house, then through a conveyor on top of the steep tanks, where it is distributed to the different tanks. In this tunnel is also located the malt conveyor, which takes the malt back to the storage elevator, where it is cleaned and distributed according to the different grades into different bins.

Kiln

The kiln is of the three-floor type, and is divided into two separate kilns, with

Fig. 7. Filling and Corking Machines. Daily Capacity 250,000 Bottles

a stair house between them. The floors are perforated steel dumping floors with hoppers underneath, into which the malt is dumped when finished.

Artificial draft is used, which is created by fans located above the upper kiln floors.

Fig. 6 shows a tunnel 350′ long leading from the new grain elevator to the new fermenting house. This is the longest line of conveyors in the world and is composed of three lines of 14" steel grain conveyors, triple strength, capacity 3000 bu. per hour. Each conveyor is driven by one CQ 15 h.p. 650 r.p.m. motor. The drive is direct by silent chain.

The north end of the bottling works is shown in Fig. 7. A long line of filling and corking machines are well in view. Also 10 soaking tanks or rotating sterilizing drums. This equipment is driven by 2 CE 10 h.p. motors. The capacity of this plant is 250000 bottles per day.

FUNDAMENTAL PRINCIPLES OF CENTRIFUGAL FANS

Part II

By Maxwell W. Day

Theory of Fans

As considerable confusion exists concerning the action of centrifugal pumps and fans, it may be well to give the fundamental principles. It is quite commonly supposed that the pressure developed by a blower or pump is due to the peripheral velocity of the water as it leaves the wheel; that is, the pressure, expressed as the head of the liquid or fluid, is equal to:—

$$\frac{V^2}{2g}$$

This, however, is not so, and furthermore a great portion of this peripheral velocity is not utilized in producing pressure, but is spent in eddies, unless a proper set of diffusion vanes be used.

In Fig. 4 let W represent a body revolv-

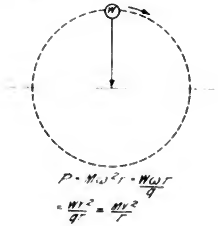


Fig. 4.

ing about the center, assuming the weight to be W, its mass will be:—

$$\frac{W}{g}$$

and the centrifugal force produced by it equals:—

$$\frac{W\ V^2}{gr} = \frac{M\ V^2}{r}$$

In Fig. 5 is represented a tube containing fluid, open at the inner end and revolving about the center B; each particle exerts an outward centrifugal force dependent upon its mass and its distance from the center. The total centrifugal force or pressure per square foot, P, of all the particles is equal to:—

$$\frac{W\ V^2}{2g} = \frac{M\ V^2}{2}$$

in which W and M represent not the total weight and mass, but the weight and mass

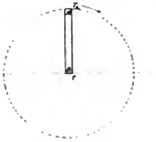


Fig. 5

$$d\,P = \frac{d\,r\,M\,V^2\,r}{r} = d\,r\,M\,\omega^2\,r$$

$$P = \int_{r=0}^{r=r_2} dr\,M\omega^2 = \frac{M\omega^2 r^2}{2}$$

$$= \frac{M\,V^2}{2} = \frac{W\ V^2}{2g}$$

of unit volume assumed in air calculations at 1 cubic foot.

If the tube, as shown in Fig. 6, does not extend entirely to the center, the centrifugal force will be less and is represented by:—

$$P = \frac{W}{g}\ \frac{(V_2^2 - V_1^2)}{2}$$

Fig. 7 represents a bent tube dipping in fluid and revolving about a vertical axis. The centrifugal force produced will raise the fluid to a certain height H. This height depends upon the pressure produced and is determined by the equation:—

$$HW = P, \text{ or } H = \frac{P}{W}$$

in which W represents the weight of unit volume and H the height of the column. Therefore, the height:—

$$H = \frac{V_2^2 - V_1^2}{2g}$$

Fig. 8 shows a simil-r tube extended to the axis of rotation, in which case V_1 becomes zero and the centrifugal force is, therefore, greater and the head

$$H = \frac{V_2^2}{2g}$$

It is not practicable in pumps and fans to get the full benefit of the entire radius,

Fig 6

$$P(AC) = \frac{M\omega^2 r_2^2}{2}$$

$$P(BC) = \frac{M\omega^2 r_1^2}{2}$$

$$P(AB) = \frac{M\omega^2 (r_2^2 - r_1^2)}{2}$$

$$= \frac{M(V_2^2 - V_1^2)}{2}$$

$$= \frac{W}{g}\frac{(V_2^2 - V_1^2)}{2}$$

because a certain inlet opening must be provided.

Fig. 9 represents a similar tube with the inner end bent forward in the direction of

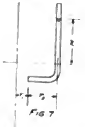


Fig 7

$$HW = P = \frac{W}{g}\left(\frac{V_2^2 - V_1^2}{2}\right)$$

$$H = \frac{V_2^2 - V_1^2}{2g}$$

rotation. This acts like a Pitot tube moving through water and produces a head equal to

$$\frac{V_1^2}{2g}$$

which makes up for the loss of centrifugal force, due to the fact that the tube does not extend to the axis of rotation. This reaction or Pitot tube effect produces a

Fig 8

$V_1 = O$ Then $H = \frac{V_2^2}{2g}$

portion of the head and the centrifugal force produces the rest of it.

If this tube were carried in a straight line through the water there would be a certain head produced:—

$$\frac{V_1^2}{2g}$$

but revolving it about an axis gives the advantage of the additional head due to centrifugal force,

$$\frac{V_2^2 - V_1^2}{2g}$$

If the vertical part of this tube be cut off

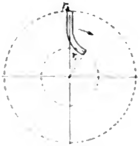


Fig 9

Cent. force $H_{cf} = \frac{V_2^2 - V_1^2}{2g}$

Reaction head $H_r = \frac{V_1^2}{2g}$

$$H = \frac{(V_2^2 - V_1^2) + V_1^2}{2g} = \frac{V_2^2}{2g}$$

below the head to which the water is raised, the water will flow out through the tube with a velocity, neglecting friction, due to the amount that the pipe is cut off below this head. Calling this amount H_2

and the velocity of the water through the tube as C—

$$C = \sqrt{2gH_2}$$

If the tube is revolved without any discharge of water, the only work done is overcoming friction, but if the water is discharged, work is done in raising a certain quantity of water per second through

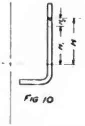


FIG 10

REDUCE HEIGHT OF PIPE WATER WILL FLOW WITH A VELOCITY $C = \sqrt{2g\ H^2}$

the height of the tube plus the kinetic energy of the moving water. This static head, to which the water is raised, and the velocity head of discharge, are, together, equal to the total head produced by the revolving pipe.

Taking the cu. ft. of water per second to be Q and weight of one cubic foot by k, the work done in raising the water will be equal to QkH, and as

$$H = \frac{V^2}{2g}$$

the work of raising the water is equal to—

$$Qk \times \frac{V^2}{2g}$$

In addition to this work, this same amount of water has been accelerated up to a velocity V, and therefore its kinetic energy due to this velocity is equal to

$$\frac{MV^2}{2} = Qk\frac{V^2}{2g}$$

and the total work done on the water or other fluid by revolving the tube is equal to

$$2 \times Qk\frac{V^2}{2g} = Qk\frac{V^2}{g}$$

which is double the amount of work required to accelerate the same mass in a straight line to a velocity V.

A wheel of a centrifugal fan or pump may be considered as several tubes or channels assembled together in a radial direction, taking fluid at the inside and discharging it at the outside ends, but the relative velocity with which it escapes out from the wheel is very much less than the relative velocity with which the inner edge of the blades approaches the fluid. Figure 11 represents the wheel of a pump with the pipe extending down in the water. After this has once been filled if it is rotated with sufficient speed, the water will be drawn up the pipe and discharged out throrgh the wheel, or a similar wheel rotating in the air without any casing around it will draw air in through the inside and throw it out at the outside. The centrifugal force produces an outward pressure, the head of which is equal to

$$\frac{V_2^2 - V_1^2}{2g}$$

and the static pressure of which will be equivalent to the total pressure diminished by the velocity of the outgoing air.

By turning the inner edge of the blades forward toward the direction of rotation,

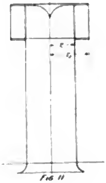


FIG 11

a reaction effect is produced the same as shown in the case of a revolving tube, and if the blades are bent sufficiently forward the combined reaction and centrifugal effect is equivalent to the centrifugal effect of blades extending entirely to the center, and is therefore equal to—

$$\frac{V_2^2}{2g}$$

the velocity head of the outgoing air.

As previously explained in the case of the revolving tube, there is, in addition to producing the pressure and velocity just mentioned a velocity of rotation also, which, when the wheel discharges freely into the air, is entirely lost and it is desirable, of course, in order to make an efficient fan or pump, that this kinetic energy should be saved.

The common way of doing this, which is however quite inefficient, is by the use of an ordinary spiral shaped scroll surrounding the wheel, and as the air leaves the wheel at high velocity it is gradually reduced in speed and leaves the outlet of the fan, as shown in Figure 13, with a velocity that is considerably reduced.

There is, however, considerable loss in eddies and the condition is similar to that of a small pipe discharging the fluid at high velocity into a larger pipe with less

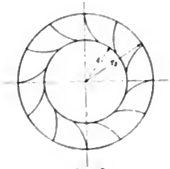


FIG. 12

velocity, the loss of energy being proportional to the square of the differences of the two velocities.

Figure 14 shows the velocity diagrams for which the following nomenclature is used —

W = Absolute velocity in space,

U = The peripheral velocity of the wheel, and

C = The relative velocity of the fluid along the blade.

Figure 1 is used to denote the velocities at the inlet of the wheel, and Figure 2 to denote the velocities at the outside of the wheel.

The velocity of the air going through the wheel depends upon the diameter and also upon the width.

The air which comes in through the inlet of the blower is suddenly turned and starts to enter the wheel in a radial direction. The inner edge of the blades moves rapidly through this air and the air travels outward through the wheel with a radial

FIG. 13

velocity which depends upon the area of the wheel at any particular point, and has a relative velocity along the blade depending upon the angle of the blade with the radius of the wheel.

To avoid impact losses when the air is suddenly caught up by the inner edge of the blade, it is desirable to have the blade cut the air on edge and not pick it up sidewise, and for this purpose it is desirable to make the inner edge of the blade in line with the resultant relative velocity.

Assuming that the air enters the wheel with a radial velocity W_1, as for instance

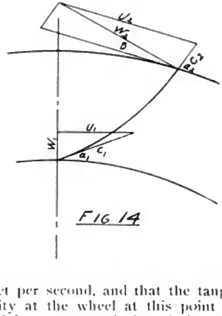


FIG 14

13 feet per second, and that the tangential velocity at the wheel at this point is U_1, say 72 feet per second, the relative velocity

is determined in magnitude and direction by completing the right-angle triangle shown in Figure 14, and its value is 73.2 and its angle from the tangent is a_1. With this shape of blade the air starts to move along the blade with a relative velocity of 73.2 feet per second, and leaves the outer

Fig. 15. Type EC-10 Centrifugal Fan, Direct Connected to Open CR Motor

edge of the wheel at a very much less velocity C_2, which is determined by the angle of the blade which may be assumed, for instance, to be 20° from the radius or 70° from the tangent.

Assuming that the air leaves the outer side of the wheel with uniform velocity throughout the whole surface of the wheel, its radial velocity will depend upon the area of the wheel and the volume of air passing through, which, in this case, is assumed to be 9.75 feet per second, and the relative velocity C_2, which is in a direction 20° from the radius, will be

$$\frac{9.75}{\cos. 20^\circ}$$

which equals 10.4 feet per second. The outer tangential velocity U_2 is assumed to be 96 feet per minute and the absolute velocity of the air in space W_2 is the resultant of these two velocities, which by solving this triangle is equal to 93 feet per second. This is less than the outer tangential velocity of the wheel on account of the backward slope of the blades.

The theoretical head produced by the wheel, disregarding friction and eddy losses, is as follows:

Assuming that the air is drawn directly from the atmosphere and is discharged by the fan under pressure, the static pressure at the inner edge of the wheel is less than atmospheric pressure by the velocity head.

$$\frac{W_1^2}{2g}$$

and also by the inlet losses, which, it is assumed, are neglected, the reaction head produced by the wheel is—

$$\frac{C_1^2 - C_2^2}{2g}$$

and the head produced by centrifugal force is—

$$\frac{U_2^2 - U_1^2}{2g}$$

and the velocity head of discharged air is—

$$\frac{W_2^2}{2g}$$

Fig. 16. Type EC-29 Centrifugal Fan, Direct Connected to Open CR Motor

all of which is measured above the inlet pressure which is less than atmospheric pressure by the velocity head,

$$\frac{W_1^2}{2g} \text{ and the inlet loss.}$$

Hence, the total theoretical head above atmospheric pressure produced by the wheel is—

$$\frac{(C_1^2 - C_2^2) + (U_2^2 - U_1^2) + (W_2^2 - W_1^2)}{2g}$$

There is quite a loss at the inlet where the air is suddenly turned from an axial to a radial direction. There is also loss in friction of air passing through the wheel, and a much greater loss in converting the velocity head of the discharged air into static pressure; and in addition to this there are losses due to leakage around the edge of the wheel, friction of the wheel revolving in the air in the case and bearing friction.

If the inner edge of the wheel is laid out strictly in accordance with the velocity diagram, the blade may be too flat to properly resist centrifugal force and on that account it is desirable sometimes to slightly depart from this angle, but a slight change does not seriously affect the efficiency.

On account of the importance of efficiently converting the velocity head of the discharged air into static pressure with the ordinary construction of centrifugal pumps, it is customary to give the blades a very strong backward angle at the outside of the wheel to reduce its absolute velocity as much as possible, but in fans it is not so necessary and a good efficiency has been obtained with blades which actually curve forward at the outside end.

For turbines, pumps and centrifugal air compressors guide vanes are provided in the casing beyond the outer edge of the wheel, which receive the fluid on the edge of the blades and gradually reduce the velocity before it is delivered to the outer part of the casing, and in this way a large part of the velocity head is recovered as static pressure.

With few blades and especially if they are shallow in a radial direction, the air does not strictly follow the curve of the blade but passes through the openings in the wheel with a greater backward angle than the blades, as is shown by calculation which I made on a standard fan in which the total calculated energy put into the air by the formula given above was greater than the output of the motor, which showed that the absolute velocity was much less than the mathematical calculation would indicate. This does not mean that the energy is wasted because, although the developed pressure is reduced, the power to drive is also reduced.

Standard Fans

These fans, as explained in the GENERAL ELECTRIC REVIEW of Jan., 1907, are convertible and they can be turned in sixteen different directions for steel plate fans and eight different directions for the cast shell fans, besides being able to change the fan to run in the opposite direction for each one of the different positions.

The illustration on the cover of this issue of the REVIEW, together with Figs. — and — of this article, show the general appearance of these fans.

Besides being used for ventilation of vessels, these fans are adapted for ventilating transformers, turbo-generators and other electrical apparatus, and for general building ventilation and forced draft for boilers.

Where there is to be no inlet pipe, it is frequently desirable to use a fan with a double inlet in which case the fan casing and wheel are double the ordinary width and will deliver double the quantity of air of the single inlet without being run at a reduced speed, thus allowing the use of higher speed motors for the same delivery than the single inlet fans. When either single or double inlet fans are used for this purpose, they are provided with a bell shaped inlet as, otherwise, on account of the vena contracta the incoming stream does not completely fill the inlet at full velocity, and therefore the velocity in the center of the inlet is very high and a considerable head is lost. I believe that energy equal to hundreds of horse-power is being continually lost throughout the country on account of the omission of this type of inlet and the discharge chute on fans, which could conveniently be equipped with them.

MAGNETITE HEADLIGHT

By G. N. Chamberlin

The characteristics of the metallic or magnetite arc which have made the system an important factor in street illumination are now well understood. The details of arc control, electrode composition and lamp mechanism have been perfected and about 15,000 lamps are in successful operation.

The magnetite arc, which has made this street lighting system a success, is found to be ideal for locomotive and street car headlights.

The demand for a powerful and reliable headlight has increased rapidly with the extension of high speed interurban railroads. These requirements until the present time, have been quite satisfactorily met by the enclosed arc headlight.

The new headlight which is shown in Fig. 1 is very similar in external appearance to the carbon headlight, and consists of a galvanized sheet-steel casing about 15" in diameter, 9" deep, reinforced by iron door castings, making a rigid structure.

The mechanism is not of a regulating type, but so arranged as to strike an arc of a fixed length. With the slow rate of burning of the electrodes there are sufficient interruptions of the circuit incidental to regular operation to maintain the arc within safe voltage limits. This permits of a more simple and substantial construction, suitable for railroad service as found in high speed interurban cars. The lamp, together with reflector, being held in place by one wing nut on the back of the casing can be readily removed for inspection or repair (Fig. 2).

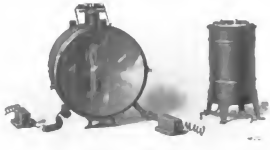


Fig. 1. Magnetite Headlight and Series Resistance

In order to protect the arc from air which might otherwise get between the sections of glass and the door, there are two separate panes used with the joints overlapped. The use of sections or slats instead of solid glass lessens the liability of breakage from extreme temperature changes.

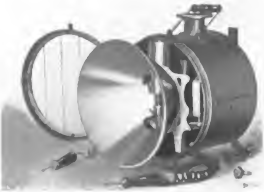


Fig. 2. Magnetite Headlight Opened

At the focus of a highly polished metal reflector is the magnetite arc. The upper electrode is a "T" shaped copper forging. Having a life of 2000 to 3000 hours, it may be considered as non-consuming, and being stationary, forms an arc which remains in the focus of the reflector. This upper electrode is held at the bottom of the draft chimney, where the natural draft keeps the arc burning on the electrode ends and carries off the fumes of iron oxide. The chimney is covered at the top by a hinged shield so designed as to protect the arc from high winds and rain, and makes the tubes easily accessible for cleaning with a brush furnished for the purpose. The lower electrode consists of an iron tube ½" x 5" filled with material which will give the necessary vapor in the arc stream to produce an efficient luminous arc.

That the track illumination is most satisfactory is shown from illustration on page 174, which is a reproduction from a night photograph. The headlight not only illuminates the track for a distance of 1200 to 1800 feet ahead of the car, but the beam is exceptionally broad.

The lighting of a considerable area each side of the track is found to be of great assistance to a motorman in approaching and taking curves; also an additional insurance against collision with vehicles, animals or persons approaching the track.

The magnetite headlight is designed to operate at 75 volts and 4 amperes. The difference between the line potential and arc potential may be taken up in the re-

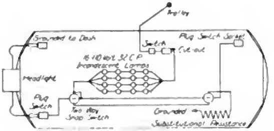


Fig. 3. Diagram of Car and Headlight Wiring

sistance shown in Fig. 3. While the use of such a dead resistance gives satisfactory operation, incandescent lamps for lighting the interior of the car may be employed instead, thereby utilizing the energy represented by the difference in voltage between line and arc. Different combinations of incandescent lamps can be used to make up this resistance, according to the number of lamps required to light the car. One very satisfactory combination is a group of sixteen 32 C.P. 110 volt lamps, consisting of four series of four lamps each, connected in multiple. If it is desired to increase the number of lamps in the car, thirty-two 16 C.P. lamps may be used, in eight series of four lamps each, connected in multiple.

If it is desired to keep these incandescent lamps burning when the headlight is removed, or while it is being transferred from one end of the car to the other, a substantial resistance unit may be employed, wired up to a pair of two-way snap switches, one placed at each end of the car. This arrangement permits the headlight to be turned on or off without interfering with the incandescent lamp. Suitable connections for this arrangement are shown in Fig. 3.

The vapors which make the metallic arc of high illuminating value come from the negative electrode, so it is evident that in order to get this high candle power arc, the lower or composition stick must be negative. This peculiar characteristic may be further taken advantage of in producing a dimmed light, where one is required for certain sections of the car route. With the current reversed and reduced to 2½ amps., a copper arc of low efficiency is produced of an intensity suitable for city operation. Fig. 4 shows suitable wiring for such connections. This two-part resistance will be furnished when required and the advantage of an available switch within reach of the motorman for immediately dimming the light will be appreciated by anyone approaching in another street car, automobile or other vehicle.

Several of these new headlights have been in actual operation on high speed interurban cars for several months, giving in each case very gratifying results. That this new headlight must practically supersede the enclosed headlight, is evident from a review of its following advantages.

1st—The higher efficiency of the magnetite arc giving quantity and quality of illumination.

2nd—Arc maintained at focus of reflector, insuring permanent direction of rays.

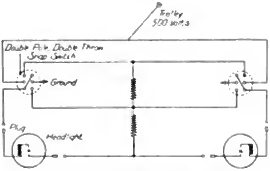


Fig. 4. Reversing Switch and Wiring

3rd—No enclosing globe used thereby eliminating greatest expense of enclosed headlight maintenance.

4th—Long life of electrodes—2000 to 3000 hours for upper, 50 to 75 hours for lower, showing a further reduction in operating expense.

5th—Available means of quickly and effectually dimming the light—a modern method as compared with the use of screens hung in front of headlight door.

NEW LOW TENSION MAGETO

By M. J. Fitch

The growth of the automobile industry has been accompanied by a marked increase in the use of magneto ignition, so that now the magneto is considered an important factor in the equipment of not only high priced automobiles, but wherever improved and advanced devices are considered as essential and as adding to the worth of the machine itself.

The principal arguments for the adoption of magneto ignition are—reliability, ease of maintenance, simplicity and uniform quality and strength of spark,—all vital qualities. The magneto being geared or driven by chain from the engine itself ensures a supply of energy for ignition at correct and regular intervals. In design it is simple; it eliminates complicated wiring, with its attendant dangers of short circuits; vibrating spark coils; and batteries, which are always more or less troublesome and require much attention.

Fig. 1. Low Tension Magneto

The demand for magneto ignition has now become so general that the General Electric Co. has developed a magneto which embodies the most desirable of those features of construction which in past experience have proven eminently successful.

The low tension magneto may be regarded as the fundamental type; consequently, this has been developed first. Mechanically, it differs in many respects from other machines on the market at the present time. The general construction is

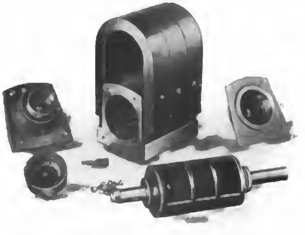


Fig. 2. Parts of Low Tension Magneto

most substantial and minus all superfluous trimmings, yet sufficient weight has been incorporated to ensure stability and durability of all parts.

Lubrication is effected by use of waste packing, in the same manner as has been successfully applied in connection with General Electric automobile motors.

Generous oil wells are provided with overflow holes to prevent excess lubrication. The type of bearing above described eliminates the small wick oiling device heretofore so often used, and ensures the ample lubrication necessary for these machines. The oil wells are readily accessible, and when covers are in place, are dust proof and will operate for months without attention. Oil bafflers are provided on both ends of the armature to prevent oil from working into the armature and interior parts of the magneto. Ample bearing surfaces are provided, as well as a shaft of large diameter to ensure strength, rigidity, and a minimum amount of wear. The base and bearings are of bronze and are given a sand blast finish which presents a very attractive appearance. It has been found that bronze is a more satisfactory metal than aluminum, as it is less fragile, much more durable, and looks cleaner after extended use.

One end of the armature winding is brought out through the hollow shaft by means of a steel conductor. The insulation bushing between the shaft and the conductor is of bone, which experience indicates is very satisfactory, as it is little affected by moisture or heat. To avoid loose contacts, the current is carried from the steel conductor by means of a phosphor bronze spiral spring to the outside terminal, which consists of a lever nut. The contact with all its parts is carried in a hard rubber cover screwed to bearing and provided with a knurled surface on the exterior, so that it may be readily grasped by the hand. The grounded side of the armature winding is firmly fastened to the core, and a carbon brush insures a good contact between the armature winding and the frame or ground.

Long experience of the General Electric Company in producing millions of permanent magnets for meters and instruments has been of material assistance in the design and manufacture of permanent magnets for these magnetos. The magnets are of the double type, sprung on the frame and secured by but one screw on each side, thus reducing to the smallest amount the detrimental effect caused by drilling.

Drilling of the pole pieces is also avoided so far as possible, the bearings being screwed to the top and base of the frame rather than to the poles.

When it is in a vertical position the armature core slightly overlaps the pole gap and there is therefore at no time a complete breakage of the permanent flux, and demagnetizing of the field magnets is prevented.

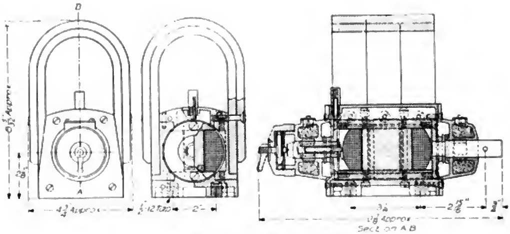


Fig. 3. Elevation and Cross Sections of Magneto

In order to secure a high short circuit current, the resistance of the armature winding is as low as possible, yet the number of turns is sufficiently high to give an adequate open circuit voltage. The dimensions of the armature permit both of these advantages to be achieved, and also allow generous insulation. An open circuit voltage of over 100 volts is easily obtained and approximately 0.4 of an ampere in short circuit current.

ELECTRIC DRIVE IN COTTON GINS

By A. N. Feinemann

If every cotton gin in the United States could be equipped with electric motors, the total horse power required would approach the million mark, as there is scarcely a town in the "Land of Cotton" so small but that it supports at least one gin, and sometimes three or four.

An example of a modern gin equipped with electric drive is shown in the accompanying illustration, which gives an external view of the W. H. Coyle Company's gin at Guthrie, Oklahoma, the power for which is supplied by the Guthrie Light and Power Co. The gin proper is shown in the foreground, while the tower shaped building is an unloading house containing two motors, one of 15 h.p. and the other of 7½ h.p. capacity.

Electrically Operated Cotton Gin and Oil House

The large buildings in the rear are a part of the cotton oil mill. One of these being the seed house, which is used as a store room for the oil mill and takes the product of some twenty or more gins. An 85 h.p. motor is installed in this building and is used for elevating, unloading, and cleaning the seed, as well as for driving a large screw conveyor which carries the seed the entire length of the seed house and some eighty feet into the oil mill.

It may be remarked, that the seed house bears the same relation to a cotton oil mill that a grain elevator does to a flour mill. The seed house being some distance away from the main engine, requires a good deal of shafting, with a consequent loss of power in bearings and belting and, in addition, the cleaning and unloading from an intermittent load. For these reasons, it can be shown that a material saving will be effected by equipping a seed house with motors.

Returning to the present installation: The gin proper consists of a two story, four stand outfit, with two presses equipped with friction tramper and hydraulic ram; while there are also separate unloading and storage houses supplied with the necessary accompaniment of elevator, conveyors, and fan.

The gin itself is operated by a 2080 volt three phase motor, of 60 h.p. capacity and running at 720 r.p.m. This is belted to the main shaft in the basement, and to this shaft are belted the four gin stands, the friction tramper, and the power pump for the hydraulic ram. Oil, however, is used in the ram instead of water, as it proves more satisfactory.

The fan is driven by a separate 15 h.p. motor, while one of 7½ h.p. drives the unloader and cleansers in the storage house. Both of these are three phase machines and are operated at 220 volts and 60 cycles.

Gins of this capacity may be operated from one 75 h.p. motor, but as it is often desirable to run the unloaders and cleaners without the gin, it is advantageous to use several motors. The Coyle gin has more power than is necessary.

The Guthrie Light & Power Co. has a contract with the Coyle Gin Co. for a flat rate of 50 cents per bale, including all operations, and which calls for a minimum amount of $500.00 per year for power. For the past season, this was equivalent to about 4.1 cents per kw. hour, and in consideration of the special rate, the Gin Company agreed not to operate the large motor during the peak hours in the winter months. The small motors may, however, be operated at that time, and during the busy season sufficient cotton can be unloaded and stored up to supply the gin proper from 9 A.M. until 12 P.M., or longer. This is another advantage to be gained by operating an unloading and cleaning house with individual motors.

Both the owner and the operators of the gin are extremely well satisfied with the electric drive, and Mr. Coyle, who owns a great number of gins, regrets that the majority of them are located in small villages where it is impossible to obtain electric power.*

In installing the electric drive in a gin already built, it is very desirable to do away with the screw press, as this press throws a heavy temporary load on the motor, requiring a larger machine than otherwise necessary, and thus affecting the regulation of the entire system. The press is not always abandoned, however, and if the motor is of sufficient capacity the press, together with the tramper, may be retained by simply substituting the motor for the steam engine, no other change being necessary. Where a hydraulic press is to be used the screw press must, of course, be taken out, and a power pump added to the equipment.

The manufacturers of cotton gin machinery are well equipped for supplying the necessary appliances for substituting motors for steam engines, inasmuch as a number of electrically driven gins have already been installed, and the manufacturers are conversant with the requirements.

*The General Electric Company manufacture a line of generating sets that are well adapted for use in localities like these, where it is difficult or impossible to secure reliable electric power. These sets consist of a gasoline engine direct connected to a generator and are furnished in various sizes up to 200 Kw.

COST OF COOKING BY ELECTRICITY

Mr. E. L. Callahan, Oak Park, Ill., has employed General Electric heating appliances in his home for all cooking and baking and has kept a careful record of the cost and current consumption for a period of twelve months. During this time, two to three meals per day were prepared for one to three persons. The total single-person-meals (number of meals multiplied by number of persons) was 3035. The power consumed was 803 kilowatt-hours, or 264 watt-hours per person per meal, which, at 5 cents per kilowatt-hour, is equal to $.0132 per person per meal.

The following utensils were employed:—

One 6 qt. Vegetable or Soup Boiler
One 2 qt. Vegetable and Cereal Cooker
One 2 qt. Water Heater
One 1 qt. Water Heater
One 5 inch diameter Frying Pan
One Oven
One 7 inch diameter Frying Pan
One 6 inch Stove
One 12 inch Gridle
One 12 inch Broiler

INDIVIDUAL MOTOR DRIVE FOR LITHOGRAPHIC PRESSES

R. J. Binford

The plant of Messrs. E. P. & L. Restein Company, Lithographers, corner of Dickinson and 7th Streets, Philadelphia, presents a good illustration of electric drive. This company are manufacturers of calendars and advertising novelties.

The plant occupies a three story brick structure, 65 x 120 feet. The offices are in the front part of the first floor—the greater part of which floor is devoted to the press room. The storerooms and designing department are on the second floor, while the third floor is devoted entirely to cutting and packing. On this latter floor are a number of cutting machines, which will be driven by a single 20 h.p. motor belted to a line shaft.

In the press room are nine large presses and one bronzer. At the present time only two of the presses are operated by motors, one of these presses being a Potter No. 5. The application of the motor to this press is as follows:

Directly behind the driving pulley of the press is a Reeves variable speed countershaft, which is driven by means of a General Electric 2-phase, 60 cycle, standard induction motor. This motor is located directly back of the countershaft, and the whole driving equipment, consisting of the Reeves countershaft and the motor, is covered by means of a platform built up around the operating side of the press. This platform serves a twofold purpose, namely; to operate the driving equipment, and to provide a platform for the pressman. The starting compensator is mounted on two upright pieces just to the right of

Induction Motor Driven Lithograpic Presses

the pressman's position. The adjustment handle to the countershaft is reached by raising a section of the platform directly over the countershaft. This handle is located in the countershaft apartment arrangement. As there will at no time be sheets going through the presses when changing the speeds, this arrangement is satisfactory.

The other press operated by motor drive is a Hoe, 3½, and has a countershaft similar to the one on the Potter, but arranged under the press so that the pulley extends out behind the press pulley. The motor used in this case is a General Electric standard 2-phase-60-cycle-induction motor, and occupies a position on the floor alongside of the press, directly back of the countershaft. As the countershaft is located under the press, it was only necessary to build a small bridge over the motor to protect it—the pressman's platform being to the right. The compensator is mounted in a similar manner as on the Potter, but to the left of the pressman's position.

The service to these motors is obtained from lines of the Philadelphia Electric Company.

The Potter is a new press, and has just recently been installed together with the motor, and consequently a comparison cannot be made, but in the case of the Hoe 3½, where with the old steam drive to line shafting, 750 to 800 impressions were made, there can be obtained at the present time anywhere from 950 to 2000 impressions.

It has been decided to equip the entire plant with electric drive. The line shafting is to be cleared away, thus giving the press room more light, and in the space taken up by the steam engine there is to be located a new press, making in all ten presses, which will be operated by individual motors. The elevator is in the front of the building, and will also be operated by a motor.

Mr. S. W. Bowerman sold and installed the present motors, and during the coming year will install motors amounting to 105 h.p., thus equipping the entire plant.

NOTES ON EMERGENCY REPAIRS

By W. G. ELY, Superintendent
General Electric Company's Construction Dept.

Aside from the difficulties met with in the regular routine of installing apparatus, the construction man is often called upon to use his ingenuity in making emergency repairs, and locating troubles. A few examples may be of interest.

On one occasion, the armature of a 750 KW 2300 volt alternator, bar wound, burned out, and inspection showed that a number of bars would have to be replaced. As is usually the case, the customer had not seen the advisability of carrying any repair parts in stock, and it was necessary to call on the factory for new bars. Unfortunately the factory had none in stock, and advised that it would take from a week to ten days to ship properly insulated bars. As the disabling of the generator seriously crippled the output of the station, the customer appealed to the construction man to help him out, at least temporarily, until repair material arrived.

A close search of the town resulted in the discovery of a few copper stay bolts. These were hammered and filed to approximately the proper size, and then formed and taped with several layers of cotton tape, and thoroughly filled with P & B paint. These improvised bars were then dried on top of a boiler over night. Within twenty-four hours from the arrival of the construction man on the ground, the temporary bars were installed, and the machine in service. It might be interesting to know that contrary to expectations, no trouble was experienced with these bars, before the permanent repairs were made.

On another occasion, on being called upon to dry out several large direct current generators, that had been partially submerged in water for a number of hours, the usual methods were applied, that is the generators were short-circuited with the fields bucking, giving any where from full load to 50% over-load current. After running twenty-four hours frequent insulation tests being made, it was found that a point had been reached where additional running did not seem to accomplish any results on the armature, although the insulation resistance was still considerably too low to warrant putting the generator in service, while the field coils tested out satisfactorily. Concluding that the trouble must be in the commutator, a number of blow torches were used to drive out the moisture. This however, did not appear to accomplish the desired result, and it was decided that if the trouble was in the commutator, the inability to get any results was due to the fact that moisture had no chance to escape.

Several of the bolts passing through the commutator were then removed, and funnel shaped tubes were fastened in the bolt holes on the outside of the commutator, with the mouth of the funnel facing the direction of rotation. The machine was then brought up to speed, air was forced into the commutator, and out the holes at the back. The drying out process was then completed in a remarkably short time.

Another interesting case occurred in connection with an accident to a transformer, where a short length was burned out of several of the outside turns of one of the coils. No copper ribbon was available to make repairs. The difficulty was overcome however, temporarily, by removing the outside damaged turn, and using it to piece out the other turns. The transformer was then operated satisfactorily, less one turn.

First appearances often indicate a far more serious situation than really exists. In fact oftentimes the real trouble is so trifling that it is overlooked at the beginning of the investigation. One small Company, operating a number of mono-cycle generators, had one of the machines burn out, and ordered a full set of armature windings, and an armature winder to install them. On the installation of new coils the generator was started up, and operated satisfactorily with the exception that it would not run in parallel with the other generators in the station. As this machine had operated in parallel with the other machines for years, the customer assumed that the trouble was in the winding. The armature winder was positive that he had connected the machine properly, and it was found that the connections to the switchboard were correct. The customer became very much excited and telephoned in for a competent man to be sent at once, to locate the trouble. An investigation by the expert showed that everything about the generator was all right. He then turned his attention to the engine and pulleys. He found that the pulley on this generator was slightly smaller than on the other machines. On calling this to the attention of the customer, he admitted that while the generator was shut down waiting for repairs, he noticed that the pulley had a very shiny surface, and that he had put it in the lathe, and had a cut taken off, in order to make the belt stick to the pulley better. He was very much surprised to know that this would effect the operation of this machine in parallel with the others.

FOR SALE—DISPLACED

The following is an extract from a letter received at the Chicago Office of the General Electric Company:

"Enclosed, find a photograph (Fig. 1) of two carloads of engine and boilers,

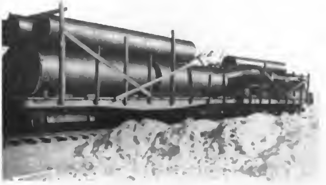


Fig. 1. Two Car Loads of Boilers and Engine, Replaced by G. E. Motor

which were sent here for the ———— Elevator Company. They are for sale, having been displaced by 125 h.p. General Electric motor, the current for which is to be furnished for five years by the Oklahoma Gas & Electric Co.

The cost of material, as you see it on the cars, was $3465.00, besides which there is $2000.00 worth of materials for a power house which is not to be used. The cost of the motor installed, including belts, etc., was $1775.00.

Yours very truly,
OKLAHOMA GAS & ELECTRIC CO."

Fig. 2 shows the motor that has replaced these two carloads of "steam fittings."

This is but one of the many grain and elevator plants that have found it advantageous to employ electric drive in place of steam. One elevator concern has estimated the power used at 15 1 3 kw.

Fig. 2. G. E. 125 h.p. Form M Induction Motor

hours per thousand bushels of grain, which is equivalent to a trifle over 1 50 of a h.p. per bushel.

The induction motors built by the General Electric Company are peculiarly adapted to work of this description, as in addition to materially reducing the cost by dispensing with the necessity for a power house, the services of an engineer and fireman, and the outlay for fuel; all sparking and risk of fire are eliminated, a matter of serious consideration in buildings of this description where the air, being supercharged with dust, is liable to ignition or even explosion.

ABSTRACTS OF IMPORTANT TECHNICAL ARTICLES

Illustrated *

The McCall Ferry Hydro-Electric Power Plant on the Susquehanna River

(Engineering News, Sept. 12, '07, p. 267**)

An excellent description of the engineering features of the hydro-electric plant, now under construction near the town of McCall Ferry, Pa. The equipment will consist of ten pairs of Francis turbines mounted on vertical shafts, and driving 7500 kw., 94 r.p.m., 11,000 volt, 25 cycle General Electric generators. Two 1,000 h.p., 240 r.p.m., 250 volt turbine driven exciters will be used for field excitation.

Oil Engine Driven Power Plant of the Pittsfield Electric Company

(Electrical World, Sept. 7, '07, p. 446*)

The new station is to assist an old steam plant, and is equipped at present with one 350 kw., 60 cycle, 2300 volt, two-phase Stanley alternator, which is direct driven at 154 r.p.m. by two three-cylinder Diesel engines. A 15 kw., 900 r.p.m., 120 volt induction motor driven exciter furnishes excitation for the alternator field.

At night the plant operates the street lighting circuits of Pittsfield, and the street and commercial lighting circuits of Dalton. In the daytime it operates a synchronous motor generator set, which supplies direct-current at 500 volts to the net work of feeders in the business district of Pittsfield.

Gary Plant of the Indiana Steel Company

(Railway Machinery, Sept., 1907, p. 27)

All auxiliary machinery of the rolling mill will be driven by electric motors. The mill will consume approximately 10,000 kw. to be obtained from blast furnace gas engines, driving three-phase alternators. The principal machines, together with the units for driving them, are as follows: Breaking-down stands for reducing ingots to fair sized blooms, two 2250 h.p. motors; blooming mill, 6000-9000 h.p. motors; intermediate mill, two 4500 h.p. motors; finishing mill, 2500 h.p. motor.

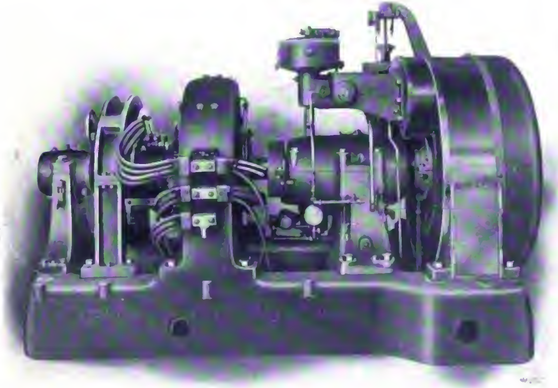
The Kaministiquia River Water Power Developments

(Electrical World, Sept. 14, '07, p. 519*)
(See also Electrical World, Jan. 26, '07, p. 179)
(General Electric Review, March, 1907, p. 124)

Additional information pertaining to the Kakabeka Falls power house of the Kaministiquia Power Co. This power house has an initial installation of 14,000 h.p., and an ultimate capacity of 40,000 h.p., all machines and apparatus being of Canadian General Electric Co.'s make.

GENERAL ELECTRIC REVIEW

VOL. IX No. 6
PUBLISHED MONTHLY BY
GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU
SCHENECTADY, N. Y.
NOVEMBER, 1907



Type CC 4 pole 100 kw. 2400 r.p.m. 125 Volt Curtis Steam Turbine

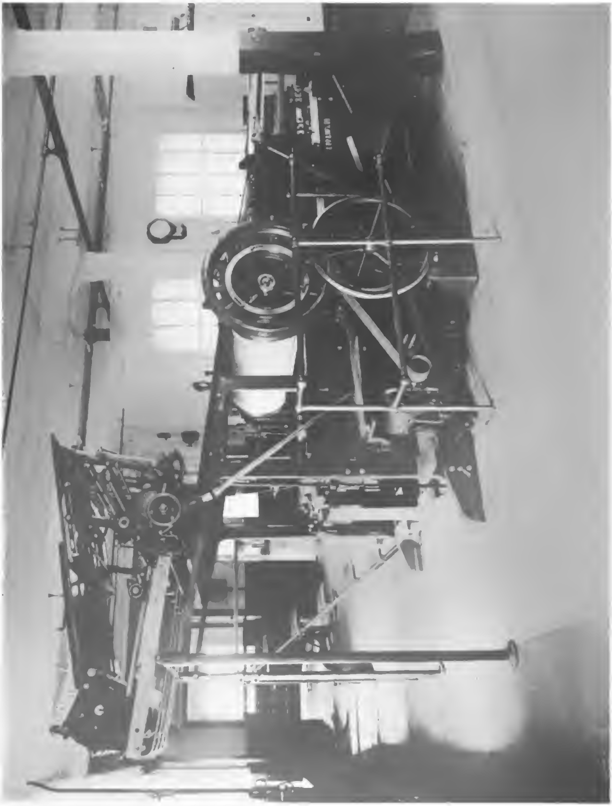
(See page 237)

GENERAL ELECTRIC REVIEW

VOL. IX NO. 6

NOVEMBER, 1907

CONTENTS



Flat Bed Press with Automatic Feeder, Showing Driving Motor

(See page 226)

Vol. IX No. 6 SCHENECTADY November, 1907

GENERAL ELECTRIC REVIEW

ELECTRIC DRIVE IN CEMENT PLANTS

By W. C. Durant

It is safe to assert that there is no staple product of manufacture in the United States of which the output has increased with such rapidity as Portland Cement. In 1880, the country produced 42,000 barrels of this commodity. In 1890, the output had grown to 335,000 barrels. At about that time the possibilities of reinforced concrete for building purposes began to be appreciated. New cement plants were constructed to meet the demand. The manufacture of cement was enormously stimulated, until in 1906 the United States produced 46,500,000 barrels—over 1000 times the output of twenty-six years ago.

Fig. 1. 2-I-4-10-750-K-440 volt motors flexibly coupled to Buffalo blowers, used to force a mixture of air and coal dust into the slag and limestone dryers. Similar blowers are used for forcing powdered coal into the rotary kilns. The apparent fog around the right hand machine is due to the large amount of dust in the air

The following curve illustrates graphically the steady and increasing gain in production from 1890 to 1906. As opposed to this gain, the output of natural cement has fallen off since 1899, and mills producing this class of cement have been forced either to limit their output, or to install rotary kilns and manufacture Portland. The third class of cement, called

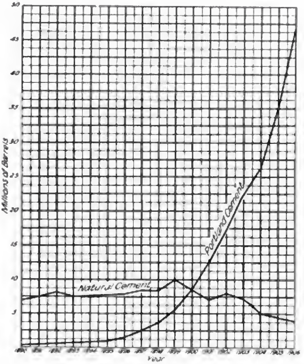


Fig. 2. Curve showing production of Cement in the United States from 1890 to 1906

Puzzolan, or slag, is showing a small but steady increase. The production has increased from 280,000 barrels in 1901 to 480,000 barrels in 1906. The total production of hydraulic cement in the United States in the last year was 51,000,000 barrels, 91 per cent of which was Portland.

In spite of the astonishing growth of this industry, the demand is still unsatisfied. Our exports—never very large—dropped from 900,000 barrels in 1905, to 580,000 in 1906; and the imports increased in the same time, from 850,000 to 2,200,000 barrels. In view of the increasing number of building operations for which concrete is found to be peculiarly adapted, including railroad, dock and harbor work, office buildings, aqueducts, bridges, canals, tunnels, factories, hotels, dwellings and many other constructions, there appears to be no probability of any diminution in the rate of growth of the cement business for many years.

The Manufacture of Portland Cement

The essential elements of Portland cement are alumina, silica, and lime; which are ground finely, mixed in the right proportion, (approximately 8% Al_2O_3, 21% SiO_2, 62% CaO, and 9% impurities impossible to eliminate commercially), and roasted at about 2800 deg. F., when it is again ground. There are many raw materials in which the necessary ingredients are found. The right proportion is generally obtained by combining two materials, in one of which lime predominates, and in the other silica and alumina. The materials used in this country are,

1: Cement rock and limestone,
2: Limestone and shale or clay,
3: Marl and shale or clay,
4: Blast furnace slag and limestone,
5: Caustic soda waste, and clay.

Fig. 3. Induction Motor Covered with Thick Coating of Cement Showing Conditions of Operation

Combination No. 3 is effected by what is called the wet process. Numbers 1, 2, 4 and 5 are combined in a dry state. Of these various combinations, numbers 1 and 2 greatly predominate; 51.4 per cent and 35.6 per cent respectively of the entire output of Portland Cement for 1906 was made by these two combinations.

Limestone, cement rock and shale are usually quarried, while clay is dug from pits, and marl is dredged, often under water. In blasting the stone at the quarry, it is shattered as much as possible and the remaining large pieces are broken up by hand and conveyed in skips or cars to the crushers. These reduce it again to one to 2½ inch cubes. This is then sent through driers until almost all of the moisture is evaporated. In order to produce a good grade of cement, a very intimate mixture must be made, and the material ground until 95 per cent will pass a 100 mesh sieve before burning. The approved method is generally to introduce two sets of grinding machinery between the driers and the kilns, generally ball mills and tube mills. The two materials are ground separately to pass through a 20 mesh sieve in the first set of grinders—the ball mills—and then mixed and sent through the tube mills. The output of the tube mills is sent to the rotary kilns for burning. After gradually rolling down the length of the rotary kiln, the material is discharged as cement clinker. This hot clinker is cooled, and again ground to the desired fineness, after which it is conveyed to the stock house as finished cement.

From the time the rock is fed into the crushers, it is not handled again until the cement is delivered by the weighing and packing machine into bags or barrels. All transportation from one machine to another, or to the storage bins, is accomplished by means of conveyors, either bucket, belt or screw.

Advantage of Electric Drive for This Industry

The manufacture of Portland cement has certain features which differentiate it commercially from almost any other industry. The raw materials underlie more than 20 per cent of the entire area of the United States. Their initial cost is low, the cost of quarrying or dredging is slight, and, owing to the eager market, and more particularly, to the widespread deposits of raw materials, no successful merger can be formed to regulate the selling price. The price of the finished cement is determined almost entirely by the actual cost of the different operations through which the raw material passes. In the light of this fact, it is obvious that the most prosperous companies will be those that adopt, at the outset, the cheapest and most efficient means of operating the various machines necessary in cement manufacture.

The advantage of individual electric drive in machine shops and factories, in eliminating line shafting and adding to flexibility and economy, have now been almost universally demonstrated. These general advantages apply with equal weight to cement operations. There are, however, certain inherent requirements in the manufacture of cement which com-

Fig. 4. 12-1-18-100-166 2/3-K-440 volt motors driving raw material tube mills in Universal Portland Cement Co., Plant No. 4. These motors are coupled through flexible couplings to the countershafts of the mills. This necessitates only one gear reduction. The concrete wall separating the motors from the mills secures an unusually clean motor room

pletely establish the argument in favor of electric motors for this class of work.

(1) Fourth of July and Christmas are the only holidays for the cement trade. For the rest of the year, twenty-four hours a day, and seven days in the week, the mill must be kept in continuous production. The shut down of any one machine, or the failure of its driving power, must not affect the operation of any other machine.

(2) The general layout of the plant, to be most economical, should be determined solely by the relative locations of the quarries, the storage bins, the best available place for the machinery, and the space

available for future growth. The direction and distance of the power transmission should not interfere with the most efficient layout.

(3) In order to keep a check on the cost of manufacture, a continuous and accurate record should be available, showing the amount of power used in each of the different departments.

(5) Above all, the prime mover must be adapted to severe service conditions. The cement machinery does not require much attention, and the driving machinery is not apt to get it. Almost all the employees, except the burners, are unskilled workmen. If motors are installed, they must be of a rugged type to need little attention and to operate in an atmosphere

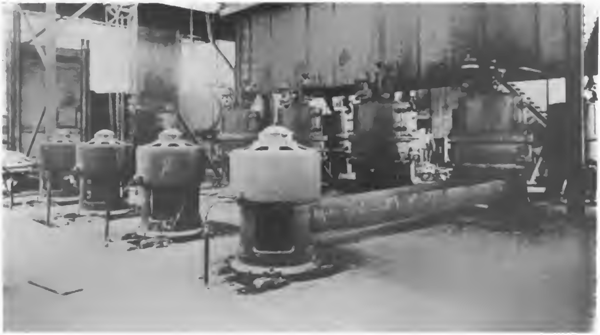


Fig. 5. 1-6-40-500-K-440 volt vertical motors, belted to Fuller mills, Plant No. 4, Universal Portland Cement Co. There are eight of these driven altogether. The bearings on these motors have given entire satisfaction in spite of the dust and grit that naturally tend to produce excessive wear

(4) Most of the machines used in cement manufacture start under a heavy overload, and some are liable to short overloads during operation. The driving unit must be designed to give its best efficiency at the load required in normal operation, and yet have a large margin of overload capacity which can be drawn upon at starting or when necessary.

thick with stone and cement dust.

A complete electrical installation, composed of two or more General Electric engine or turbo driven alternators, switchboard, and the proper motor equipment, consisting of General Electric alternating current, form K induction motors, will successfully meet all of the above conditions.

(1) As long as the boilers produce steam, continuity of operation is assured. Both the motors and generators will run without shut down for any desired length of time. The individual electric motor drive allows for the independent shut down or starting of any one of the cement machines, without affecting the operation of any other.

(2) The location of the power house need not be considered in laying out the plant. In case water power is available at some distance from the mill, the generating station may be located at the source of power and the electric power transmitted at high efficiency to the cement plant. No line shafts need be considered in designing the mill, and the machines may be placed wherever most convenient to feed or discharge. This results in a great saving of floor space and improvement in design.

(3) The switchboard can be laid out to have a separate feeder circuit for each of the departments, with a recording wattmeter in each feeder, and an indicating ammeter on each of the motor panels. If the board is still further equipped with a recording wattmeter on each generator panel, a complete check on all power used is obtained. Any increase or loss in efficiency of any department can be instantly noted, and the cause ascertained. This record will be found a great aid in working towards higher total efficiency and in lowering the cost of production.

(4) The form K motor, which we recommend especially for this class of work, is given the normal running horsepower rating of the machine it drives. These motors are supplied with high resistance rotors for producing a starting torque of twice normal torque if necessary. The rotor bars are bolted to the end rings instead of being soldered, which enables the motor to stand the heavy current required for starting. These motors will endure short overloads of 200 per cent to 300 per cent. They are exactly suited to the duty, running at highest efficiency under normal load, with a large margin of overload for starting, when required.

(5) The first applications of electric drive to this manufacture were made before the merits of the alternating current for power were fully demonstrated. The General Electric Co. has installed direct current equipments in a number of plants with great success, notably in the Edison Portland Cement Co. at Stewartsville, N. J. Among the electrical apparatus at this plant, are ten 25 h.p., slow speed, variable speed motors driving rotary kilns 150 feet long, the heaviest kilns in the world. Where it is possible for the mill designer to determine the character of the power to be used, however, the best practice is to install alternating current of 25 or 60 cycles. Form K induction motors, operating on this current, are peculiarly adapted to the se-

Fig. 6. View taken at the further end of motor annex shown in Fig. 5 showing 1-6-20-500-K-440 volt motor belted to a conveyor

vere service outlined in paragraph No. 5 above. There are no sliding contacts; no current carrying parts exposed to the air; absolutely nothing to be injured by the dust except the bearings, which are made dust proof by felt dust guards on each side. The compensators for starting these motors are arranged with a latch, so that the operator cannot throw the motors directly on the line until they start to run; once running, they can be left all day without attention. They are protected—and in turn protect the machinery—against excessive overloads, by fuses or circuit breakers on the starting panel. The revolving part is nothing more than a number of copper rods, parallel to and surrounding the shaft, and embedded in an iron core, with their ends connected by rings at each end. Owing to the appearance of this rotor, it is commonly known as the "squirrel cage" type. There is nothing more complicated about it than a piece of shafting revolving between journals. Dust cannot hurt these motors. It is almost impossible to damage them. It would be hard to find any driving machinery more nearly "fool proof."

Machines Used in Cement Manufacture

ROCK CRUSHERS. With the exception of the Giant Rolls installed by Thomas A.

Fig. 7. I-18-40-166 2 3-K-440 volt motors driving ball mills in the raw material mill. Universal Portland Cement Co., Plant No. 4. There are nine of these mills together, and very satisfactory results have been obtained by this type of slow speed drive, which eliminates one gear reduction

Edison at the Edison Portland Cement Co., the almost universal type of crusher is the gyratory. The Giant Rolls consist of four pairs of corrugated steel cylinders, arranged one under the other, each pair being separately belt driven. The largest pair is on top, the cylinders being about 5 feet in diameter, and from 4 to 6 inches apart. As these rolls will crush a solid 10 ton piece of rock, no hand breaking is required, and the rock may be loaded into the skips at the quarry, directly after blasting.

The gyratory type, which is used in almost all cement mills employing the dry process, consists essentially of a vertical spindle, on the upper end of which is mounted a chilled iron crushing head that moves inside a hopper shaped top into which the rock is fed. The bottom of the spindle passes loosely through an eccentric, driven from a horizontal shaft by bevel gears. The spindle, therefore, has a gyratory motion, and may or may not rotate on its own axis. As the head, running eccentrically, approaches and recedes from the sides of the hopper, the stone is gradually crushed and falls down between the crushing surfaces. The stone must be broken by hand to a convenient size to feed into the hopper. A crusher having a hopper about 40 inches in diameter and a crushing head about 20 inches will have a stroke of approximately 5/8 inch.

The h.p. necessary to drive, averages 1.2 x tons crushed rock per hour; figuring on rock of moderate hardness. A crusher of this type is suitable for individual belt drive. Sometimes two or more crushers are belted to one motor, though this is not the best practice, as all crushers must be stopped when the motor is shut down. Gearing is not suitable for these machines, as the driving gear would be subject to a severe strain should the crusher become clogged with rock.

BALL MILLS. These mills take the output of the crushers or the rotary kilns and reduce it to a coarse grit, generally about No. 16 to No. 20 mesh. The mill consists of a drum, having a diameter of about double its length, filled with steel balls. The drum revolves on a horizontal axis, at a speed of from 21 to 27 revolutions per minute. The lining of the drum is made up of overlapping steel plates which form steps. As the drum revolves, the balls drop over the steps, pounding the material to pieces. This mill, with the balls it contains, is very heavy and takes almost double normal torque for starting. It is adapted for either belting or gearing. In gearing to the mill, it is common practice to gear to the countershaft, making two gear reductions between the driving motor and the mill. When a low frequency alternating current is available, however, very good results are obtained by using a slow speed motor (about 166 r.p.m.) and coupling directly to the countershaft, thus doing away with one gear reduction. The General Electric Company has recently supplied a number of 40 and 60 h.p. motors running at this speed, to the Universal Portland Cement Co. for driving ball and tube mills.

KOMINUTERS. These are modifications of the ball mills, having drums of the same diameter and of about twice the length and capacity of the ball mills. The other modifications apply to the method of discharge and do not affect the essential features.

TUBE MILLS. The tube mill consists of a cylinder 20 to 22 feet long and 5½ to 5 feet in diameter, filled with flint pebbles, generally imported from Europe. These mills take the output of the ball mills—either raw material or clinker—and grind it to the desired fineness for burning or for finished cement. In their general features they are similar to the ball mills, and should be either belted or geared to a motor having a high starting torque.

GRIFFIN MILLS. These mills are used for grinding clinker or rock to the required fineness for finished cement or for burning. When working on raw material, it is generally necessary to crush the rock into fragments smaller than those used in feeding ball mills. The mill is driven from a pulley at the top, revolving on a vertical axis. The power is transmitted to a vertical shaft, which is hung from a universal joint inside the pulley and is free to move in any direction at the bottom. A crushing roll is rigidly connected to the bottom of the shaft.

When the pulley revolves, the crushing roll is thrown off center, and revolves against a fixed ring or die with a centrifugal force of about 6000 lbs. pressure. The grinding is done between these two surfaces. Two distinct actions on the material to be ground are obtained; the roll revolves against the die in the direction of the pulley, and this contact causes the roll and shaft to revolve around their own axis in an opposite direction. These mills are best adapted to belting, and may be driven from a vertical motor, or a horizontal motor with a quarter turn belt.

The Griffin mill is manufactured in two sizes, 30 inch and 36 inch, designated according to the diameter of the ring against which the crushing roll revolves. A new mill has also been brought out by the manufacturers, called a Three Roll Griffin mill. This is similar in its action to the standard mill, but, as the name implies, has three crushing rolls instead of one.

FULLER-LEHIGH MILLS. These are commonly called Fuller mills. They are used on the same material as the Griffin mill described above, and the grinding is done by four unattached chilled iron balls about 9 inches in diameter, that are propelled by four equidistant horizontal arms or push-

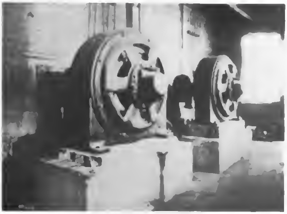


Fig. 8. 2-1-18-100-166 2 3-K-440 volt motors direct connected to countershaft of raw material tube mills through six arm flexible couplings, in Universal Portland Cement Co., Plant No. 4. These motors were started four months ago and have run continuously ever since without any shut down

ers, radiating from a vertical central shaft. The orbit is a circular die against which the balls exert great pressure, since they weigh about 112 lbs. each and revolve at about 210 r.p.m. The main shaft is driven from a pulley mounted at the bottom, below the grinding level.

This mill, like the Griffin, may be belted to a vertical motor, or to a horizontal motor with a quarter turn belt.

KENT MILLS. These mills will grind clinker to the required fineness for finished cement, or they may be set to give a coarser output for use in connection with tube mills for further grinding. When used on raw material, they will grind to the required fineness for burning. The output of an ordinary crusher is generally further reduced in size before feeding into the Kent Mill.

The essential features of this mill consist of a ring revolving on a horizontal axis, with three rolls revolving inside, pressed by springs against its inner surface. Centrifugal force carries the material to be ground in a layer about an inch thick around the inner face of the ring, where it passes between the ring and the rolls.

These mills are driven from two pulleys, one at each end, and are very well adapted to belting to a motor that has two pulleys and an outboard bearing, and which is provided with a sliding base under the motor and outboard bearing so that the slack of both belts can be taken up simultaneously. The Kent mill is also furnished with one pulley if desired.

ROTARY KILNS. The raw material, properly mixed, is fed into rotary kilns and burned. These kilns vary from 60 to 170 feet in length, but it is doubtful if any future installation will contain kilns shorter than 100 feet.

In its usual form, the kiln consists of a cylinder 6 to 8 feet in diameter, constructed of sheet steel 1/2 to 9/16 inches thick, lined with fire brick. The cylinder is supported at a slight angle from the horizontal on two or more rolled steel tires, each of which revolves on four heavy cast steel rollers mounted in pairs on a rocker.

The fuel used is generally powdered coal, which is forced into the lower end of the kiln by compressed air. The flame passes through the entire length of the kiln and the gases are discharged into a stack at the upper end. The raw material is fed into the upper end of the kiln by a water jacketed screw conveyor, and gradually rolls down the entire length, being discharged at the lower end into a rotary clinker cooler, or directly into a bucket conveyor.

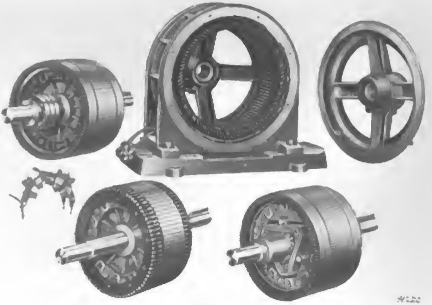


Fig. 9. General Electric Induction Motor Frame and Armatures

The speed of the kiln varies from ½ to 3 r.p.m. in the various sizes. In the 150 ft. kilns in the Edison Portland Cement Company's plant, the material takes about 1½ hours to pass through. Rotary kilns are driven by a circular rack situated generally at the middle, and connected by a train of gears either to a pulley to which the driving motor is belted, or to a pinion on the motor shaft.

A rotary kiln is the only machine of any importance in a cement plant which requires two or more speeds. The general practice is to use variable speed form M induction motors, with a drum controller and resistance, capable of operating continuously at any speed between ½ and normal. In a number of plants a constant speed, form K motor is used to drive the kiln line shaft, to which all the rotaries are connected. A clutch and gear shift is installed with each kiln, so that any one of the kilns can be connected or disconnected independently of the others and operated at either of two fixed speeds. Another method is to use constant speed motors for driving, interposing a mechanical speed changer between the driving shaft and the kiln.

MISCELLANEOUS. The machines described above perform the most important of the cement operations. In addition to these, however, there are numerous auxiliary operations. Among the other machines are the belt, bucket and screw conveyors, fans, air compressors, coal crushers and pulverizers (a good many of the machines used in grinding cement are suitable for grinding coal), pumps, driers and rotary coolers. The driers and coolers are generally built on the same plan as the rotary kilns. All of these auxiliary machines are perfectly adapted to electric motor drive.

The Power Station

In the present stage of the cement industry, it is doubtful if any new plant can be profitably operated with a capacity of less than 1500 barrels per day. Results obtained from a great many cement plants, indicate that the horsepower necessary to operate varies from 0.8 to 1.2 h.p. per barrel per day. For the smallest practicable plant, this would indicate about 1500 h.p. Unless electric power can be bought at an exceptionally low price, it will be found cheaper in the end to install a complete generating plant to furnish this power. Besides the factor of economy, this will eliminate all chances of a shut down of the plant resulting from exterior causes.

The load of a cement mill is steady, and its load factor high, sometimes above unity. For industrial conditions, when the load is steady and can be closely calculated, it is a decided economy to install generators rated according to the maximum output. The General Electric Co. is prepared to furnish turbine units rated on this principle. For a 1500 barrel plant, 2 ATB 750 kw. 1800 r.p.m. 440 volt 60 cycle turbo generators will be ample, and will be worked constantly at their highest efficiency. These generators are a modification of the 500 kw. unit of the same rating, and sell at a small advance over the standard 500 kw. price. They are designed especially for the low power factor load caused by induction motors and will give the rated output continuously at 80 per cent power factor.

The General Electric Company has lately equipped with turbo generators the Fordwick Cement Company, the United States Portland Cement Company and the York Portland Cement Company. From Mr. Elbert Walker Shirk, the owner of the U. S. Portland Cement Company, the following unsolicited statement has been received:

"The 800 kw. turbine, now in operation, is giving splendid satisfaction, and there is no question in my mind but that this type of power equipment is far and away the best for cement mill practice. We have had absolutely no difficulty of any kind or description in starting, or operating this machine, and from our experience so far we are inclined to think that when once properly adjusted, the Curtis turbine will practically run without mechanical attention indefinitely."

The best guarantee for any apparatus is a satisfied customer. There is probably no one in this country interested in the cement business who is not familiar with the chain of plants in the United States and Canada known as the "Cowham System". These plants, which comprise the following, have been financed, installed and operated by Mr. W. F. Cowham of Jackson, Mich., through the Cowham Engineering Company, of which he is President:

Southern States Portland Cement Co., Rockmart, Ga.

Peninsular Portland Cement Co., Cement City, Mich.

Western States Portland Cement Co., Independence, Kan.

Northwestern States Portland Cement Co., Mason City, Iowa.

National Portland Cement Co., Durham, Ontario.

International Portland Cement Co., Hull, Quebec.

These plants have all been installed throughout with General Electric apparatus, the Canadian plants being equipped through the Canadian General Electric Company. To the four plants in the United States only, the General Electric Company has supplied over 10,000 h.p. in motors and over 8000 kw. in generators, besides switchboards and cable. In giving us a list of this apparatus, Mr. W. J. Maytham, Chief Engineer of the Cowham Engineering Company, says:

"We have had excellent results with all the apparatus mentioned above, especially considering the extremely severe use to which it has been subjected. As you know, we run our mills 24 hours a day and seven days a week, and sometimes run a machine weeks without stopping. We believe your apparatus to be the best obtainable."

TABLE OF HORSEPOWER, OUTPUT AND SPEED

(For some of the figures contained in the following table, we are indebted to Mr. Richard K. Meade's treatise on Portland Cement.)

Type	Size	H.P. to Drive	Revs. Per Min. Pulley	Revs. Per Min. Main Shaft	Output in Tons Per Hour Hard Lime.	Output in Tons Per Hour Cmt. Rock	Output in Tons Per Hour Marl Clay	Output in Tons Per Hour Clinker	Output in Tons Per Hour Coal	Remarks
Gyratory Crusher *	5D	25-40	400-450	200	20-30	25-35				Vertical shaft, horizontal driving pulley output passing 1 in. screen
Gyratory Crusher *	6D	30-60	400-450	200	30-40	30-50				
Ball Mill †	7	30-40	125	21-23	3-5	4-6		2½-3		Horizontal; fed from crusher or kiln output passing No. 16 mesh
Ball Mill †	8	40-50	125	21-23	4-7	5-8		3½-5		
Tube Mill †	5′ x 22′	70-80	180	21-27	3-4	4-6	8-12	2½-3	2	Horizontal; fed from ball mill 95% output passing No. 100 mesh
Tube Mill †	5½ x 20′	80-90	180	21-27	4-6	5-8	10-15	3-4	2½	
Kominuter †	No. 66	40-55	160-175		5-7	6-8		5½-7		Similar to ball mill
Griffin Mill ‡	30″	25-28	190-200	190-200	1½-2½	2-3		2-3	1½-2	Vertical; fed ½″ crush. rock or clinker 95% output passing No. 100 mesh
Griffin Mill ‡	36″	30-35	135-150	135-150						
Griffin 3 Roll ‡	30″	40	150	150	4-5	5-6			4-6	
Fuller Lehigh Mill ‡		30-50	210	210	3-3½	3½-4			2¼	Vertical; feed and output same as Griffin mill
Kent Mill ‡		25-30	180-220	180-220	3-4	3½-4		3½-4	3-4	Horizontal; feed and output same as Griffin mill

Type	Length	H.P. to Drive	Revs. Per Min.	Output in Barrels Per Day
Rotary Kiln §	60 ft.	10-15	1-3	250
Rotary Kiln §	80 ft.	10-15	1-3	300
Rotary Kiln §	100 ft.	15-20	1-2	450
Rotary Kiln §	120 ft.	15-25	1-2	580
Rotary Kiln §	150 ft.	20-25	½-1	740
Rotary Kiln §	170 ft.	20-30	½-1	8[illegible]0

* Starts light when empty; overload torque at starting if hopper contains rock.

† 80 to 100 per cent. overload torque necessary for starting.

‡ Starts light.

§ Starts with 50 to 70 per cent. overload torque.

THE INDUCTION MOTOR AS A PHASE CONVERTER

By C. C. Batchelder

Converting from one polyphase system to another having a different number of phases is a problem which can always be solved by the use of transformers, since in the original system there must be two components of electromotive force in quadrature, and by varying the values of these components a resultant of any desired phase can be obtained; but a single phase system cannot be converted into a polyphase system by such simple apparatus, because the quadrature component must be supplied by some auxiliary means.

Also since the energy flow is pulsating in a single phase and steady in a polyphase system, conversion from the former to the latter requires apparatus which can store energy while the single phase input exceeds the polyphase output, and give up this energy into the polyphase system during that part of the cycle when the input falls below the output. In phase splitting devices employing inductance or capacity, an electromotive force in quadrature with the impressed electromotive force is obtained from the reactive drop of the current flowing through an inductive winding, or into a condenser, as the case may be; and the necessary energy is stored as magnetic energy, $\frac{I^2L}{2}$, in the core of the winding, or as electrostatic energy, $\frac{E^2C}{2}$, in the dielectric of the condenser; but such devices are inefficient and costly and are used only for such intermittent work as starting single-phase motors. The requirements are more satisfactorily met by induction and synchronous motors, which, by means of their rotating magnetic fields, can supply the electromotive forces and currents displaced in phase from those of the primary system, and can receive kinetic energy into their rotating parts and return this to the system as electrical energy when needed. Such machines are known as phase converters.

The possible use of the induction motor as a phase converter depends upon the fact, that the magnetic conditions existing in the single phase induction motor when running near synchronism approach those of the polyphase motor; that is, the field of the single phase motor has two components approximately in quadrature as to time and space. So if a motor having a polyphase primary winding be run single phase, there will be induced in the "idle" windings electromotive forces which are dependent in phase upon the angular displacement of these windings from the primary phase; thus, a three phase motor when run single phase gives three phase electromotive force at its terminals; a two phase motor, two phase electromotive force, etc.

The induction motor when used in this manner presents an instance of double transformation, in which energy is first transformed from one primary phase of the motor to the secondary or armature, and from there transformed into the other primary windings, which are known as the tertiary windings. Since the induction motor has comparatively poor regulation as a transformer, due to the unavoidable leakage of magnetic flux in the airgap, it is apparent that this double transformation can be accomplished only at the cost of appreciable loss of voltage, so that the resulting polyphase system must necessarily be somewhat unsymmetrical; the inequality of the resulting voltages depending on the self induction and resistance of the field and armature windings.

Graphically the phenomena may be represented as in Figure 1. Let ϕ_1 be the magnetic flux interlinked with both primary and secondary, or rotor, circuits. Then E_1' is the electromotive force induced in the primary, which must be overcome by an equal and opposite component of primary impressed electromotive force E_1. The quadrature magnetic flux is represented by ϕ_2, nearly 90 degrees behind ϕ_1, and of somewhat lesser magnitude on account of the resistance and reactance of the rotor. The quadrature flux ϕ_2 interlinks with the secondary and tertiary circuits, inducing in the latter the electromotive force E_2. This electromotive force is impressed upon a circuit whose impedance is equal to the sum of the internal impedance of the winding and the impedance of the receiving circuit, and causes

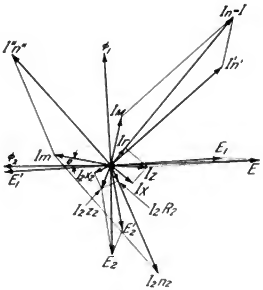


Fig. 1.

a current I_2 to flow. The electromotive force consumed in forcing this current through the internal impedance is the resultant of the electromotive force I_2R_2 required to overcome the resistance, and which is in phase with the current, and the electromotive force I_2X_2 required to overcome the reactance, and which leads the current by 90 degrees. The resultant internal drop I_2Z_2 when subtracted from the induced electromotive force E_2 gives E_2', the electromotive force at the terminals of the receiving circuit.

The magnetomotive force required to produce the flux ϕ_2 is Im, which leads the flux by the angle α, the angle of hysteretic advance. The magnetomotive force of the tertiary winding is I_2n_2, n_2 being the number of turns in the winding. The magnetomotive force of the secondary will be of such magnitude and phase that when combined with the tertiary magnetomotive force, the resultant will be I_m: this is therefore represented by I″n″. The effect of this magnetomotive force on the primary is that of an equal magnetomotive force I′n′ 90 degrees ahead of I″n″ in time and space. The phase of this magnetomotive force I′n′ has been determined from the standpoint of the machine acting as a generator; if, therefore, we reverse it, it will represent the magnetomotive force of the secondary as referred to the primary, as an input or motor phase. So reversing a second time to obtain the primary balancing magnetomotive force, we have I′n′ as the component of primary magnetomotive force required to overcome that of the secondary. I_M is the magnetomotive force required to produce the main flux ϕ_1, therefore the total primary magnetomotive force is In. Since as shown in the diagram, the tertiary magnetomotive force I_2n_2 was drawn equal to I_2, and since in all practical motors the number of turns in the tertiary equals the number in the primary, In = I, the primary current. The primary resistance and reactance must be overcome in forcing this current through the primary winding, and this requires the components of impressed electromotive force IR in phase with, and IX 90 degrees ahead of the current. Adding the resultant of

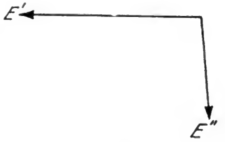


Fig. 2.

these, IZ, to the electromotive force required to overcome the primary induced electromotive force E_1, we obtain E as the primary impressed electromotive force. The electromotive forces of the quarter phase system are E′ and E″, in Figure 2, E′ being the reverse of E in Figure 1, since the latter was plotted when considering the machine as a motor.

The phase converter is the equivalent in its electrical and magnetic quantities to a divided circuit represented diagramatically in Figure 3, where R_1 and X_1 are the primary resistance and reactance respectively. R_2 and X_2 the secondary resistance and reactance and R_3 and X_3 the same quantities for the tertiary. Y_1 is the primary exciting admittance, Y_2 the quadrature exciting admittance, and Y_3 the admittance of the receiving circuit. Then if I_1, I_2 and I_3 are

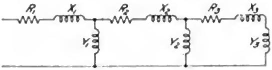


Fig. 3.

the currents in the respective branches, the total current input I is $I_1 + I_2 + I_3$ added vectorially.

Let E = voltage impressed on motor, E_1 = voltage across Y_1, E_2 across Y_2 and E_3 across Y_3.

Then, vectorially

$$I = I_1 + I_2 + I_3$$
$$= E_1 Y_1 + E_2 Y_2 + E_3 Y_3$$
$$E_2 = E_3 + I_3 Z_3$$
$$E_1 = E_2 + (I_2 + I_3) Z_2$$
$$E = E_1 + (I_1 + I_2 + I_3) Z_1 \qquad (1)$$

The value of the resultant voltages in the case of a three phase motor is made clearer by a further study of the vector diagram of the quantities involved. Let a voltage E be impressed on the primary

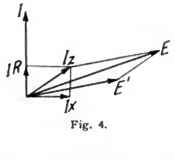


Fig. 4.

phase of such a phase converter (Fig. 4). Then a magnetizing current I will flow in the winding. The impedance drop due to this current is IZ, so the voltage induced in the winding is represented by E'. Now the quadrature voltage is 90 degrees behind the induced voltage, therefore it is somewhat less than 90 degrees behind the impressed voltage, and the voltage triangle will be somewhat distorted, as shown in Figure 5, even with no load on the tertiary phases. Now as the machine is loaded the current I shifts more and more toward the induced voltage E', and this throws the impressed voltage ahead of E. This is equivalent to increasing the angle a, and it is evident that at some value of the current, a will pass through 90 degrees, and the voltage triangle will be distorted in the opposite direction. If the load on the machine be inductive, the current required to make a = 90 degrees will evidently be larger than that required if the load be non-inductive, and the opposite is true if a leading current is taken from the machine. Moreover, in the case of large machines with small air gaps requiring relatively

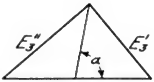


Fig. 5.

small magnetizing currents, with a large angle of hysteretic advance, it is improbable that the impressed voltage E would ever lag behind the induced voltage E'; so that the distortion of the voltage triangle would always be in the same direction, except when a large inductive load was drawn from the tertiary windings. In the case of most small machines, however, this change of direction of distortion is very likely to occur.

The impedance of the tertiary phases results in a further distortion of the electromotive force triangle. Let the voltages induced in the tertiary windings and the voltages impressed on the primary be as shown in Figure 6; this will represent the no-load terminal voltage of the phase converter. As the machine is loaded up the reactance of the tertiary will cause the terminal voltage to lag behind E_3' and E_3'', tending to assume the values and phase indicated by the dotted lines. Since, however, the terminals of the two tertiary phases are connected, and therefore at the same potential, the terminal voltages coincide and give a resultant triangle as shown in Figure 7; where the dotted lines represent the no-load voltage of Figure 6, and the full lines the voltage with load on the machine. This unbalancing can be produced only by unequal division of the

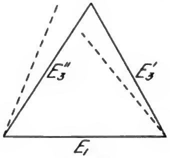


Fig. 6.

current between the two phases, so that in a phase converter with load the current is unequally divided between the two tertiary phases.

For the purpose of calculation, however, it can be assumed without introducing serious inaccuracy that the current divides equally between the two tertiary legs. Under these conditions the resultant impedance drop in the windings, due to the current flowing in the third line, is equal to the product of this current and half the impedance of one winding of the machine, since the current in one leg equals the current in the third line divided by the $\sqrt{3}$, and the drop in one leg must be multiplied by $\frac{\sqrt{3}}{2}$ to give the resultant drop at right angles to the impressed primary voltage; that is, if I = current in third line, $\frac{I}{\sqrt{3}}$ = current in each leg of winding, and $\frac{I}{\sqrt{3}} \times$ (impedance of one phase) $\times \frac{\sqrt{3}}{2}$ = resultant quarterphase drop = $\frac{IZ}{2}$

This expression is slightly inaccurate since it assumes a balanced electromotive force triangle; i.e., an angle of 120 degrees between the currents in the two legs; but since the error is proportional to the cosine of the angle of variation, and not to the angle itself, it is not of very great magnitude.

Therefore, to calculate the resultant terminal voltages under varying conditions of load in the case of a three phase machine, we can proceed as indicated in equation (1), by using for Z_1 the primary impedance, 2/3 the impedance of one phase of the winding, and for Z_3, the tertiary impedance, 1/3 the impedance of one coil; and in the case of a two phase motor, by using the actual impedance of one phase for both Z_1 and Z_3. The angle between the primary impressed and the resultant displaced electromotive forces will be 90 degrees ± the angle between the primary impressed and primary induced electromotive forces ± $\sin^{-1}$ (tertiary reactive drop divided by resultant terminal electromotive forces), the latter quantity being represented vectorially by a line from the center of the primary impressed electromotive force, or base line, to the apex of the electromotive force triangle. In the three phase electromotive force triangle the actual quadrature voltage plotted must be the calculated quadrature voltage multiplied by .866.

In the foregoing analysis the motor slip has been neglected, but its effect on the results is insignificant, as in any practical case it is very small. It acts to reduce the effective quadrature electromotive force in

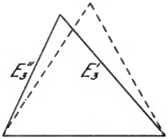


Fig. 7.

proportion to the cosine of the slip, expressed in electrical degrees; and even for a slip of one tenth, this would only reduce the voltage by about one per cent. The slip of a phase converter is not dependent directly on the power output, but upon the power factor as well, as the slip is proportional to the current in the rotor. Thus for small outputs at low power factors, the slip may be as large as for high outputs at high power factors, since the copper loss in the rotor may be as high in the first case as in the second.

The phase converter does not "fall out of step" as an induction motor does, when it passes beyond its point of maximum torque, but it has the same power characteristics as other induction machines, limiting it to a definite maximum output. However, when running from a single-phase system of large capacity, this limit to the output of the phase converter does not limit the input to the receiving system, as after the maximum output of the converter is exceeded, the apparatus running from it will merely draw more heavily upon the single-phase supply system, and continue running, although under conditions of greatly distorted impressed electromotive force.

The curve Figure 8 shows the results of the above calculations applied to a 600 h.p. 1150 volt quarter phase motor run as a phase converter, and gives a good idea of what can be expected from commercial induction motors used in this way. It will be seen that with the machine running light (no load on the polyphase system), the tertiary electromotive force is about 92 per cent of the primary, and that with 200 amperes output, representing about 400 kilowatts input to the polyphase receiving circuit, the tertiary voltage has fallen to about 87 per cent of the primary.

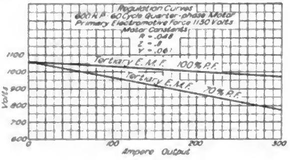


Fig. 8.

With 200 amperes output at 70 per cent power factor, the regulation is, of course, somewhat worse, the tertiary voltage having fallen to about 78 per cent of the primary. The motor upon which these results were obtained was above the average in size, and on small machines such good results cannot be expected; in the case of a 50 h.p. motor operating as a phase converter, with the polyphase system drawing about the rated power of the motor, the tertiary electromotive force would be about 80 per cent of the primary electromotive force at unity power factor, and about 60 per cent of the primary electromotive force at 70 per cent power factor.

The practical uses of the induction phase converter are necessarily limited on account of this voltage distortion, and in

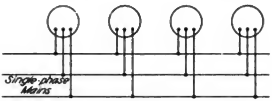


Fig. 9.

fact, it is little more than an emergency machine. In case of an urgent demand for machinery to supply power to three phase motors from single phase mains, it offers the cheapest and most easily available solution of the problem, and in case a permanent installation is desired, will serve the purpose very well while the requisite motor-generators are being manufactured.

In installations of several single phase motors it has also been proposed to eliminate the use of phase splitting devices for all motors except one, by starting this one with the usual resistance-reactance phase splitter and then utilizing it as a phase converter for starting the rest of the motors as polyphase machines. One interesting and important feature of such a system has, however, been generally overlooked. If, after being started from the first motor, the others are left connected to it so that all are running in multiple from the single phase mains, and also have their third terminal connectel, as in Fig. 9, both the continuous and maximum capacity of the motors will be materially increased, provided the motors are not all loaded at the same time. If part are heavily loaded and the rest are running light or underloaded, the latter will supply power to the loaded machines, enabling them to run as polyphase instead of single phase motors. Such a connection allows the use of smaller motors than would be necessary for handling the load peaks if the straight single phase system were used.

THE ELECTRIC DRIVING OF JOB AND FLAT BED PRINTING PRESSES

By H. B. Emerson

The electric driving of printing machinery has advanced to such at art at the present day that all up to date publishers and job houses look upon the electric motor as indispensable in their business. By its use the power can be applied just where

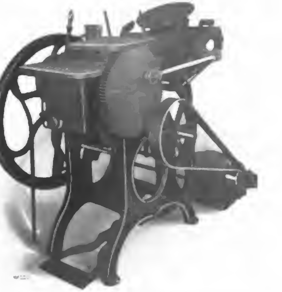


Fig. 1. Gordon Job Press driven by 1 4 h p. motor. Controller on front of Press

it is needed, and one, two, or any number of presses can be run without in any way affecting the rest of the equipment. Each press with its motor and controller is a unit, and consumes power only when doing duty. An operator can start, run his press at any desired speed, or stop, with thought only of the job on which he is working. There are no squeaking belts to distract his attention, and no countershafts and belting to obstruct his light. The press is under his complete control, and when running, should necessity require, he can bring it to a full stop by simply pressing any one of a number of push buttons placed about the press.

Printers at first were slow to adopt the electric drive, but after a few had found that the many essentials necessary for economical operation could be better supplied by the electric drive than by any other motive power, and the conditions conducive to fine work in the press-room better met, it did not take the others long to follow their example.

The electrical engineer, however, became aware that his standard motors were not exactly suited to the requirements of this class of business, and after studying the subject, he found that to equip a job or flat bed press most economically the motor and controller had to meet the following requirements:

First:—The motor had to be of as small dimensions as possible, so that it could be placed under the press and not occupy valuable floor space.

Second:—It had to be capable of some speed variation, in order that the press could be run at the most suitable speed for the various work brought to it. That is, if the work in hand was some fine magazine with cuts or colors, the speed had to be much slower than when turning out some cheap flier or publication.

Third:—This variation had to be obtained by other than armature control, as such control was costly on account of the

Fig. 2. Rotary Job Press driven by 2 h.p. motor

waste of power in resistance, and as the speed was not entirely constant, due to variations in torque at different positions of the bed.

Fourth:—The motor could not be geared on account of the liability to disalign the press.

Fifth:—The controller must be substantial but of such form that it could be easily fastened to the frame of the press within easy reach of the operator.

Realizing that the above requirements were of vital importance to the printer, the more progressive electrical manufacturers immediately designed motors specifically for this work. They were made compact and rugged, of especially small diameters, and capable of a variation in speed of from sixty to one hundred per cent. The changes in speed were obtained by weakening or strengthening the shunt field, and by this method of variation the efficiency of the motors was altered only two or three per cent throughout the full range of speed. The motors were furnished for belt connection, and were supplied with a unique belt tightening idler, which gave flexibility to the drive, and also compensated for any stretch in the belt, as well as for the shortness of the distance between the centers of the press and motor pulleys, necessitated by placing the motors under the presses.

Such equipments are now almost universally used for this class of work, and although there are various types, makes, and sizes of presses, with slight modifications the type of motor above described may be used with each.

Since this line of motors has been brought out, however, some of the press manufacturers, seeing that the speeds of their pulley shafts were very slow, have increased the ratio between the pulley and impression shafts; and by so doing, have increased the speed of the pulley shaft and reduced the liability of shock to the train of working gearing. On such presses there is less need for a flexible belt tightening idler.

Fig. 3. Flat Bed Press with Automatic Feeder; driven by 3 h.p. motor. Controller on left of Pressman's position

The smaller or job presses are of two distinct classes, namely: "Gordons", and Rotary Job presses. The Gordons require motors of one-quarter to one horsepower capacity to drive them, and Figure 1 shows the usual method of drive. The motor is placed on the floor directly in the rear of the press, and is connected by belt to the main driving pulley, a belt tightener attachment being employed to compensate for the short centers and small sizes of pulleys used.

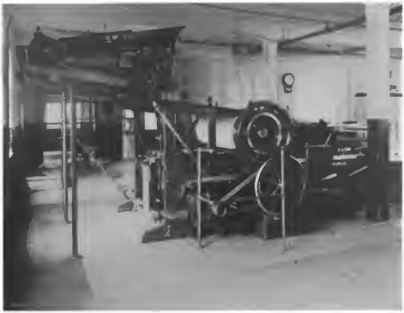


Fig. 4. Flat Bed Press Motor Side

The Rotary presses, of which Figure 2 illustrates two sizes, require motors of from one-half to five horsepower capacity to drive them. The presses shown in this figure are equipped with motors placed beneath the receiving board, and as these particular presses are furnished by the manufacturers with mechanical means of speed variation, standard constant speed motors are used.

Figures 3 and 4 illustrate a flat bed press and show the usual method of making the motor and controller attachments. This press, however, is one of the newer types in which the speeds of the pulley and impression shafts are in the ratio of twelve to one; the normal pulley shaft speed being three hundred and fifty revolutions per minute. The motor is placed beneath the platen and between the webs of the frame of the press. The controller is fastened to the frame of the press just above the operator's platform near the feed board, so that the operator does not have to leave his position to start, stop or otherwise control the press.

These presses are built in various sizes and require motors of from two to ten horsepower capacity to drive them.

Besides the presses, all auxiliary machin-

Fig. 5. Lanston monotype machine operated by a one-half horsepower motor mounted on the side of the base of the machine and connected to the main shaft by belt

Fig. 6 Punching Machine, driven by one-half horsepower motor

Fig. 8. Paging and numbering machine operated by a one-eighth horsepower motor. This motor is stopped and started by means of the snap switch shown at the side of the machine head

Fig. 7 Thirty-eight inch paper cutter, driven by a standard compound wound motor, the controller being situated directly beneath the feed board

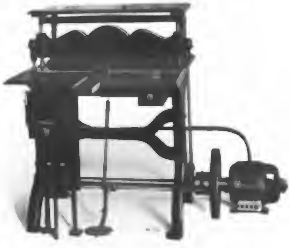


Fig. 9. Perforator driven by a one half horsepower motor, the controller being situated directly beneath the feed board

ery in a printing house may be driven electrically, and Figures 5 to 13, inclusive, are good illustrations of how motors and controllers are attached to machines of this class. In addition to the machines shown, there are many others that may be used in plants of this kind, but none that cannot be readily operated with an electric motor.

The General Electric Company was one of the first electrical manufacturers to realize the needs of the printer and to meet his demands.

They originally used their CE type of motor with a drum controller for this work, but later designed a new motor that was much more compact and of considerably smaller diameter for a given horsepower. These motors they call their type CR, and build them in capacities of from one and one-half to ten horsepower. They can be furnished in either slow or moderate speeds—as required by the shaft speed of the press to be equipped—and are capable of giving either sixty or one hundred per cent speed variation. They can also be furnished either with or without the belt tightener attachment.

The controller furnished with the above type of motor is of compact design, being of the flat dial type, and is provided with all of the latest safety devices. With this controller the press can be started, run at any speed between the maximum and minimum impressions for which it was designed, or at a constant slow speed for making ready or limbering up.

They are so constructed that all arcing is taken care of on renewable segments having powerful blow out magnets, and both starting and regulation is accomplished with a single handle.

The General Electric Company has also seen the need of an alternating current motor having proper characteristics for this class of service, and has designed motors for use on three-phase circuits of standard potentials and periodicities. It has been the general impression that the alternating current could not be used in this class of service where individual motors were required, except for those cases where a constant speed motor could be employed. Several such installations have been made, however, and the following letter recently received speaks for itself:—

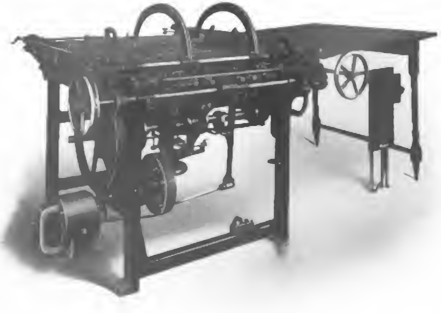


Fig. 10. Dexter folder driven by a 1 h.p. motor with the control placed beneath the feed board in front of the operator

"Gentlemen:—When you suggested that we could successfully operate a variable speed motor on an alternating current, we were a little skeptical—as you will remem-

Fig. 11. Ruling machine operated by a one-eighth horsepower, back geared motor, the controlling rheostat being placed on the side of the machine near where the operator stands

Fig. 12. Row of Gordon Job Presses driven by Individual Motors

ber—but as events have proved, our fears were groundless. It is now about three months since you installed the two 5 h.p.

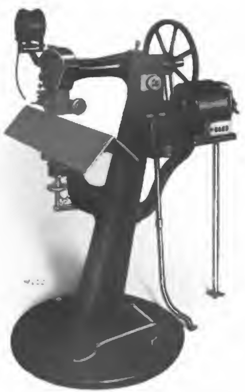


Fig. 13. Wire stitcher operated by a one-eighth horsepower motor. This motor is started and stopped by means of a snap switch in a similar manner to the one driving the numbering machine

variable speed motors and controllers, furnished by the General Electric Company, and never for a moment have we experienced any trouble or delay by reason of their failure to work perfectly. We are using them on our number 4 and number 00 Miehle job presses, and can secure absolutely any speed we may desire to run them.

It is a great source of satisfaction to us, and we are positive that we have an ideal power equipment for high-grade press work.

We are using, altogether, eight of the General Electric motors for individual drives, and believe that we have made no mistake in our power arrangement."

This is but one of several such letters received, and it is the belief of the writer that in the future the induction motor will play an important part in printing houses employing job and flat bed presses.

ELECTRIC SWITCHING LOCOMOTIVE FOR BUSH TERMINAL COMPANY

The Bush Terminal Company employs for switching purposes, around its extensive docks and warehouses in South Brooklyn, a number of steam locomotives, and one electric locomotive. This latter was built by the General Electric Company about three years ago, and has given such satisfaction in the way of tonnage capacity, ease of control, and low cost of maintenance, that the Company has recently given an order for a second.

The new machine has just been jointly completed by the General Electric Company and American Locomotive Company,

Fig. 1. End View of Switching Locomotive for Bush Terminal Co.

and the two illustrations presented in this article show some features of the locomotive that are worthy of comment.

While the truck is of a bar frame equalized design, the construction adopted differs from that ordinarily used on electric motor trucks, and follows, rather, a type which has been used with a good deal of success for the tender and guiding trucks of steam locomotives. The bolsters are carried rigidly on the side frame, and the weight of the frame and bolster is transmitted to the equalizers through one semielliptic spring on each side, instead of through bolster springs and helical side springs, as is the customary construction in the so-called M.C.B. equalized truck. This produces a simple, substantial form of truck, suitable for locomotive duty, and having a low cost of maintenance in such service.

The driving axles are 6 inches in diameter, and are made of forged steel, and have 36 inch fused steel tired wheels. Each truck is equipped with two GE-55-A (90-h.p.) two turn motors, with a gear ratio of 52/21. With this gearing, these motors will give at their one hour rating, a tractive effort of 3000 lbs. per motor, or 12000 lbs. per locomotive, at a speed of approximately 18 miles an hour.

The cab is built of sheet steel, supported by a frame work of small angles. It consists of a main operating cab, and sloping end cab, with narrow side platforms extending from the main cab to the ends of the locomotive. The floor of the locomotive is ⅜ inch sheet steel, but the floor of the main operating cab is covered with a ¾ inch wood covering.

The locomotive is equipped for both straight and automatic air, and in the center of the main cab is a CP-23 air compressor having a capacity of 50 cubic feet per minute and supplying air for the brakes. In the operating engineer's corner is located a C-6 master controller together with the valves and handles for operating the combined straight and automatic air. In the end cabs are located a sand box, air drum, contactors and rheostats. As the locomotive is to be used solely for switching service, it is supplied with a pantagraph trolley instead of the ordinary wheel trolley; thereby obviating the frequent reversal of the trolley which would be otherwise necessary in such service.

Fig. 2. Side View of Switching Locomotive for Bush Terminal Co.

The locomotive is equipped with bell, whistle and headlights. The headlights are supplied with 32 c.p. incandescent lamps, and gauge lamps for illumination of the instruments are wired on the headlight circuit and controlled with the same switches.

The principal dimensions of the locomotive are as follows:—

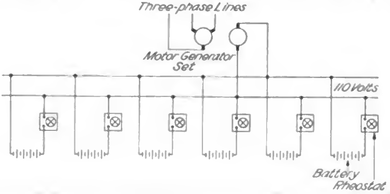
Length over bumpers. . 29 ft.
Height over cab. . . . . . . 11 ft. 9 in.
Length of rigid wheel
base . . . . 6 ft. 6 in.
Track gauge . . . . 4 ft. 8½ in.
Weight on drivers. . . . . 80000 lbs.

MERCURY ARC RECTIFIER AUTOMOBILE GARAGE OUTFIT

By R. E. Russel.

In most electric automobile garages having a capacity for charging two or more batteries at one time, the charging is done directly from either direct current feeders, or through an A.C.D.C. motor-generator set, from alternating current feeders. The general connections are similar to those shown in Fig. 1, either with or without the motor-generator. There is a small number of garages using single circuit rectifier outfits, one for each battery to be charged, but while this method is very satisfactory and highly efficient, the cost of the original installation is rather more than most garages care to invest for this purpose.

Referring again to Fig. 1, let us assume that six batteries are to be charged from the 110 volt busses, and that the number of cells in the various batteries is as follows: No. 1, 44; No. 2, 40; No. 3, 30; No. 4, 24; No. 5, 16; No. 6, 12. The tabulation in Fig. 1 shows the actual watts delivered to the battery, the watts loss in the rheostats and the efficiency of each circuit, neglecting the loss in the motor-generator set. It will be seen from the last column that the efficiency of the complete system, exclusive of the motor-generator set, will be about 58 per cent; with a motor-generator set having an approximate efficiency of 75 per cent, the efficiency of the system will average about 44 per cent.



	CIRCUIT						TOTALS
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	
No. Cells	44	40	30	24	16	12	166
Volts Av.	101	92	69	55	37	28	
Amps. Av.	20	20	20	20	20	20	120
Watts Used	2020	1840	1380	1100	740	560	7640
" Lost	180	360	820	1100	1460	1640	5560
" Total	2200	2200	2200	2200	2200	2200	13200
% Eff.	92%	84%	63%	50%	34%	25%	58%

Fig. 1. Diagram of Connections and Table for Charging Group of Batteries from Motor Generator

The General Electric Company has recently designed and built a new type of charging outfit for use on alternating current circuits which is known as the Catalog No. 46929, Mercury Arc Rectifier Automobile Garage Outfit. This outfit, which is shown in Figure 2, consists of a two-panel dull black slate switchboard with necessary compensating and regulating reactances, equalizing rheostats, rectifier tubes, and switches, all mounted with a view to obtaining the most compact and convenient equipment possible. The left hand panel of the switchboard is very similar to the standard rectifier outfit which has become familiar, and so it need not be described in detail. An additional feature on this panel is a triple throw transfer switch, by which the various A.C. voltages required in the operation of the outfit may be applied to the tube. The right hand, or charging circuit panel, is equipped with six triple pole double throw switches, and two 60 ampere ammeters; and also a six point voltmeter switch for reading the voltages of the various batteries being charged.

The scheme of connections of the charging circuits is outlined in Fig. 3. The rectifier, when charging a group of batteries similar to that shown in Fig. 1, would supply the busses with an average of about 193 volts D. C. It will be noted from Fig. 3 that the six batteries are arranged in two circuits of three batteries each, the batteries being so divided between the two circuits as to make as nearly as possible an equal number of cells in each. The table just below the diagram gives the corresponding losses and efficiencies when charging with these connections. It will be noted from this table that the average efficiency in the charging circuits alone, neglecting the losses in the rectifier and the very small losses in wiring, etc., is 99 per cent. As the efficiency of the rectifier when delivering 193 volts D. C. is about 84 per cent, the total combined efficiency of the complete charging equipment would be about 82.5 per cent.

Referring to the table in Fig. 1, it will be seen that the total watts used in the

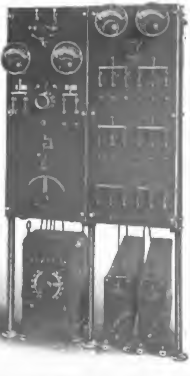
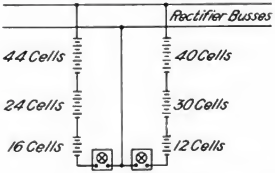


Fig. 2. Mercury Arc Rectifier Automobile Garage Outfit

charging circuits is 13200. At 75 per cent efficiency this would mean an input to the motor-generator set of about 17.6 kilowatts. As only 7,720 watts are required in the charging circuits from the rectifier, the total kilowatt input at 84 per cent efficiency would be 9.2. It will be seen from this that the saving in power is considerable when using the rectifier. Of course, a part of this saving in the cost of power would have to be used for buying renewal tubes



	CIRCUIT No. 1	CIRCUIT No. 2	TOTALS
No. Cells	84	82	166
Volts Avg.	193	189	
Amps. Avg.	20	20	40
Watts Used	3860	3780	7640
" Lost	0	80	80
" Total	3860	3860	7720
% Eff.	100	98%	99%

Fig. 3. Diagram of Connections and Table for Charging Circuits for Automobile Garage Outfit

for the rectifier, but even considering this additional expense, the saving in power should figure out at least 20 or 25 per cent.

While some garage managers might consider the combination of cells as charged under the above conditions an extremely unfavorable case, it should be borne in mind that batteries of the various numbers of cells mentioned are furnished by representative electric vehicle manufacturers for use in their "electrics". Nor is it possible for a charging garage to control the conditions most favorable to its charging plant; for example, garages are frequently called upon to charge a single battery of a large number of cells, such as a 40 cell battery; and a large number of batteries with a smaller number of cells, say, five 24 cell batteries. When charging such a group of batteries from a 110 volt D. C. circuit, the efficiency would be about 44 per cent. When it is necessary to include a motor-generator set the efficiency would be approximately the same, while with the rectifier the efficiency would be as high as 75 per cent.

The tabulation of efficiencies, when charging various sizes of batteries, is given below. For the sake of comparison, the charging rate on all batteries is taken as 20 amperes and the average volts per cell as 2.3. While some batteries are designed for a heavier charging rate than 20 amperes, the average battery can be efficiently and economically charged at this rate, although the time of charging may be somewhat longer:

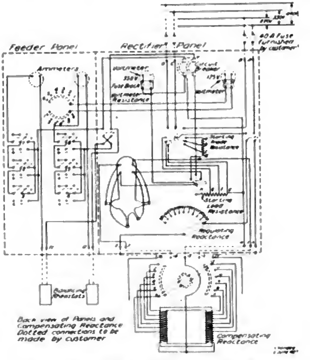


Fig. 4. Complete Diagram of Connections of Mercury Arc Rectifier Automobile Garage Outfit

There are, of course, almost innumerable combinations of batteries possible, but the above will give a general basis for comparisons between the various methods of charging.

Fig. 4 shows the connections of the whole Rectifier Garage Outfit. It will be noted from this diagram that when a battery is connected to the terminals of each of the triple pole switches marked + and −, and the switches thrown in the lower clip, the batteries are connected in two series groups similar to Fig. 3. If a large number of 12 cell batteries are to be charged at one time, the two groups may be thrown in series by simply reversing the position of a double pole double throw switch on the left hand panel. However, for practically all garage charging the circuits will be connected in series multiple.

In each of the two charging circuits a standard battery charging rheostat is connected. This rheostat is for equalizing the load between the two circuits. In order to use as little of the resistance as possible the number of cells of battery in the two circuits should be arranged to be equal, if possible, and if not equal, as nearly so as practical. When it is desired to cut out a battery for any reason the switch to which the battery is connected should be opened, a sufficient amount of the charging rheostat cut in and the switch thrown into the upper clip. This cuts out the battery, but the series circuit is not broken and the charging of the remaining batteries will be resumed.

The switches have been arranged with the idea of making them as "fool proof" as possible. It is impossible, with the arrangement of connections, to short circuit the rectifier tube by throwing all the switches in the upper clip; one battery at least must be connected in the circuit before current will flow through the tube.

The Rectifier Garage Outfit should be supplied with alternating current of 220, 330, and 440 volts. By applying these various voltages a wide variation of direct current voltage can be obtained, and from a single 14-cell battery to six 30-cell batteries may be charged at one time.

A large number of these outfits have already been sold and are apparently giving excellent satisfaction.

BATTERY		EFFICIENCIES		
NUMBER BATTERIES.	CELLS PER BATTERY.	WITH D. C. SUPPLY 110 V.	WITH M. G. SET.	WITH RECTIFIER GARAGE OUTFIT.
5	24	44%	44%	75%
1	40			
4	30	58%	59%	84%
2	24			
4	40	64%	50%	84%
2	12			
6	24	50%	54%	84%

SMALL TURBINES

By R. H. Rice

The first small Curtis turbines produced by the General Electric Company were constructed and installed some four years ago. These first units, which were designed for 160 lbs. steam and 80 volts, had a capacity of 15 kw. and were used for train lighting. They were of the square type, so-called on account of the cross section of the generator frame, and were originally placed on pilots of locomotives, a location extremely exposed to dust, cinders, rain, and extremes of temperature. In order to avoid any possible detriment from this exposure, these sets were removed later to the baggage car, where they gave very satisfactory service.

The present machines of this size, "round type", embody the results of all the experience gained with the old type, and are designed both for installation in baggage cars and for mounting on the top of the locomotive boilers. In this latter type the generator is so perfectly enclosed that no moisture or dust can gain access to the commutator or windings.

Service in cars or on top of locomotive boilers is perhaps the most severe to which turbine sets can be put. In the latter case where the machine is exposed to all conditions of the weather and can necessarily receive no care or attention while enroute, the performance of these sets has been most gratifying. In either location, the turbine forms the ideal prime mover, occupying a minimum of space, and requiring only infrequent and limited attendance. In comparison with engine sets, the latter take up much valuable room, are much heavier, require more attention from higher grade operators, and cause disagreeable vibrations in the passenger cars, a disadvantage from which the turbine sets are entirely free.

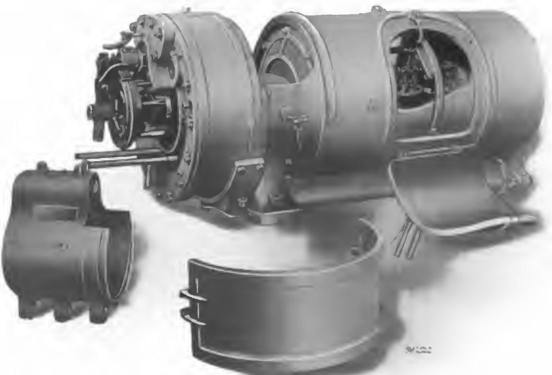


Fig. 1. 20 kw. Curtis Turbine Set—Locomotive Type

A particularly inviting field presents itself in the use of these sets mounted on the locomotive boiler, for use in lighting suburban trains; in which case the turbine is used without battery or other complicated and expensive apparatus, and the necessity for the employment of a flexible steam coupling is entirely eliminated. A number of sets are being installed in this way, and this use is undoubtedly destined to increase in popularity as its simplicity and reliability become demonstrated.

Beginning with these train lighting sets, many sizes have been developed, all of the horizontal type, up to 300 kw. These machines have until recently been of the direct current type, and for voltages varying from 80 to 250. All the generators are connected to the turbines directly without gearing and consequently run at turbine speeds. The Curtis principle renders this possible, and permits the attainment of excellent results with great simplicity of mechanism. In order, however, to attain good operation at turbine speeds, special methods of commutator construction had to be devised which would be capable of maintaining the commutator bars in absolutely fixed relationship against the influence of considerable centrifugal forces. In fact, this relationship has to be maintained more perfectly than is necessary in case of slower running machines, on account of the increased liability to mechanical sparking present at high speeds. As might be expected, however, commutators constructed to meet these conditions are more rigid and more perfect than those made in the old way; they possess greater wearing depth and are therefore capable of longer life.

The construction of the turbine and of these sets has been so planned as to obtain the greatest possible simplicity. Naturally, there are differences in design in machines varying as widely in capacity as 300 kw. and 15 kw. In the larger unit economy in the use of steam is perhaps the most important consideration; while in the smaller one simplicity and small bulk are the prime requisites. These, and similar considerations, will be found to have influenced the development consistently.

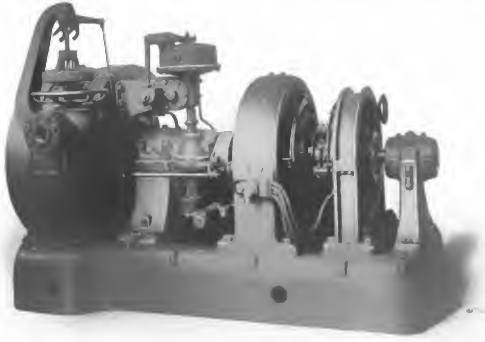


Fig. 2. Type CC 4 pole 100 kw. 2400 r.p.m. 125 Volt Curtis Steam Turbine

In the smallest sizes plain throttling has been used for governor control, since this method is the simplest possible; and as the size of the unit increases, the governing methods are increased in perfection from an economical standpoint, with the necessary accompaniment of a larger number of parts. So also in the construction of the turbine itself; the smaller sets have only a single stage, while as the capacity is increased, stages are added in order to increase the efficiency.

In the design of small units of this kind, it has been regarded as a prime necessity

Fig. 3. Type C 20 kw. 125 Volt Non-Condensing Curtis Turbine

that they should be entirely self contained, without any need of separate accessories. This consideration, which obviously does not apply to large sets, led to the choice of the horizontal type.

In this connection it may be noted that the Curtis type of turbine alone permits of the extreme of simplicity in regard to the support of the shaft, met with in these smaller sizes. These machines are provided with two bearings only, one of which does all the work, while the other simply maintains the shaft alignment. Machines with a multiplicity of stages, or of the reaction type, which require long drums and many rows of buckets, necessarily have to have a number of bearings. Some of the Curtis machines now have four bearings, but the tendency in recent designs is toward the use of two bearings, or three at the most. In the latter case, the form of flexible coupling used ensures perfect operation, without the necessity of maintaining absolute alignment of bearings.

A surprising perfection of speed control has been attained in this apparatus, due to the use of governors working on knife edges and therefore without friction; to the valve gears instantly responding to the action of the governor; and to the fact that action of the valve gear makes itself felt in the control of the turbine speed without any lag. In governing an engine no effect can be produced on the speed, except at one point in each stroke, (the point of cut-off), and consequently there is frequently considerable lag between governor action and speed control. In the turbine, however, where the steam flow can be varied at any instant, no lag occurs and speed control is more prompt.

In these machines every effort has been made to reduce the amount of attention required to a minimum. Lubrication is as nearly automatic as possible; the packings are non-adjustable and durable; the polished surfaces are small in extent; and the oil is confined to the inside of bearings and does not escape, therefore the machines are readily kept clean. Furthermore the generators are of open construction, so that brushes may be readily attended to and windings kept clean. Additional safety governors are always provided which act to stop the apparatus when the speed, for any reason, reaches a certain predetermined maximum in excess of normal.

In regard to steam consumption it may be stated that the steam consumption of the condensing turbine sets is always less than the best performances of reciprocating sets of equal capacity. Non-condensing turbines use more steam than reciprocating engines of equal capacity, when the latter are new or in the best possible con-

Fig. 4. 20 kw Turbine Set, Locomotive Type

dition. It is demonstrated, however, that the latter rapidly deteriorate in service, and the performance of the non-condensing turbine is always considerably better than that of a non-condensing engine of equal capacity after a year or more of service.

A mass of information in regard to this matter is being accumulated and will shortly be published.

It has been found that the turbine is admirably adapted to the driving of blowers and pumps, particularly where considerable pressures or lifts have to be attained. A line of single stage air compressors or blowers have been developed for turbine drive, giving pressures varying from three-quarters of a pound to four pounds; and a number of pumps have been built with steam turbines as the motive power. There is every reason to believe, from the success of these installations, that the use of the turbine as a prime mover for pumps and compressors is destined to become large and important.

AN AUTOMATIC ELECTRICALLY DRIVEN TURRET LATHE

By C. F. Lawrence.

Up among the hills of Vermont in the small town of Windsor, is located a machine company, which, a little over two years ago, manufactured a belt driven turret lathe. At this time business was very dull, and there was very little demand for their machines; their plant was running half time, and they employed only about fifteen men.

Fig. 1. Automatic Gridley Turret Lathe, driven by General Electric Motors. Rear View

Having started on a sort of missionary trip to visit a few of those machine tool manufacturers who had never considered the use of electric motors in driving their tools, I happened to visit this concern, namely, the Windsor Machine Company.

I here met the superintendent, who had charge of the men, and who also did the draughting and designing; and during the ensuing conversation, learned that they were not wholly satisfied with their belt driven machines, and the reasons for this dissatisfaction.

I then asked him if they had ever considered the use of electric motors for driving their tools, and upon his replying that they had not, suggested that we go over the entire design of his machines and see if they could not be run very successfully with variable speed motors.

After making preliminary sketches, and looking over the details, I recommended the use of a variable speed motor to operate the main drive of the machine, and a small, 2:1, variable speed machine for driving the feed. I made a strong argument to the effect that with these changes, and with the proper controlling arrangements on the machine, he could not only eliminate all belting and shafting, but regardless of the diameters of the work to be turned, he could maintain a certain maximum cutting speed at all times. If this were done, he was bound to have a machine which would increase the production, and increasing the production would mean a machine which would certainly sell.

I pointed out to him that owing to the nature of a turret lathe, a great advantage was to be derived by making it automatic and enabling the operator to run a great many of these lathes. We made preliminary detailed sketches of the whole outfit, and on leaving him the next morning, he stated that he was so enthused with the idea that he would not lose one minute in making formal detailed drawings.

I told him that I should like to keep in touch with him while the drawings were being made, and if they would order a set of motors when the machine was assembled, I should be pleased to make a special trip to his factory to see that all electrical and mechanical connections were properly made; and would make a test to see that everything was as it should be. He seemed to appreciate this, and I left him very enthusiastic over the idea.

After some correspondence covering a period of six or seven weeks, the General Electric Company received the first order from the Windsor Machine Company, which consisted of the following:—

One CR type, No. 3 frame, 3 h.p., 220 volt, shunt wound, variable speed motor; with a speed range from 500 to 1500 r.p.m., form C, (or frame cast without feet), having turned surfaces on outside of shell for placing in cradle. With this motor was included the R-75, drum type, reversing controller, with the proper resistances bolted to the back of the controller. This motor was used for running the main drive spindle of the machine.

For the feed drive was furnished a CR type, ¼ frame, ¼ h.p., 220 volt, shunt wound, variable speed motor, with a speed range of from 600 to 1200 r.p.m., form B., (or frame cast with feet). With this motor was included the R-76, non-reversing, drum type controller, with the proper resistances bolted to its back.

By referring to Figure 1, two large cam wheels will be noticed located underneath the machine. Also the two controllers can be seen on the lower part of the machine in the center. These are connected mechanically to the machine by a pinion and sector, which in turn are operated by a roller, that strikes the various shaft cams, which can be placed on the cam wheels.

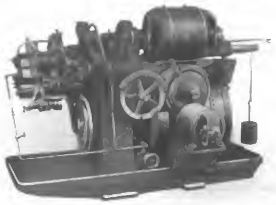


Fig. 2. Gridley Lathe. Front View showing Feed Motor

According to the class of work to be done, certain shaft cams are used, so that the whole machine is absolutely automatic.

On the extreme left of Figure 2, a weight hung on a chain will be noted. This weight presses forward a rod of steel stock, upon which the machine is constantly at work, and with the proper cams on the cam wheels the machine turns, drills, taps, mills, and finally cuts off the part to be made. As soon as it drops down into a pan below, the main chuck opens, the rod of stock steel is pushed forward, and the process of the machine again starts. As long as there is enough stock remaining, this operation continues.

Both of these variable speed motors run independently of each other; each controller being operated independently and automatically by cams. The entire range of spindle speeds from the minimum to the maximum can be obtained automatically on any operation, should it be desired, as for instance, in cutting off a piece of work, the spindle can be run slowly when the cutting off tool starts, and as it feeds nearer the center of the bar, the spindle automatically increases in speed so as to maintain a more uniform cutting speed.

This method of motor drive is the realization of the ideal in speeds and feeds, as any speed within the capacity of the variable speed motor can be automatically secured. This in itself has enabled the

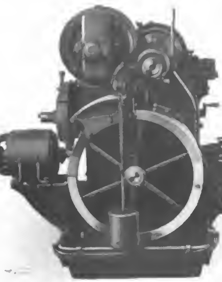


Fig. 3. Gridley Lathe. End View

operator to produce, in some instances, up to as high as 50 per cent more work than could be successfully produced with a belt driven machine. With the motor drive every operation on the piece can be performed at the best cutting speed.

Upon being notified that the machine was assembled, I made a special trip to Windsor, and upon arriving at the shop was extremely disappointed to learn that they had no generator to supply current to make a test. Upon inquiring I found that there was a small electric light station about five hundred or six hundred feet away across the river, which supplied only single phase current for lighting. I immediately telephoned to the superintendent of the central station, told him what I wanted to accomplish, and as he was an ambitious man and anxious to learn more about electric motors himself, he was quite willing to do everything he could to help us. The lighting plant contained an exciter giving a voltage of 125 volts and as the plant was driven by water power, they agreed to start up the water wheel and give us current from the exciter.

In a half hour we had six men reeling heavy line wire, the wire being hung temporarily from fences, trees, across the bridge into more trees, then to the top of the building, into a window, and along the floor to the machine to be driven.

After overcoming a great many obstacles in making connections, we started the machine about nine o'clock that night. The workmen who had left the factory at six o'clock, had many of them returned with their friends to witness the starting of the machine, and they were as pleased as a child with a new toy.

When I left that night the superintendent of the Windsor Machine Company stated that the stock of his company had certainly increased in value, and he felt sure of immediate success as soon as the machine was put upon the market. I assured him that by judicious advertising it would only be a matter of a few months when his factory would be too small to take care of the increased business.

This was a little over two years ago and their business has increased by leaps and bounds. Today instead of employing fifteen men, they have over two hundred, and have been working day and night. They have quadrupled the size of the plant, have put in new water wheels, new engines, boilers, and have new offices; and they are still thinking of enlarging their plant.

Up to the present time, they have given orders for over two hundred motors, and I understand that the General Electric Company has purchased nearly one hundred of their machines. As the motor drive has increased the production in some cases as high as 50 per cent, no one can afford to use the belt drive.

Another remarkable feature of this machine is its symmetry. The Windsor Company has received many letters complimenting them upon the symmetrical proportions of their machine.

In conclusion I would say that everyone connected with the above company is very enthusiastic over this machine, as they have seen such wonderful results accomplished in such a short time.

THE UTILITY OF THE SINGLE PHASE MOTOR

By Fred. M. Kimball,
Manager of the Small Motor Department.

As a means for enlarging the field for the use of electric power, especially among small industries located in suburban towns or on the outskirts of large cities, the modern single-phase motor occupies a unique and unassailable position, and is held in ever increasing regard by those who appreciate and cultivate the many advantages to be derived through its use.

Twenty years ago it was scarcely possible for a central station to develop a power load outside the zone of the thickly settled portion of the town in which it operated, because the only motor available for remote service was the direct current, series wound machine, adapted for use on arc light circuits. The Baxter, Excelsior, and Cleveland motors are well remembered examples of the general type referred to. These motors possessed substantially no inherent regulation, but made use of more or less complicated mechanical devices for automatically changing the strength of the series field to correspond with variations of load, or employed equally complicated means for shunting the magnetic strength of the field or varying the air gap to effect speed regulation. These devices were subject to disarrangement, and the regulation effected by them was, at the best, mediocre, considered from the present day standpoint. Judged by the state of the art at the time they were put on the market, however, they represented a notable contribution to the apparatus available to the growing central station.

If at that period, when the alternating current system was just making its way to the front, there had been a thoroughly reliable and satisfactory single-phase motor available, it is altogether probable that the extraordinary development of polyphase apparatus and distribution might have been very considerably affected and possibly postponed thereby.

If the aggregate manufacturing industry which is now, or may be, supplied with power by single-phase motors, be considered, it will be found to be enormous. A great many quite small towns have from three to ten manufacturers in the aggregate, which, if all could be induced to adopt the electric drive, would afford sufficient power demand to justify the operation of a day circuit. On the outskirts of our larger cities and towns, a still greater number of isolated factories exist, the power requirements of which can well be served by the electric drive. As a general statement, the single-phase motor will enable all this collectively large business to be added to the revenue of electric stations.

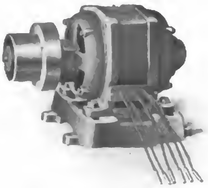


Fig. 1. Form KG Induction Motor

The single-phase motor as at first developed, left much to be desired, and owing to the unreliable service which was frequently afforded, the difficulties experienced in keeping it in successful operation and its high cost, it gained the confidence of central stations and customers but slowly. Particularly within the last five or six years, however, vast improvements have been effected, both in reliability and operation, until now there is a fair choice among several machines which are well designed, thoroughly built, reliable in operation, economical of maintenance, and reasonable in first cost. Central stations are realizing the opportunity of developing a power load beyond the limits of their direct current circuits, and in many cases beyond the limits of their polyphase circuits; so that at the present time we find the demand for single-phase motors is large, stable, and constantly growing.

In developing the power load in a sparsely settled portion of a city, the cheapest possible method is to be found in the use of the single-phase motor; operated, if necessary, from an aerial circuit which may be fed from one phase of a polyphase net covering the more thickly settled portion of the territory. Land values about the thickly settled portion of manufacturing cities are constantly increasing; material suitable for buildings within the fire limits is also rapidly advancing; so that it is frequently very necessary for the smaller industries starting in business to forego a location near the centre of the town in order that cheaper land may be obtained and the lower cost building erected.

By means of single-phase motor circuits, central stations can take care of this class of business; and from time to time, as the suburbs grow so that the expense of polyphase circuits is justifiable, they can be run into these new districts, and the single-phase motors exchanged for polyphase machines, the former being then used for developing business in localities beyond the then limits of polyphase circuits.

As manufacturers have found ways and means of solving the very difficult problems involved in the design and construction of single-phase motors, it has become possible to decrease the old and prohibitive prices, until at the present time single-phase motors of good quality may be purchased at prices fairly comparable with prices of direct current motors.

Among the most successful single-phase motors ever designed are the celebrated "KG" machines, built by the General Electric Company. They partake, in a marked degree, of the most excellent characteristics of the polyphase motors of the General Electric Company, which have an unassailable and world wide reputation. Compact in design, sturdy in construction, and always to be relied upon in operation, these motors furnish a most notable contribution to the catalogue of twentieth century electrical apparatus. In the design of the "KG" motor, all condensers, commutators, brushes, and other equivalent accessories

Fig. 2. Form RI Induction Motor

are eliminated, and simplicity and sturdiness are dominant and noticeable features. They may be used for substantially all purposes to which shunt wound direct current motors for constant speed purposes would be employed.

For service requiring specially heavy starting torque, the General Electric Company has designed, and has now developed in several sizes, another type of single-phase motor known as the "RI". This motor is of the repulsion type, and embodies, to a degree, the characteristics of the compound or series motor. It is especially useful in driving some varieties of fans and blowers, choppers, and mills.

By means of one or the other of the motors described above, a large share of all the power requirements of remote suburban or ultra-zone city districts may be successfully met.

THE LOCAL OFFICE

By J. Scribner
Manager Lighting Dept., Chicago Office of General Electric Company

So much depends upon pleasant relations existing between the customer, the Local Office and the Factory that it may be beneficial to point out how such relations can be established and maintained.

The purchaser seldom comes in contact with the factory, but does his business with the local office; therefore, the local office representative acts as the intermediary between the buyer and the manufacturer, and as such must necessarily be familiar with the apparatus or appliances sold and the conditions under which they are to be used, and at the same time know something about manufacturing and shop practice. Before closing a contract for a machine he should be reasonably sure that the machine is adapted to the local conditions under which it is to operate; and then having secured the order should see that the requisition is placed on the factory in such shape that there can be no chance for misunderstanding as to what is wanted.

The purchaser who is not familiar with problems of manufacturing may ask, for instance, for some modification of a standard machine that seems to him very simple but in reality involves factory labor and expense greatly in excess of its true value. In such a case, it is the duty of the representative to adjust the matter in a way that will be acceptable to the purchaser and at the same time impose no unusual burden on the factory.

On the other hand, it sometimes happens that after an order has been placed, the factory engineers will make certain recommendations that, while in themselves advantageous, do not fit the local operating conditions. The local representative should realize that the suggestions are made solely with the idea of assisting the customer, the salesman or the factory, and when they are not applicable it is usually because complete information has not been furnished the factory. This sometimes happens in switchboard work where the practice changes frequently because of the rapid development of the art.

We cannot too strongly emphasize the necessity for "complete information with the order". The proper filling of the order depends entirely on this information being furnished. The local office should not assume that the factory knows just what is required, but should keep in mind that the factory must follow the requisition and should see that the requisition is clear and explicit.

The large increase in business in recent years and the difficulties experienced in securing raw materials, labor and machine tools, have naturally resulted in some exasperating delays and errors. If the purchaser complains to the local office and the local office passes the complaint along to the factory with inconsiderate criticisms which do not tend to make the factory man any happier, the latter—who is only human—may reply in like vein, and there is tension all along the line. If the local representative had taken up the matter in a spirit of conciliation, he would in all probability have secured results more quickly and established more friendly relations between his customer, himself and the factory. The only object in making a complaint is to rectify an error and prevent its repetition.

It is unfortunate that local office men as a rule do not have better opportunities to become personally acquainted with the factory men with whom they are in frequent correspondence, thus giving each of them a chance to familiarize himself with the work of the other. The problems which each has to meet and solve are generally very different, and unless a man has had experience at both the local office and factory—which seldom occurs—he will not readily appreciate the troubles of the other fellow. The General Electric Company has long realized the necessity of close co-operation between its local offices and factories and provides for frequent meetings of local representatives and the engineering and commercial departments at its various works.

The purchaser has his troubles as well as the manufacturer, and the local office man can frequently establish more friendly relations with the customer by lending assistance, as, for instance, helping him to secure a contract for service, posting him on what is being done in other towns, and generally taking an interest in making his business satisfactory and profitable. His interest should not cease with the securing of an order.

One important duty of the local representative is to avoid ordering special apparatus when standard apparatus will answer. Orders for special apparatus are seldom desirable as, even at the advanced price, the margin of profit is too small in proportion to the extra work required on the part of the factory. When a customer wants a machine of special capacity, it will generally be to his advantage in many ways to order a standard machine of somewhat greater capacity.

In a large company a certain amount of routine is necessary to handle orders intelligently, correctly and rapidly, and while in some instances it may seem unnecessarily burdensome, the local representative should remember that departures from an established routine are liable to result in confusion and delay. It is better to spend a day in putting the order in proper shape before it goes to the factory than a week in straightening it out afterwards.

QUESTIONS

This section is open to inquiries upon engineering subjects. The questions will be submitted to the respective departments and such as are of general interest will be answered in this column, while those of less importance will be answered by letter.

Q. Suppose that a quarter phase circuit is connected to two twin conductor lead enclosed cables, each cable being brought up through the floor through a separate piece of pipe; then, if one of the cables is connected to one side of each of the two phases of the quarter phase circuit, the other cable of course being connected to the other side of each of the two phases, would there be an induced current in the pipe?

How would the impedance in the pipe compare with that produced if a single conductor were passing through it?

A. If the two cables of the same phase are put in the same lead cover there will be no losses introduced, or at least they will be so small as to be negligible. If, however, one lead of phase No. 1 and one lead of phase No. 2 are put in one lead covering, and the other two leads in a second covering, there will be loss in the load and this loss can be figured out in accordance with the two first equations given on page 150 in the General Electric Review for April, 1907.

In that particular case a current should be used which is equal to the current in each wire multiplied by the square root of two, and the resistance and inductance are then determined according to the formula given in the article quoted. E.J.B.

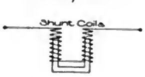


Fig. 1

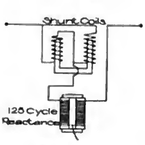


Fig. 2

* * *

Q. How shall I reconnect 125 cycle series alternating lamps so that they will operate on a 60 cycle circuit?

A. In meeting the demand for a high frequency (125 to 140 cycles) series alternating lamp, which could be later readily changed for operation on a 60 cycle circuit, the General Electric Company has for several years furnished the so-called interchangeable frequency lamp.

This is the standard 60 cycle lamp with

a small additional reactance sufficient to maintain the correct number of ampere turns in the shunt coils when connected for the higher frequency.

Fig. 1 shows the standard 60 cycle shunt connections, the two magnets being in series.

Fig. 2 shows the same shunt spools connected in multiple and in series with the small reactance, a connection suitable for 125, 133 or 140 cycles.

The change is invariably made from the higher to the lower frequency. The small coil when disconnected may be left in the lamp, or removed at the customer's discretion. In connecting the shunt coils, care should be taken that the original direction of current in each shunt coil is maintained; otherwise, there will not be sufficient pull to actuate the armature.

In order to overcome the extra impedance of the series coils at higher frequency, a greater starting resistance is required. Where two sticks of resistance are found it is recommended that one only be used in circuit for 60 cycle operation.

G.N.C.

NOTES

Mr. Geo. T. Fielding, Jr., of the Power & Mining Engineering Dept., General Electric Co., was married at the Bedford Park Presbyterian Church, New York City, on October 1st, to Miss Helen Ross Hornaday. Mr. and Mrs. Fielding will make their home in Schenectady.

* * *

The petition of the Schaghticoke Electric Co. to build an electric transmission line from its power houses near Schaghticoke and Johnsonville, to Schenectady, was given a hearing by the up-State Public Service Commission at Albany on September 31st.

This company was organized for the purpose of developing electric power on the Hoosic river, and proposes to construct dams at Schaghticoke and Johnsonville, where between 20,000 and 25,000 horse power will be available. It is contemplated that most of this power will be transmitted to Schenectady.

With the exception of a very few acres, all the property necessary for the erection of the proposed plants has been purchased. The committee reserved its decision on the application.

* * *

The Chicago Office of the General Electric Co. recently received the following order from Mr. H. W. Hillman, formerly associated with the Heating Department of this Company, but who is now with the Grand Rapids Muskegon Power Co. as Commercial Manager:

500 flat irons,
126 glue pots,
250 luminous radiators,
10 tailor irons,
22 2 kw. air heaters,
40 small water heaters,
100 cigar lighters,
50 shaving cups,
25 heating pads,
25 soldering irons,
6 6-in. stoves.

* * *

During the past month the General Electric Company has had the pleasure of visits from a number of prominent men associated with the A. E. G., among whom were Superintendent Auerbach and Director A. Elfes, manager of machine shops, and Mr. H. Zader and Mr. Bassler, engineers respectively in charge of the sales department of heating apparatus, and the factory of heating apparatus and insulating materials.

The engineers spent the greater part of their time in going through the different shops, and warmly complimented the organization and products of the General Electric Co.

* * *

NEW YORK ELECTRICAL SHOW

The General Electric Company's exhibit at the New York Electrical Show in Madison Square Garden, September 30th to October 9th, occupied the space at the left of the main aisle in the center of the Garden. The space was partially covered by a booth roofed with an arched frame work thickly studded with incandescent lamps. This booth was equipped to demonstrate a model dining room and kitchen. The corps of demonstrators effectively utilized various electric cooking and kitchen utensils in the preparation of attractive delicacies, which were served to visitors at the exhibit. Arranged on counters around the booth were samples of the devices used in the kitchen and dining room.

Outside of the booth were several motor applications of interest to housekeepers, including among other things an electrically driven sewing machine, ice cream freezer, washing machine, potato peeler, carpet renovator, dough mixer, coffee grinder, meat chopper, music box. In addition to these were shown several industrial applications of an interesting nature, including an electric air rock drill in operation, circular mitre saw, mercury arc rectifier charging outfit, direct connected gasolene engine generator set, electrically driven floor sander, and a Curtis turbine train lighting set.

In one part of the exhibit was a color booth containing four different types of illuminants, showing the variable effects of different kinds of artificial light on color comparisons.

* * *

The following list of patents was issued to the General Electric Company during the month of September:

865,588, Sept. 10, Hewlett & Button. Electric switch.

865,617, Sept. 10, Steinmetz. Induction motor.

865,618, Steinmetz. Production of nitrous compounds.

865,707, Jodrey. Self-sustaining field-magnet coil.

865,907, Sept. 10, Jodrey. Coil for electrical purposes.

865,985, Sept 17, Bains. Variable voltage transformer.

865,988, Sept. 17, Batchelder. Electric locomotive.

865,997, Sept. 17, Churchward. Electromagnetic variable speed mechanism.

866,011, Sept. 17, Ferguson. Method of improving vapor electric devices

866,012, Sept. 17, Fleming & Halvorson. Arc lamps.

866,068, Sept. 17, Rice. Nozzle and diaphragm for turbines.

866,075, Sept 17, Schneider Water jet grounder for protection against excessive potentials in electrical systems.

866,081, Sept. 17, Stern. Control of separately excited generator.

866,089, Sept. 17, Tournier. Combined lamp socket and shade hold.

866,090, Sept. 17, Troutman. Fuse box.

866,105, Sept. 17, Whittlessy. Flush receptacle and plug.

The following bulletins were published by the General Electric Co. during the month of September:

4530 Mercury Arc Rectifiers

4531 Curtis Steam Turbine-Generator

4532 Direct-Current Motor-Starting Rheostats, Types SA and SO

4533 Wright Demand Indicators

4534 Curtis Steam Turbines—Horizontal Shaft Type

4536 Railway Signals, Top Mast, Direct Connected Two Position Type

4538 Catenary Line Material

4539 Inductor Alternators

We print below some verses that have been going the rounds of the English papers, and also a paraphrasing by Mr. N. C. Ross of the Cincinnati office of the General Electric Co.

THE RECEEPROCATIN' MON

By Robert Burns and others, including Gavin Hamilton.

Oh! woesome 'oor that saw the birth
O' turbine thocts in Pairsons' head;
I weesh that I wis aff the earth,
Or else the turbine man wis deid.

I'm a receeprocatin' mon;
I luve tae hear the bearin' bump,
Or yet the piston groan and grunt
That's religated tae a pump.

This whurligeegin' thing I hate,
For whatnae gude is it tae dae?
Tae sae the fearsome thing gurate
Gars me puir stummuch gang agley.

I widna care if it had ocht
Tae need a tender fitter's haund,
But it runs sae weel sin it was bocht
I hivna had tae slack a glaund.

I hate the tribe of whurleegigs,
It's jist a pinch o' steam, then "Scatt!"
I'm a receeprocatin' mon,
I stan' or fa' wi' Jemmie Watt.

AFTER USING

(The Conversion of the "Receeprocatin' Mon")

Oh! gladsome 'oor that saw th' birth
O' turbine thochts in Curtis' heid;
He'll knock thae ithers aff th' earth—
I'm fash they weesh that he wis deid.

Lang syne wi' muckle din an' blether
I telt a tale in doleful rhyme;
I tint ma reason a' thegither;
But gat it back, an' mair, wi' time.

I'm no receeprocatin' mon, th' day,
But e'en convairtit haird an' fast;
Th' upright shafts hae come tae stay,
Th' blades stay in; step bearin's last.

It gars me greet tae count th' years
I patched, an' oiled, an' swore an' swat;
Th' "Curtis" gies nae cause for tears—
Deil tak th' tribe o' Jamie Watt!

Tho' ither turbines run or stop,
Or let th' steam straight through them blaw;
Wi' Geordie Curtis an' his top
I'm here tae stan' or here tae fa'.

—N. C. Ross.

General Electric Review

INDEX TO VOLUME X

December, 1907 — June, 1908

GENERAL ELECTRIC COMPANY

Schenectady, N. Y.

GENERAL ELECTRIC REVIEW

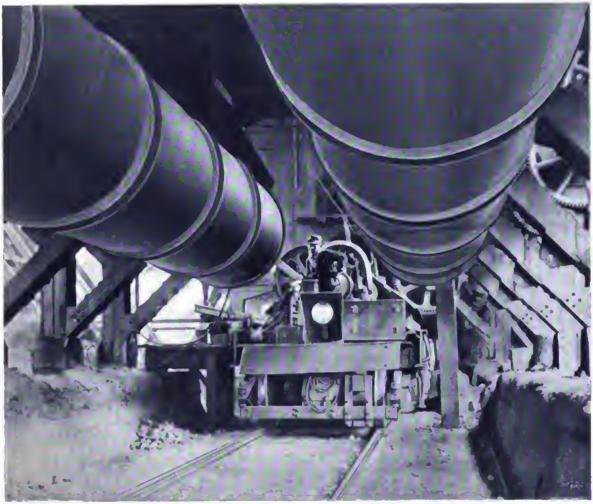
INDEX TO VOLUME X

INDEX TO AUTHORS

TWO DOLLARS A YEAR TWENTY CENTS A COPY

GENERAL ELECTRIC REVIEW

VOL. X, No. 1 PUBLISHED MONTHLY BY GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU SCHENECTADY, NEW YORK DECEMBER, 1907



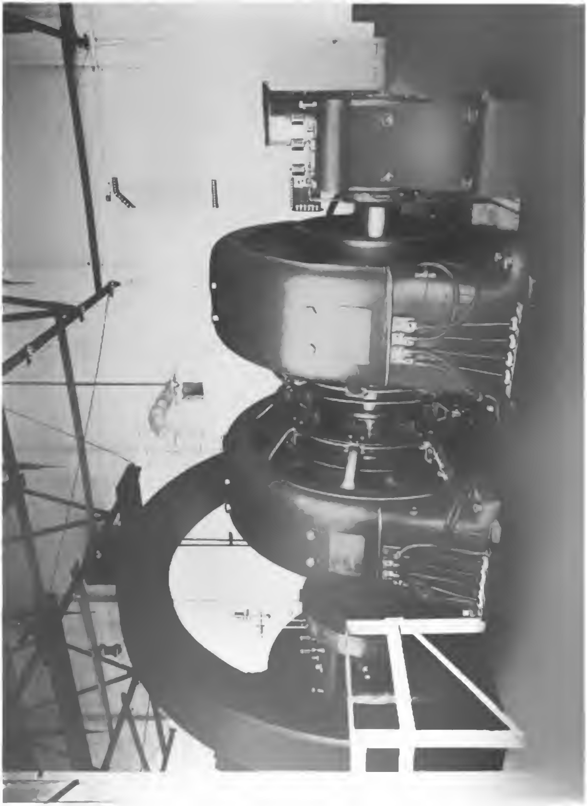
Motor-Driven Scale Car, Operating Under Ore and Limestone Pockets
Illinois Steel Company
(See page 3)

GENERAL ELECTRIC REVIEW

VOL. X NO. 1

DECEMBER, 1907

CONTENTS



Generators of Indianapolis & Louisville Traction Co., Scottsburg, Ind.

(See page 13)

VOL. X No. 1 SCHENECTADY DECEMBER, 1907

GENERAL ELECTRIC REVIEW

ELECTRICAL MACHINERY IN STEEL MANUFACTURE*

BY W. T. DEAN

The object of this article is to present an outline of the mechanical processes and means of transportation involved in the production of the several forms of commercial steel, without attempting to impart technical information, which would only be of interest to the manufacturer of steel, and would be quite beyond the ability of the writer.

The materials required in the production of pig iron, from which nearly all steel is made, are as follows:

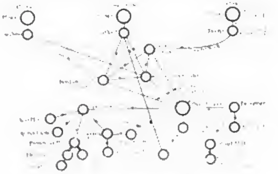


Fig. 1. Diagram of Steel Making Process

First, iron ore, consisting of various oxides of iron of different degrees of purity with respect to the percentages of silicon, manganese, phosphorus, and sulphur contained.

Second, lime stone, which is used as a flux.

Third, coke, which acts as a fuel and as a reducing agent when transformed to carbon monoxide. Theoretically, any form of carbon should serve the above purpose, but in modern blast furnace practice, the great size of the furnaces, with the consequent heavy burdens, require a fuel which combines great resistance to crushing, with a rough structure which will make the entire charge within the furnace as porous as possible. Coke is the only fuel which meets the above requirements.

Fig. 2. Shaft House for a deep mine in the Lake Superior region with skip car about to dump and with loaded railway car under the pockets

Figure 1 is a diagram illustrating the entire process of steel making, beginning with the ore, coke and limestone; the transportation agents bringing together the raw material at the blast furnace, thereafter diverting the pig iron to the Bessemer, or to the open hearth process for converting to steel; after

* Presented before the Schenectady Section, A.I.E.E., October 25, 1907

which the raw steel is sent to the various finishing processes.

The principal source of iron ore in this country is the Lake Superior district, and mining is accomplished by open cut working—with steam shovels loading directly into the cars—and by deep mining, usually using the caving system, with narrow gauge dump cars and high speed, powerful hoists; the latter automatically dumping the ore into cars on the ground level. The open cut work is now being done, in at least one mine, by means of towers, cable ways, and motor-operated grab buckets or excavators. For underground transportation both mules and electric locomotives are used.

Fig. 3. Open Cut Mining in the Lake Superior District

However mined, the ore must be transported by rail to the loading docks, where the cars are usually run up an incline and dumped into bins, from which the boats are loaded by gravity; it being possible to fully load a ten thousand ton boat in from four to six hours if the bins are full.

From Lake Superior ports the boats must pass through the locks at the Soo—which now pass more tonnage than any other port in the world—and from thence they continue their passage down the lakes, either to Chicago or the Ohio ports, a trip that consumes about four days. By the munificence of Uncle Sam, ample harbors have been provided at South Chicago, so that several boats may anchor in safety within reach of the docks.

Fig. 4. Ore Bridge with Clam-Shell Grab Discharging Ore into a Transfer Car

Several methods of unloading are in vogue, the motor-operated grab bucket or clam-shell unloader being the fastest device yet developed for the purpose. The original method of unloading involved shoveling the ore into buckets, which were hoisted from the hold by more or less efficient means, and the ore dumped into cars, which were pushed by hand over a structure elevated above the stock piles. Great gangs of laborers from southeastern Europe performed this work a few years ago; now a single operator with a motor-driven unloader displaces one hundred laborers, and five or six operators will unload a ten thousand ton boat in four hours.

Fig. 5. Ore Bridge and Ore Unloaders

Fig. 6. Top Rigging of Blast Furnace showing a Skip Car about to Dump into the Upper Bell

The unloaders deliver the ore into cars under their own structure, or else into a great concrete trough parallel to the dock, from which the ore bridges remove it to stock piles or directly to pockets supplying the furnaces.

The ore bridge is a steel bridge structure, usually about 600 feet long, mounted on multiple trucks on parallel tracks, and pivoted at both supports; so that, within certain limits, it may take any position across the stock yard. A clam-shell grab, similar to that used on the unloader but of greater capacity, digs and transports the ore. So powerful are the grabs, that six inches of solidly frozen ore offer no obstacle, and the furnaces may be supplied from the stock piles at any season. The grab bucket is operated by means of steel cables and winding drums; the latter receiving their power from motors. Two separately actuated drums are required for each grab, one for the opening lines, and the other for the closing lines; they are used in conjunction with each other, and divide the load when the grab is fully closed and hoisting begins. The grab is opened by holding the opening lines and releasing the closing lines, the lines being held by means of dynamic and solenoid brakes, or air brakes.

Fig. 7. Base of Blast Furnace During the Cast

Taking the ore from the trough at the dock, or from the stock piles, the ore bridge deposits it into hopper-bottom bins, or into hopper-bottom transfer cars on top of the bins.

Similar bins are supplied with coke and limestone from cars, and the proper mixture of ores, together with suitable proportions of coke and limestone, are withdrawn from the bottom of the bins and weighed; hopper-bottom scale cars being used in weighing the charge, and accurate records kept by means of tape printing devices.

The scale cars are motor-operated, and run on standard gauge tracks, which pass over pits into which the buckets or skip hoist cars descend at an angle to clear the tracks. The whole scheme of ore handling may be readily seen from the illustration.

The top of a typical blast furnace of the largest size—the nominal capacity of which is six hundred tons of pig iron in twenty-four hours—is shown in Figure 6, and the bottom is illustrated in Figure 7.

The charge is hoisted and dumped automatically by motor-driven hoists, adjusted so accurately that the position of the cars, when at the top or bottom, never varies more than six inches. All parts of the hoisting machinery are made as strong as possible to prevent the possibility of delays; and spare motors, controller parts, gears, etc., are kept constantly on hand, for the success of a blast furnace depends very largely upon the absolute regularity of all its functions.

Without going into the chemistry of the complicated reactions taking place in the interior of a blast furnace, it may be said in general that the combination of fuel, flux, ore, and heated air under pressure, produces pig iron, slag, and combustible gas.

The pig iron is tapped out at intervals of four hours through an orifice near the bottom of the hearth, while the slag is tapped out as often as is necessary through the "cinder notch," which is located some four feet higher than the iron tapping hole. The gas flows continuously, and is used in part to heat the stoves, the excess being burned under boilers to produce steam, used in internal combustion engines, or allowed to escape into the atmosphere.

The molten pig iron is transferred in special ladle cars to the Bessemer or open hearth departments, as the case may be, while the slag is hauled away in molten form in "cinder pots," or is granulated, by means of water, for the manufacture of cement.

Bessemer Process

The Bessemer process is too well known to need extensive description. The pig iron, still molten from the blast furnace, is poured into a large cauldron or "mixer," where the product of several furnaces may be mingled and averaged; still molten it is transferred in quantities of about fifteen tons to the Bessemer converter, the pig iron being poured into the top of the converter, which is partially tipped downwards for the purpose; air blast is then turned on and the vessel turned upright.

After being "blown" for the required length of time (as judged by the color of the flame, which varies from dark orange to white), the vessel is partially turned down, the blast shut off, and spiegel-eisen added.

The length of the "blow" varies from seven to fifteen minutes, depending largely upon the amount of silicon in the pig iron. The blowing process reduces the pig iron to nearly pure iron, the spiegel-eisen is added to bring the carbon and manganese contents to the specified figure.

After the addition of spiegel-eisen, the vessel is immediately turned down and the contents poured into a waiting ladle, from whence it is poured into cast-iron molds, on small flat cars called "turtle backs." The

Fig. 8. Bessemer Converter

steel chills upon contact with the molds, and the latter are strpiped off within from five to ten minutes after casting, leaving the ingots, as the steel is now called, red hot and solid on the exterior but still soft, or even molten, within.

The ingots are now quickly transferred to the rail mill reheating furnaces, or to the "soaking pits," where a high homogenous temperature throughout the ingot is obtained in less than two hours. They are then drawn by electric ingot cranes, and are transferred over motor-driven tables to the blooming mill, where the first reduction in section is made. From three to seven passes are made in the blooming mill and the product is called blooms.

The blooms are then sheared into lengths which will produce from two to four rails of the weight desired, and about 15 per cent. of the end of the bloom goes into scrap, in order to reduce the percentage of defective rails, as this portion of the bloom is the part most likely to be lacking in homogeneity.

The sheared blooms pass through some fifteen stands of rolls, being gradually reduced in section and elongated until the finished shape is attained, when hot-saws cut them into commercial lengths.

The entire time from ingot to finished rail is about 90 seconds, and an ingot is bloomed every 35 seconds. When sawed to length the rails are still at a bright red heat, and they must be allowed to lie on the cooling beds some time before being straightened, drilled, and shipped.

Open Hearth Process

As pointed out previously, the Bessemer converter requires about ten minutes to produce fifteen tons of steel. The open hearth process handles larger quantities of metal but is a much slower operation, a complete reaction requiring about eleven hours. As a consequence, the open hearth process is costly; on the other hand it is certain of results, and many ores not suitable for the Bessemer process may be used. The demands of the railroads for better rails, and the increasing scarcity of Bessemer ores, are rapidly retiring the Bessemer process. In fact, no Bessemer plants are under construction or are contemplated at the present time.

The open hearth furnace is a large, shallow vessel, in which approximately equal portions of pig iron and cold scrap steel are melted by means of a gas flame. Suitable fluxes are added as required, forming a protecting

Fig. 9. Reheating Department of the Structural Shape Mill showing Overhead Charging Cranes

Fig. 10. Charging Side of Open Hearth Plant showing Motor-Operated Charging Machine

coating over the top of the bath. The temperatures attained are so high that the steel boils violently. Samples are taken at intervals, and the furnace is tapped when the desired analyses are obtained weighing sixty tons or more, must be tapped at one time and into one large ladle suspended from the crane. From the ladle the steel is tapped into ingot moulds, as in the Bessemer process.

Fig. 11. A Close View of a 40 in. Slabbing Mill showing Vertical and Horizontal Rolls

All of the molten metal, as well as the cold scrap about an open hearth plant, is handled by means of motor-driven machines; such as

Fig. 12. A 40 in. Slabbing Mill showing overhead charging and drawing cranes, motor-operated tables and mill in background

charging cars and pit cranes. The pit cranes are usually of about one hundred tons capacity, as the entire cast of a furnace,

In addition to operating the charging cars, cranes, rail mill, etc., motors are used to drive the various other mills, *viz.*, the slabbing, shear plate, blooming, and structural mills. The first of these, *i. e.*, the slabbing mill, is a form of blooming mill equipped with vertical as well as horizontal rolls and produces slabs of suitable thickness and width for further rolling in a shear plate mill or a universal plate mill.

A shear plate mill may be defined as a mill for rolling plates to a definite thickness, without particular regard to width. Such a mill is not provided with vertical rolls, and the product is sheared on both sides and ends to the required shape.

Finished sheared plates are handled about the mill and on the loading docks by electromagnets attached to traveling cranes.

The blooming mill, when alone, is used to convert ingots into blooms for some subsequent process, and it is frequently used to produce various sized commercial billets as well. The processes are similar to those described when discussing the rail mill.

Blooming mills, when engine-driven, are usually "two high," *i.e.*, have two rolls, and are reversed for each pass. When motors are applied to the driving of such mills, it has been thought best to build the mills "three high," or with three rolls running continuously in one direction, the piece passing first between the middle and lower roll, returning between the middle and upper roll.

Fig. 13. A 40 in. Blooming Mill with Motor-Driven Screw Down Motion

Blooms for subsequent rolling into channel and I beams are rolled into a shape roughly approximating the letter I, then reheated and transferred to a structural shape mill.

The structural shape mill differs from the rail mill only in that the several passes are usually made through several roll stands, driven by a single engine; thus necessitating frequent returns over practically the same space. This requires special machinery for transferring the piece from one pass to another; a duty performed by motor-driven traveling tilting tables. The machine consists of a roller table with its driving motors, the whole mounted on motor-driven trucks so as to pass along in front of the several roll stands. The table must also tilt up and down, in order to reach the upper and lower passes of a "three high" mill.

As the piece becomes elongated, means must be provided to support and move the portion which would otherwise overhang the table. For this purpose traveling roller tables are provided behind those just described. The operator—who rides on the front or traveling, tilting table—must be

Fig. 14. Pit of Drawing Side of Open Hearth plant showing 100 Ton Overhead Ladle Cranes

able to control, almost simultaneously, ten distinct motions, as well as watch the piece of steel. I have explained the above at length in order to show the importance of supplying strictly reliable and easily operated automatic controllers for such work.

Fig. 15. A 24 in. Structural Shape Mill with Motor-Operated Traveling Tilting Tables

Cement Plant

When discussing the blast furnace, the granulating of the slag was mentioned. The slag, or cinder, as it is more commonly called, is allowed to run from the furnace in open channels towards concrete tanks. About ten feet from the end of the run, water is forced at a pressure of 20 pounds into the bottom of the run, and mingles with the stream of molten cinder. The result is a buff colored, light weight, granular substance, known as granulated slag, which is dug out of the tank with motor-driven, clam-shell grabs, and loaded into cars for transfer to the cement plant.

Fig. 16. Concrete tank for granulating cinder with clam-shell grab bucket operated from overhead traveling crane

Approximately 55 per cent. of crushed limestone is added during the process of cement making, and the mixture is finely divided in tube mills, calcined, and again finely divided in ball and tube mills; making an excellent Portland cement known as the Universal brand.

All of the machinery in the plant of the Universal Portland Cement Co. is motor-driven; an article describing this plant and its equipment was published in the November issue of the Review. The power is supplied from the Illinois Steel Company's plant at South Chicago, distant ten miles, and as it is largely obtained from waste blast furnace gas, its cost is surprisingly low. Approximately 9000 kw. is transmitted to the cement company at 22000 volts, and the output of the cement plant is about 10500 barrels per twenty-four hours.

When a stranger visits the works of the General Electric Company at Schenectady, he is astonished at the splendid provision for every form of manufacturing, and wonders who can grasp the details of so complicated and yet so perfect an enterprise; but the stranger visiting a great steel plant is lost in awe at the Titantic forces made to do man's bidding at the touch of a finger, and trembles at the rumblings of the volcanoes in leash, spouting white hot iron and molten steel.

Fig. 17. General view of North Slip, Illinois Steel Company, South Chicago Illinois, showing steamers, ore unloaders, ore bridges and transfer cars and furnaces in the background

THE HIGH TENSION D. C. LINE OF THE INDIANAPOLIS AND LOUISVILLE TRACTION COMPANY

By John R. Hewett

In the issue of the "Street Railway Journal" for September 7, 1907, there was a reprint of a paper read before the Chicago section of the American Institute of Electrical Engineers on March 26th by Mr. W. J. Davis, Jr., which paper contained the very interesting table given below:

600 VOLTS DIRECT CURRENT	LENGTH OF TRACK	NO. OF CARS	SIZE MOTORS	TOTAL MOTOR H.P.
Texas Traction Co.	63 miles	15	4 x 75 h.p.	4,500
Elmira, Corning & Waverly	15 "	7	4 x 60 "	1,680
Buffalo, Lockport & Rochester	70 "	19	4 x 75 "	5,700
Oregon Railway	40 "	8	4 x 75 "	2,400
	188 miles	49		14,280
1200 VOLTS DIRECT CURRENT				
Central California Traction Co.	16 miles	6	4 x 75 h.p.	1,800
Pittsburg, Harmony, New Castle & Butler	63 "	12	4 x 75 "	3,600
Indianapolis & Louisville	41 "	10	4 x 75 "	3,000
Indianapolis, Columbus & Southern	.. "	3	4 x 75 "	900
San Jose & Santa Clara	9 "	8	4 x 75 "	2,400
	129 miles	39		11,700
SINGLE-PHASE 3300 or 6600 VOLTS			4 x 125 h.p.	
Washington, Baltimore & Annapolis	52 miles	25	2 x 125 "	11,500
Central Illinois Construction Company	40 "	10	4 x 75 "	3,000
Anderson (S. C.) Railway	35 "	3	4 x 75 "	900
Richmond & Chesapeake	15 "	4	4 x 125 "	2,000
	142 miles	42		17,400

Total horse-power in motors sold 43,380, of which
1,200 volt direct current has 27 per cent.
600 volt direct current has 33 per cent.
Single-phase alternating current has 40 per cent.

This table shows the horse-power, motor capacity, number of cars and length of track of the various high speed interurban roads for which the General Electric Company has recently taken orders; and the point of prime interest is to be found in the fact that fully two-thirds of the total motor capacity sold consists of 1,200 volts direct current and single-phase alternating current motors, which is a plain evidence that there is an earnest movement on foot in the engineering world to reduce the first cost of constructing roads by the application of higher working voltages.

A careful study of the above table will be instructive as showing what confidence is now being placed in what may be styled the "New Systems."

The lines of the Indianapolis & Louisville Traction Company are the first to be put into operation with the trolley pressure of 1200 volts D. C., and for this reason an additional interest will be attracted to that system. As the name implies, the company will operate their cars from Indianapolis to Louisville, although their right of way only extends from Seymour to Sellersburg. Very favorable agreements have been entered into with the Indianapolis, Columbus & Southern Traction Company, the Louisville Northern Railway & Light Company and the Louisville & Southern Indiana Traction Company, which are the roads to bridge the intervening distance not covered by the Indianapolis and Louisville lines.

The car barns and power house of the Indianapolis & Louisville Traction Company are erected at Scottsburg, Indiana, and both are substantial red brick buildings. The power house contains two horizontal single cylinder Corliss engines rated at 750 horse-power each, coupled to four General Electric MP-8-300-120-600 volts compound wound generators. Two generators are mounted on the extended shaft of each engine, and the windings are connected in series in order to be additive and to give 1,200 volts. The fields are also connected in series on the grounded side. The boiler equipment consists of four Babcock & Wilcox water tube boilers, each rated at 300 horse-power and working at a steam pressure of 160 pounds per square inch. The switchboard consists of two generator panels, two feeder panels and two equalizer panels, all of which were supplied by the General Electric Company.

The car barn is 173 ft. 4 in. long and 69 ft. 10 in. broad. It is provided with four parallel tracks and four wheel pits each 55 feet in length, and has more than sufficient capacity for holding the present equipment, which consists of eight 50-foot passenger cars and two express cars. One end of the car barn is fitted up as a work shop, being equipped with lathes, drills, forges and other appliances which are sufficient, not only to maintain the cars when once in operation, but to do all the work incident to installing the electrical equipment in the first place. The offices of the master mechanic, train dispatcher and secretary and treasurer of the line are also under the same roof as the car barn.

The length of the road at present in operation is a little over 40 miles, and the most noticeable feature of the line construction throughout is that it differs in no single respect from a well equipped 600 volt D. C. road. The trolley, which is of 0000 capacity, is supported by a bracket construction and the feeders are arranged as shown in Figure 1.

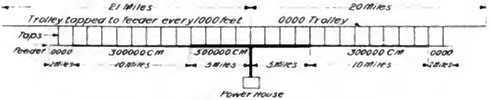


Fig. 1. Diagram Showing Arrangement of Feeders

It will be noticed that the power house is situated in a central position and that the feeders extend for a distance of approximately twenty miles in each direction. It is possible to operate the road for its entire length at 600 volts pressure, but as will be anticipated, under such condition the voltage is poor at both ends of the line.

The road bed is rock ballasted throughout and the grading is finished in a style seldom equalled on any new interurban system. It is very possible that exceedingly good schedule speeds will be maintained between Indianapolis and Louisville. The two largest bridges on the road are respectively 525 and 480 feet in length, the former crossing the Muscatatuck River and the latter the Vernon Fork of the same.

The greatest interest will undoubtedly be centered in the electrical equipment of the cars, as the arrangements are such as to permit their operating on both 600 and 1,200 volts D. C. Each car is equipped with four GE 205 motors, which are commutating pole machines and have a capacity of 75 horse-power each. These motors are connected in two pairs, each pair consisting of two motors in series, so that the voltage across the terminals of each individually never exceeds 600. The fields and armatures are provided with extra insulation as a safeguard against any momentarily high values of voltage should any pair of wheels skid or slip during operation. Extra large creepage surfaces are provided owing to the fact that there is 1,200 volts between the brushes and the ground. The Sprague General Electric multiple unit Type M automatic control is used. The control circuits proper are operated by current at 600 volts, the high tension of the trolley being reduced or transformed by means of a dynamotor. This dynamotor works on the same principle as the auto-transformer, or perhaps it may be more clearly described as a motor-generator with both windings wound on the same core and in the same slots. It is provided with a commutator at each end. The 600 volts for operating control circuit when the car is running on 1,200 volts is obtained by the dynamotor as follows:

The trolley is connected to one set of brushes on the first commutator, the other set of brushes on commutator No. 1 being connected to a set of brushes on commutator No. 2, while the remaining set of brushes on commutator No. 2 are grounded. As one set of windings is always generating while the other set is motoring, it is obvious that the potential across the brushes of commutator No. 2 will be half of the applied voltage, namely 600 volts. The 600 volt current obtained in this manner is not only used to energize the contactor coils, but also to operate all the auxiliaries. The dynamotor has a rated capacity of 12 kw.

Fig. 2. Two-car train of the Indianapolis & Louisville Traction Co.

The contactor fingers make and break the motor circuit current when operating on both 600 and 1,200 volts, and for this reason they are designed with additional insulation.

As stated previously, the motors are provided with commutating poles, and as this is the first instance of a D. C. commutating pole railway motor being placed in service to operate at 1,200 volts, the most essential features may be of interest. The exterior of the motor, as shown in Fig. 3 is of the box frame type, and in general the construction is similar to that of the Standard General Electric Railway Motor of the same rating, with the addition of commutating poles.

The commutating poles are situated midway between the exciting poles and have their windings all connected in series with one another and with the armature. The function of these commutating poles and their operation may best be understood by considering an imaginary view of the armature with two poles developed to form a flat surface. In such a diagram there will be a broad sheet of current flowing in the armature in the direction of the motor shaft under one pole, and in the reverse direction under the other pole. This sheet or band of current produces a magnetic field of its own which is opposed to the main flux of the field poles and changes the distribution of this main exciting flux. Not to enter too much into detail, the principal effect of this distortion may be stated as the formation of a strong magnetic field midway between the N. and S. pole of the motor, which field has the harmful effect of producing a local current in the armature conductors at the very instant when their current is being commutated and reversed by passing from the influence of one field to that of another. Or, in other words, the magnetizing effect of the armature is at its maximum value midway between the poles, and it is the cutting of this field that produces a local voltage and causes sparking at the commutator. The function of the commutating pole is to produce a field of equal strength and in an opposite direction to this magnetizing force produced midway between the exciting poles, and thus to counteract or wipe out the magnetic field which causes local currents at the point of commutation, and consequently to eliminate sparking.

Fig. 3. GE-205 Commutating Pole Railway Motor

The fact that the commutating poles are connected in series with the armature insures their magnetic strength varying in accordance with the strength of the armature current when operating on fluctuating loads. There are other minor factors which enter into this consideration, but the above will show the fundamental principles.

The practical benefits derived by the use of commutating motors may be summarized as follows. With the elimination of sparking the etching of the commutating bars will be materially reduced, and as the carbon brushes are required to carry only the line current and no local current, they will wear better and disintegration will be materially reduced. The outcome of this will be that the commutator bars will wear less rapidly and there will not be so much high mica to be worn down, with the result that a car will be able to make a greater number of car miles before its being necessary to send it to the car barn for repairs.

The lack of sparking will further permit the use of higher voltages between commutator bars and consequently greater trolley voltages, which means that it is now practical to operate a D. C. road of 1,200 volts for double the distance between sub-stations. The application of commutating poles is by no means limited to the 1,200 volt motor; the General Electric Company are now manufacturing a complete line of commutating pole motors to operate on 600 volt circuits.

Fig. 4. Power House of the Indianapolis & Louisville Traction Co.

The following table will give some idea of the elasticity of a combined 600-1,200 volt system, and it is worthy of mention that the range of speed can be still further increased if the requisite commutating switches are provided.

VOLTAGE AT MOTOR TERMINALS	TROLLEY VOLTAGE	VOLTAGE OBTAINED WITH	SPEED OF CAR	CLASS OF SERVICE
600	600	Motors in parallel	40 miles per hr.	Suburban and Interurban
300	600	2 Motors in series	20 miles per hr.	City service
600	1,200	2 Motors in series	40 miles per hr.	Suburban and Interurban
300	1,200	4 Motors in series	20 miles per hr.	Suburban and City

TWENTY-FIVE YEARS OF INSTITUTE HISTORY

By T. C. Martin

In view of the fact that according to the printed records of the Institute, the first steps towards its formation were taken in April, 1884, it may seem premature for me to-night to talk even twenty-five minutes about twenty-five years. But we are on the verge of 1908, and the Institute was already in existence in the minds of its advocates and friends in 1883, long before we circulated for signature the "call to arms" now hanging on the walls of the headquarters in the beautiful new home on Thirty-ninth Street, New York. I had the honor to assist Dr. N. S. Keith in the preparation of the famous April circular and to secure many of the notable signatures to it. It fell equally to my lot to prepare and issue the first volume of transactions and to make the first secretarial report. I have never enjoyed the confidence of the Institute sufficiently to be trusted as its treasurer, but I have been elected to every other office in its gift and may therefore venture to discuss it, on your invitation, from the inside and its various other respects. A good many of us in the electrical field—over 5000 now in membership—are interested in the Institute's welfare, and to us the story of its trials and struggles and evolution is not altogether vain and insipid. History repeats itself, and probably the growth of every engineering and scientific society follows much the same course. We electrical engineers came pretty late in the procession, but after all are not in a class by ourselves. Scientific and engineering bodies are ancient rather than modern inventions. A young mother whose infant was ailing went to an old-fashioned doctor and asked for treatment. He prescribed castor oil. "But doctor," she exclaimed, "castor oil is such an old-fashioned remedy." "Madam," replied the doctor drily, "babies are such old-fashioned things."

*Paper read before the Schenectady Section, A I E.E., November 1st.

No one will deny to the Institute, however, characteristics and idiosyncrasies due to the circumstances of its birth and to the development of the mighty agencies included under the generic name of electricity. There may be, and I trust there is, something personal in the feeling that the makeup of the Institute has a youthfulness and vivacity about it that the other kindred societies do not all possess. I was only thirty myself when elected to the presidency, and while some of my successors, down to this very year, have been dangerously near that age I am told that in other societies such juvenility in high office would be regarded as scandalous. It seems likely that amongst the Electrical Engineers, youth will not yet be a bar to the supreme dignities. A notable orator in speaking about the late Mr. James G. Blaine, said that his magnetism had to be taken hot or else it soured on the stomach. It is certain that the Institute rarely had its electricity or magnetism served up on cold plates. I know of one president who never attended a single meeting, but his contribution to the art and to mankind would condone vastly greater indifference, just as the verse of Burns, "a tender boon to all humanity, has won pardon for the shortcomings of his brief, chequered life."

Speaking as the senior surviving president of the Institute, it might be expected that I should make some allusion to the nineteen men who have held the office since the beginning in 1884. How some persons get elected to presidential office is a mystery, even granting their great individual qualifications; and it is equally strange how others miss the distinction. It does not follow that because a man is a great engineer or inventor he has the executive ability for leadership; and moreover, he may be right in shunning instinctively that which would only be a distraction from his true work. Two of our most distinguished members, known throughout the world, have not accepted this office; yet it is surely a matter for congratulation that of the nineteen men no fewer than fifteen have been engineers very distinctively, and the names of seventeen are attached to inventions some of which are the greatest of the last fifty years. This is a large proportion, particularly when it is borne in mind that no fewer than eight of the nineteen have followed the profession of teacher, and three others have been journalists, who speak not as those having authority but as mere scribes. Perhaps the most striking fact about the list and the testimony it bears to the catholicity of the American engineering spirit, as well as the manner in which our national strength is reinforced—is that seven of the nineteen, including the present incumbent, were not natives of this country. The career open to talent that was regarded by Napoleon as such a desideratum, is obviously to be found in this country as nowhere else in the world.

In truth, influential and powerful as the president is under our constitution, he is necessarily like the Institute itself, very much at the mercy of the secretary. To a certain extent the overlapping time classes in the council give, as intended, continuity of experience and tradition, but the personal depository of knowledge and the confidential adviser in all such bodies must always be the man who occupies the secretaryship. It is a singular fact that in three of our great national engineering societies, the secretary should have held office without break for nearly a quarter of a century; and in the Electrical Engineers,' with its rapid growth, its swift changes in the art, and its perenially new problems, we were fortunate to secure a man like Mr. Ralph Pope who is still there and whose worth was publicly recognized this year by the bestowal of a gold medal at the dedication of the Engineering Societies Building. Dr. Keith, with whom in 1883-4 I got up and circulated the petition for the creation of the Institute, went West almost immediately after the first meeting and I was left in charge as a stop-gap secretary. The activity in electrical development at that time was tremendous and I found I could not do justice to my regular journalistic work and to the Institute's affairs at the same time. It was a providential dispensation which gave us at that juncture Mr. Pope's services, for with instant sympathy he took up the work of development that has gone on without cessation to the present moment. Unhasting and unresting, of him it cannot be said that anybody ever saw him in a hurry but the work has always got done. The possession of the lymphatic temperament is, as in him, sometimes associated with a remarkable ability to accomplish. He has never fallen into the error of mistaking restlessness for achievement. Disraeli once compared his Liberal opponents to little children pulling up their plants every morning to see how much they had grown in the night. From such practice the conservatism of our secretary has always saved us, and we have had the growth just the same and all the more. His first report presented in May, 1886, showed a net total of 250 members. We now have over 5,000 not including students, so that our membership has multiplied twenty times in the period. The average budget was then less than $1,000. It is now $70,000. Granting the tremendous development in our field of engineering, it remains evident that only conscientious care and a thorough grasp of the situation could have brought us through all these years to the firm, stable, and prosperous position we now hold.

Comparisons were long since given a bad name, but it is only by noting the progress of other societies that we can realize how far and fast our own Institute has traveled. In the year when the A. I. E. E. was organized, 1884, the American Society of Civil Engineers had 838 members. At the beginning of this October it had 4,287, and by the end of the year will have 4,400. In 1884, the American Institute of Mining Engineers had

1,381 members; on October 5th it had 4,179. At the close of 1884, the American Society of Mechanical Engineers had 557 members and on October 1st it had 3,335 members. Hence, in spite of their flying start and time allowance, the A. I. E. E. has outrun all the other Societies, and with its 5,000 members is distinctly in the lead. I don't know that there is any special credit in this; it is simply a fact worth noting; it may carry an implication or prophecy as to relative numerical importance later on. The growth of these sister societies is reason for hearty congratulation all around. The enrollment in four national technical bodies of nearly 17,000 professional members is surely an indication of the growing influence of engineers and engineering in a civilization that they at least as much as any other factor have created.

Throughout the career of the Institute I have been constantly impressed with the evolutional nature of its growth. What I mean is that at the very outset certain elements and essentials were set forth as desirable, and that persistently, if unconsciously, the society had pursued the ideals of the founders. A perusal of the earliest volumes of transactions shows emphasis to have been laid on a library, a permanent home, branches or chapters, raising the character and qualifications of membership, standardization of apparatus and tests, securing papers on the latest advances and from representative men, and the interchange of courtesies with domestic and foreign societies. Some of these points may be fittingly noted as having been attained much more fully and richly than the idealists and prophets of 1884 deemed possible.

Think of the dignified and graceful home occupied as headquarters in New York, said by an English architect of repute to be of all the buildings he saw in America the best adapted to its purpose. We were homeless cuckoos when we began, meeting here and there, enjoying the hospitality of other societies, like the Civils and Mechanicals, changing our offices eight times in only twenty years, and living from hand to mouth in a manner utterly beneath the status and requirements of a great Institute. The first evidence of nationality is a permanent seat of government, and I for one should have regarded it as a misfortune had the Institute twenty-five years old still been without a definite center, a house and a hearth, a worthy focus for all its activities, and a proper organ for the exercise of all its functions.

At any rate the Institute has answered forever, in satisfactory fashion, the question "Why pay rent?" and is now dealing vigorously with the problem "Why stay in debt?" I am rather proud, though not vainglorious, of the fact that your Land and Building Fund Committee, of which I have the honor to be chairman, has raised in three years from about 1,000 members and friends, the handsome sum of $160,000 nearly all of which is paid in. It hopes to close its debt-lifting campaign this winter by getting the $20,000 still needed. The committee has now and again met with discouragement and disappointment in some quarters where it had high hopes, but will not relinquish its efforts, till the work is done. It believes that the public spirit and active good will of the 4,000 members, who have still to subscribe, will soon free the Institute from all this burden, leaving it with an asset of rapidly increasing value and with all its agencies in unhampered full play.

The joint library in the new Engineering Building given us by Mr. Carnegie is one of the best evidences of the good that flows already from the creation of the new home. There we have what is probably, even now in the earlier stages of organization, the best collection of engineering literature in the world. It is constanly securing valuable accessions, and students more and more frequent it. Together with the grand Public Library on the next street, now being finished, it will constitute the best center of scientific and literary investigation, through the printed world, to be found on this continent. When our past president, Dr. Wheeler, with generous impulse, gave us the Latimer Clark Library, he little thought that from such a nucleus, or so soon, would come in reality, both the building and the splendid larger library it now enshrines. We Electricals are, indeed, not as appreciative as we ought to be of what has come through Dr. Wheeler's initiative and liberal gift—a critical event in Institute history determining all the future.

There has been in some minds the haunting fear that this building and all that it represents, would make for centralization in the Society, for an undue accumulation of power in New York hands; but it is a noteworthy fact that never before was the establishment of branches and chapters carried on so strenuously. Moreover, men who have been prominent in the erection of the building have been most earnest advocates of this policy of decentralization, and past president Scott, one of the foremost in our building work, was as a matter of fact the father of the modern movement that has brought into being such wonderfully successful local bodies as your own, whose usefulness it is indeed hard to compute fully. But if you will go back into the annals and archives you will find that others of us years ago were strong federalists and at the Institute meetings favored policies aiming at the principles approved in the latter days. The vigor of the branches is cause for profound congratulation, the best proof of health; and a pledge of universal interest amongst widely scattered members of the profession, in the work of the Institute.

It would be simply impossible here to review the papers and transactions of the Institute during twenty odd years. A long serried row of 25 substantial volumes, containing 16,000 pages of printed matter, looks at me from my book shelves as I prepare these notes, and picking out any one of them I find valuable fact and data, theory and speculation, from scores of members. It might all have been done better—I know that from serving for years as the chairman of the committee on papers and meetings—but it was something to put into such permanent and readily available form that mass of useful material. As one surveys the great throbbing productive domain of electricity, it seems easy to get all the papers you want, from anybody you choose, but the exact contrary is the fact. I am not ashamed to-day that my own paper and statistics on electric railway work in 1886 were the first of the kind in America, but the literal truth is I was just stage manager called upon to fill a leading role suddenly because the chief actor in the cast was sick.

One of the most agreeable features of the Institute's development has been the interchange of courtesies with kindred societies abroad. We all know the kind of wits attributed to homekeeping youth, and even learned bodies are found to benefit by a sea change. We may yet live to see the Royal Society meeting in Chicago; the French Academy in session at Montreal; and in these days of politics more villainous than saltpetre, let me express the hope that some early day the A. I. E. E. will hold its annual meeting in friendly Tokio, when the cherry trees are all ablossom. Meanwhile, we have had the privilege to entertain in the land of Franklin, the fellow countrymen of Faraday and Volta, of Ampere and of Ohm; and they too have made us welcome in return. I feel confident that in time this closer touch must lead to more intimate union, and that in engineering solidarity we shall find one more pledge and guarantee of the peace of the world. The aptest synonym for engineering is association.

* * * *

In closing, Mr. Martin next spoke of the Code of Ethics, recently drawn up by the Institute, and said that while in sympathy with such a code as proposed it should not be made too rigid and too much should not be expected of it.

THE ROSENBERG GENERATOR

By B. M. Eoff

The General Electric Company has recently purchased the American patent rights covering a number of the more important applications of the Rosenberg Generator. The machine was invented by Dr. E. Rosenberg of Berlin, and its method of construction is a radical departure in the field of dynamo design.

Fig. 1. Rosenberg Generator

The distinctive characteristic that renders the machine especially valuable for certain purposes is its tendency to deliver a constant current at variable speed, and a constant output at constant speed. The means taken to secure these results are very simple and eminently effective; they consist, essentially, in short circuiting what in an ordinary dynamo would be the service brushes, and in placing the actual service brushes at points on the commutator midway between those of the first set. The field cores, at least in the case of a series machine, are designed for a much higher degree of saturation than is usually the case in an ordinary dynamo, and the pole pieces are of different shape and of greater size. In appearances the machine differs but little from a normal generator, as may be seen from Fig. 1, which shows a small series wound Rosenberg machine, fitted with an adjustable resistance in parallel with the field winding, the object of which will be explained later.

The elementary principles upon which the action of the machine is based may perhaps be better understood by reference to Fig. 2, which is intended to show a resolution of the magnetic fluxes into the directions of their respective magnetomotive forces.

This diagram represents a bipolar dynamo, with the armature revolving in a counter-clockwise direction between the pole pieces, marked N and S. The magnetic flux, which may be conceived of as emanating from the pole N and entering the pole S, is indicated in the diagram by the solid lines N S, and for the sake of explanation will be termed the "primary flux."

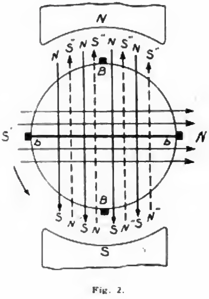


Fig. 2.

Under these conditions of rotation and field, the electromotive force induced in the armature conductors produces a current which flows toward the observer in the upper half of the armature winding and away from the observer in the lower half. This current flowing around the armature and through the short-circuited brushes creates a "secondary flux" at right angles to the primary and indicated by the lines N′ S′.

The current resulting from the conductors cutting this secondary flux creates a tertiary magnetomotive force at right angles thereto in the direction of the broken lines N″ S″, that is to say, in direct opposition to the primary flux. This current is collected by the brushes BB and supplies the external circuit.

With this explanation the action of the machine becomes at once apparent; it is, in effect, in a state of magnetic balance; any increase in current immediately increasing the tertiary magnetomotive force opposing the primary flux, with the result that the current produced by this flux is diminished, the secondary flux reduced, and finally the terminal voltage of the machine. It is evident from this, that at constant speed the generator will have a drooping voltage characteristic and a practically constant output.

At variable speed it is a constant current machine, for an increase in speed tends to raise the voltage and consequently the current;

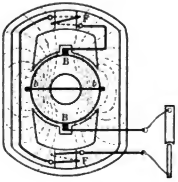


Fig. 3.

but, as has been shown, this at once reduces serially the primary flux, the secondary flux, and therefore the terminal voltage.

Tests made at Schenectady on a one kilowatt Rosenberg generator showed a voltage of 30 when the speed was 1200 revolutions per minute; the speed was then increased to 2600 revolutions per minute, and the voltage rose to 30 1/2, and then fell back to 30; thus, with an increase in speed of more than 100 per cent., the voltage increased but 5 per cent., while the variation in current was slightly smaller.

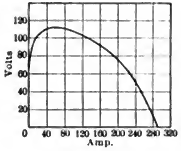


Fig. 4.

For series excitation, the field magnets are built with cores of exceptionally small cross section, and the pole shoes are of unusual size and subtend a large arc on the surface of the armature, permitting the tertiary field to become a strong counter stray field, as shown in Fig. 3.

The number of turns on the field is made large compared with the effective turns of the armature, and for very small currents the primary flux increases at a more rapid rate than the tertiary, with a consequent increase of the terminal voltage; therefore, at the beginning of the curve the characteristic is ascending (Fig. 4).

At a small value of the current, however, the field cores become highly saturated, due to their relatively small area and the large number of turns upon them, while the iron of the armature and that of the heavy pole shoes is still at a very low density. Any increase in current above this value has practically no effect upon the strength of the primary field, but produces in the large volume of iron in the armature core a counter flux which is almost proportional to the current, and owing to this condition, the machine has for the most part a drooping characteristic, as already stated.

By suitably dimensioning the various parts of the machine, it is possible to obtain a short circuit current which will exceed the normal current by any required amount, say 25, 50, or even 100 per cent., while on the

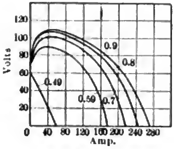


Fig. 5

other hand, the maximum voltage may be made to exceed the normal voltage by a corresponding percentage; furthermore, the machine may be designed to give a drop in voltage almost exactly proportional to the increase of current.

The current for a given voltage may be reduced to any desired value by placing shunts of different resistance across the series field; in which case the field current will no longer be equal to the current at the brushes. Fig. 5 shows the effects of connecting these resistances in parallel with the field winding The decimal given in connection with each curve represents the proportion of the total current that is flowing in the field.

If a large open circuit voltage is required, the magnet frame, or parts of it, must be made of cast-iron; since the ability of cast-iron to retain its magnetism is superior to that of cast-steel or wrought iron. The extra weight occasioned by the use of cast-iron is inconsiderable, as in any event the cross sectional area of the magnet yoke is small; and if this is made sufficiently heavy for mechanical purposes, it will amply serve to carry the small flux of the field.

The reduced cross section of the yoke is well illustrated in Fig. 6, which shows two sections of a 30 kilowatt machine designed for electric welding purposes.

The no-load voltage may be further influenced by shifting the brushes backwards or forwards, so that the axis of the short circuited brushes will not be exactly in line with the electrical neutral; under these circumstances the cross flux will have a component which directly strengthens or weakens the residual field, and is productive of widely varying results.

To secure a sufficiently weak field for good

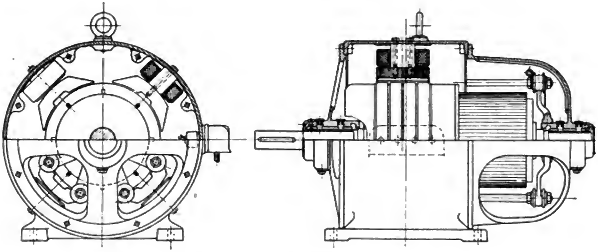


Fig. 6. Sectional Elevation of a Series-Excited Rosenberg Generator Designed for Welding Purposes

commutation at the main brushes, a slot is cut in the center of the pole face from front to back, and on all machines thus far built this has given good results. No trouble has been experienced with sparking or heating at the short circuited brushes.

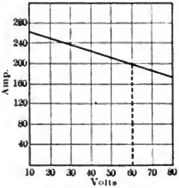


Fig. 7.

The ability of the Rosenberg generator to deliver a falling voltage with rising current, and *vice versa*, renders it especially valuable for use with carbon arcs for searchlights and electric welding; it is, in fact, the best machine

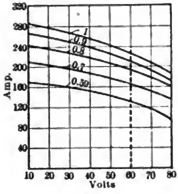


Fig. 8.

known to the profession for the purpose, giving a stability of arc and an economy of operation not approached by any other source of current yet realized.

This may be readily appreciated when the peculiarities of the carbon arc are brought to mind; for, as is well known, carbon arcs, with the exception of those of very small arc lengths, possess the distinct property, that the greater the current flowing through any given arc, the less the voltage drop across it.

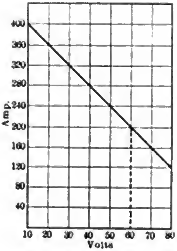


Fig. 9.

Arcs of this nature, therefore, cannot be connected across constant voltage mains without having a resistance – usually termed "ballast" – placed in series with them. The object of this ballast, as its name implies, is to create an electrical balance for steadying the arc; an increase of current producing a decrease of potential at the arc by virtue of the increased drop of potential across this resistance; thereby maintaining the stability of the arc and preventing the otherwise excessively large rushes of current. On the other hand, should the current fall in value, the ballast will produce a rise of potential at the arc, due to the reduced drop in voltage across the resistance, and thus enable the arc to continue burning.

The curve of Fig. 7 shows the currents corresponding to different voltages across the arc of a lamp designed for 60 volts and 200 amperes; the lamp being connected to 220 volt constant voltage mains, and in series with a ballast of 0.8 ohms, which consumes almost three times the amount of power actually absorbed at the arc when working under normal conditions. The curve marked 0.9 of Figure 8, shows the performance of the same lamp without ballast, when connected to a Rosenberg series generator; the generator

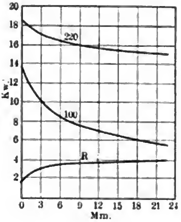


Fig. 10

having a low resistance shunt connected in parallel with its field windings. Upon comparing these two curves it will be seen that they correspond very closely, and that the power saved in the latter case is approximately three times that actually required to keep the arc burning normally. In a lamp connected in series with a ballast consuming only 100 per cent. or less, of the amount of power expended at the arc, the variations of current are greater beyond all comparison than those obtained with the Rosenberg generator. This is shown by Fig. 9, which gives the performance of the above lamp when connected to 110 volt constant voltage mains in series with a ballast of 0.25 ohms.

The curves of Fig. 10, marked 220, 100 and R, show the power consumption, as a function of the arc length, for a 75 ampere arc lamp when connected, respectively, with a series resistance across 220 volt mains; when connected with series resistance across 100 volt mains; and when connected directly to a Rosenberg generator. In addition to the fact that with normal current the power consumed in the first two cases is considerably larger than in the third case, it may also be seen that for small arc lengths the power consumption increases in the former cases, while in the latter case there is an actual decrease of power. With a complete short circuit, the machine will require but little more power for driving than when open circuited.

This last named feature of the generator, *i.e.*, the inherent impossibility of its being subject to heavy overload, opens up another extensive field of application for the machine in connection with gasoline-electric conveyances, both for railway service and for street bus lines; taking as an example of the latter, for instance, the Fifth Avenue bus, of New York City.

For service of this kind the series generator is the more suitable, because of its ability to deliver an almost constant output with widely varying currents; and further, because this means of excitation provides against an overloading of the driving engine. When climbing grades the motors naturally tend to slow down, a larger current flows through them, and the voltage of the generator automatically drops; thus, no regulating resistance need be interposed between the motors and the generator, and they may be connected by means of a simple switch directly to the generator while the latter is running.

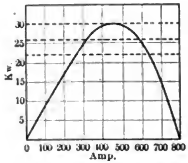


Fig. 11

Figure 11 shows the output in kilowatts corresponding to the external current of a small series generator with full field excitation; *i.e.*, with no shunt in parallel with the field winding. The maximum output of 30 kilowatts is attained with a current of 450 amperes.

and any increase or decrease of current above or below this value will result in a decrease of power output. If we consider 26 kilowatts (represented by the central dotted lines) as the normal capacity of the generator, the current may then have any value between 230 and 670 amperes, with a variation in power output not exceeding 20 per cent. of the normal. The voltage, as determined from a curve similar to Fig. 4, is found to vary between 30 and 86 volts. It is thus seen that the machine represented has a practically constant output within wide limits.

The Rosenberg generator may be further used as a reversible booster placed between two sources of variable voltage, such as a battery of 50 cells and a 110 volt generator; the voltage of the latter varying between 90 and 130 volts. If the voltage of the generator and battery are the same, a current equal to the short circuited current flows through the booster, since the terminals of the machine are at the same potential. If, however, the voltage of the generator is greater than that of the battery, the current through the booster will increase slightly

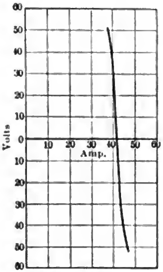


Fig. 12

above the short circuited current, the tertiary flux will overpower the primary, and the booster will generate a negative voltage; in other words, the machine will run as a motor, consuming the difference between the voltages of the generator and battery. Should the voltage of the battery be greater than that of the generator, a current somewhat smaller than the short circuited current will flow, the booster will generate a positive voltage, and the potential between the two

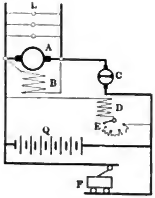


Fig. 13

circuits will thus be equalized. The machine, when used as an ordinary booster for charging accumulators from constant voltage mains, will require no regulation throughout the whole range of charging, from full discharge to complete charge. The current decreases with progressing charging, either very slowly or at any predetermined rate, depending upon the design of the machine, while the voltage of the booster adjusts the line voltage to that of the battery. Figure 12 shows the performance of a machine when operating under these conditions. For mains supplying very irregular service, the excess of current above the average may be supplied by a buffer battery; and by placing a Rosenberg generator between the mains and the battery, the mains will then supply the average power required throughout the hours of service. The booster, as has been shown above, will operate as a motor or as a generator, depending upon whether the voltage of the mains is above or below that of the battery, while the current flowing through the booster will remain almost constant. This arrangement is outlined in Fig. 13.

FORM 2 MULTIPLE LUMINOUS ARC LAMP

By G. N. Chamberlin

The luminous metallic arc is now recognized as the most efficient and best all-around street illuminant in commercial use. This system of street lighting as furnished by the General Electric Company, having passed the experimental stage, is in quite general use, and one or more of the other large manufacturers are entering the field of development and exploitation.

Fig. 1
Form 2 Multiple Luminous Arc Lamp

For low voltage, direct current, multiple circuits, 100 to 125 volts, there has been but little use made of the metallic lamp. A lamp for use on such circuits was described in the September, 1906, issue of the General Electric Review. This multiple lamp was a modification of the series lamp, requiring in addition to the necessary regulating magnets and steadying resistance, shunt magnets for striking the arc, and a cutout for protecting the shunts.

It was thought advisable to develop an improved type, as shown in Figure 1, which resembles quite closely in outline and general dimensions the standard type of General Electric enclosed lamp. The lamp is of pleasing appearance, and of suitable size for installation on multiple circuits.

The casing is of solid copper with a black oxidized finish. The main body of the casing is rolled from one sheet of .030 copper, thus eliminating all riveted connections, and furnishing a strong and durable housing for the lamp mechanism, and a support for the outer globe and its supporting ring.

The standard No. 5 outer globe is used, but the lower surface is ground to eliminate shadows directly underneath the lamp, and to obscure from view the small metal pan, placed in the bottom of the globe to catch the iron oxide. The globe supporting ring is a slight modification of the one now in general use on General Electric multiple enclosed arc lamps.

Figure 2 is an interior view, showing the mechanical construction of the lamp. The main frame consists of a 1¼ in. iron pipe connecting the top and base castings, forming a rigid construction, and at the same time providing a suitable center draft or chimney for disposing of the arc fumes. At the top this chimney is protected from rain and storms, in such manner as not to interfere with the natural and uniform draft required at all times for the proper action of the arc flames.

The upper, or positive electrode consists of a T-shaped drop-forging of copper. With a large volume of copper and a large radiating surface, it is possible to keep the electrode at a low temperature, and this condition, together with the peculiar characteristics of the luminous arc, results in a slow wearing away of the copper. To further decrease this oxidization, and increase the life of the copper electrode, an iron tube is fitted tightly around the latter, leaving the copper end bare for the arc contact. With a 4 ampere lamp this upper electrode will require renewing after about 1800 hours operation, or, with an average burning of five hours per day, this upper electrode should last a year.

The lower electrode, which is responsible for the characteristic flaming arc of this lamp, is an iron tube 11/16 in. in diameter and 5¼ in. in length, filled with the prepared composition. One electrode only is used at each trimming, with a life of about 150 hours.

The non-consuming copper electrode, and the electrode box, are attached to and carried by a non-corroding Benedict nickel tube.

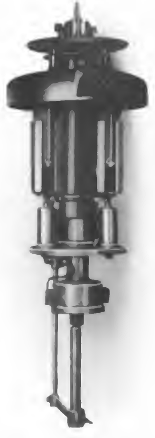


Fig. 2
Interior of Lamp Showing Construction

This tube passes inside of the draft chimney, and comes in contact with, and is carried by, the lamp clutch. This clutch consists of five phosphor-bronze balls, wedging between an inclined plane of the clutch ring, and the tube to be lifted.

There are two single magnets, with the two E armatures mechanically connected. This single solenoid construction, with the E shaped armature, has been recently proven to be one of the best, if not the best, of magnet constructions available. Its action is positive, and at the same time remarkably sensi-

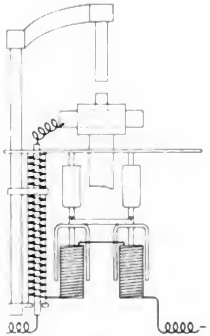


Fig. 3
Diagram of Connections

tive, responding quickly to any variations of the line or arc, and thus maintaining a close regulation of the current.

The magnet windings, as well as the resistance, are of the wellknown edgewise type. All leads are insulated with glass beads, presenting a modern indestructible lamp.

Two 1 in. dashpots are used, which provide the necessary retarding effect, with a large clearance between the shell and the graphite plunger.

Figure 3 shows the extreme simplicity of the connections. Only the electrodes, lifting magnets, and steadying resistance are in circuit, and these are connected directly in series. The lamp is equipped with leading-in cables on account of the fumes which might accumulate and ground metal binding posts on the lamp top.

[illegible]

[illegible] shows a comparison of photometric [illegible] of a 5 ampere D.C. [illegible] a 7.5 ampere D.C. enclosed arc

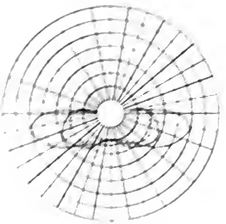


Fig. 4
Curve Showing Photometric Comparison

and the 4 ampere magnetite arc. Even with the decreased wattage the increase of candle-power is noticeable. The characteristic distribution of the metallic flaming arc, with its maximum intensity near the horizontal, is well known. This natural distribution can be changed to meet other street lighting requirements by the use of correctly designed concentric wave reflectors, as is plainly shown in these photometric curves.

Four amperes and 73 volts at the arc will be the standard adjustment for 110 volt circuits. Special windings for 4.5 or 5 amperes can be furnished, if required, but the electrodes give shorter life when operated at the higher current.

In general the lamp needs [illegible] attention [illegible] in fact than the enclosed lamp, as there are no enclosing globes and gas caps to require careful handling, cleaning and renewing. At each trimming it is necessary to clean the center or draft tube and also the box containing the upper electrode. A suitable brush is provided for the purpose.

A small metal ash pan is furnished, which is to be placed in the bottom of the globe. This pan catches the reddish brown particles given off by the burning away of the lower electrode, and can be easily emptied at each trimming. Some of the fumes go through the draft tube and out into the air, thus rendering the use of the lamp objectionable for certain indoor installations, where such fumes would be deleterious. The lamp is specially recommended for the lighting of foundries, machine shops, train sheds, freight houses, freight yards, drill halls, and riding academies, or in general, for the lighting of large areas where the fumes are not noticeable.

It is imperative that this lamp be so connected that the composition electrode is negative. To facilitate the correct connections being made to the circuit, the lamp top is plainly marked "positive" and "negative" above the respective leading-in cables.

Should the lamp be operated with the copper electrode negative, it will burn with a low efficiency copper arc, which will continually rupture itself. Such operation will cause a very rapid disintegration of the copper electrode, as well as a general abuse of the operating mechanism.

Modifications of this lamp are suitable for 220 volt multiple, and multiple series power circuit operation. These lamps will be described in a later issue of the General Electric Review.

THE ELECTRIC HEATING SITUATION

By E. L. Callahan

The summer has shown a substantial advancement in making popular the use of electric heating devices, which is not only apparent from the increased sales recorded, but is further made evident by the growing confidence shown by the central station men in their ability to sell the devices to their customers.

to have a boy peddle out a hundred irons and accept the increased revenue, but as for planning for the business and its future, they were "too busy to give it much thought," or had been "changing the plant over to 50 cycles;" or again, they had been "busy on the new plant in order to carry the present load over next winter's peak."

Fig. 1. Demonstration Room of the Milwaukee Electric Railway & Light Company

Last year, and the year before, the General Electric Company sold heating devices to their customers for the first time. In many cases the customers took the word of the salesman that a very profitable revenue could be obtained from handling this class of apparatus, and they were not disappointed in the profits derived from their flat iron business. However, few if any of these central station men thoroughly grasped the situation, for they had not as then realized that there was a great future for them in heating devices. They were willing enough

With the exception of a very few stations, the subject of installation, systematic advertising, and the establishment of rates has just begun to be threshed out.

My criticism of central station progress may seem to contradict the statement made above of substantial advancement, but to one who has studied the progress of electric heating for some time, there is every reason for taking an optimistic view of the situation; for, even if a very small beginning has been made on the whole, it is a *good* beginning. Central station managers have learned that heating devices cannot be sold over the counter like so much sugar; on the contrary, the majority of them are convinced that it will pay to employ expert heating salesmen to lay out well formulated plans for this end of their business. The electric heating manufacturing companies are to be congratulated on the good results obtained under trying circumstances: for not only the central station man has had to be won over before he could be induced to buy devices not actually necessary to his business, but it has been hard to hold the customer and his interest when the field was so large that the demand was beyond the capacity of the factory to supply. With a product more easily standardized, we are led to believe that this handicap will soon be removed.

Fig. 2. Exhibit at Oklahoma State Electrical Convention, Oklahoma City

A most prosperous year for 1908 may be looked forward to, for the heating business throughout the country is in a healthy condition. There are but very few day circuit central stations that have not placed initial orders; some are discouraged and have done nothing further, while others have forged ahead and have obtained results which have more than justified the heavy expenses incurred in establishing the business. There is an atmosphere of development and of pushing ahead pervading these backward stations, and if for no other reason than to follow the example of their older and wiser brothers, they will break away from this conservatism and former unprogressiveness

Full credit cannot be taken by the central station men for the good results in business obtained from the use of heating devices, for the General Electric Company has been instrumental in educating the public, through extensive advertising in magazines, technical papers and bulletins, to new and novel applications of electricity. Much data has been published, giving convincing results and cost of operation; and showing the practicability for every day use of electric heating devices. The result of this has been to attract the public eye, and to excite curiosity and requests for more information, with the further outcome that central station customers are much more willing to give electric heating a trial.

One of the most important things to be observed by a salesman or solicitor is the close following up of a prospective customer; if this is not done, hard earned advantage may go to a competitor, or the customer may lose interest, and it may not be possible to again arouse the necessary enthusiasm. "Following up" likewise means to find out and remedy troubles that may have been had with apparatus; for, with the best designed and constructed apparatus, little difficulties, real and imaginary, will occur; very often through ignorance on the part of the one who uses or installs the device. People should not be allowed to use things ignorantly; the persons who are interested in inducing the public to use and enjoy electric heating devices are under obligations, from a business point of view, to keep the customers satisfied.

The writer considers that we have not progressed far enough along into the heating business to fully judge of the field, but that it is large there is no doubt. For instance, the problem of furnishing electrically heated water in the summer time for bath and kitchen purposes, has scarcely been solved by the manufacturer, and not at all by the central station man. We must help the latter determine the best practical method of providing his customer with a "readiness to serve" power, of from 5 to 15 kilowatts. He must make it an easy matter to install complete kitchen ranges or outfits; manufacturers in his town will want to use glue pots, electric air heaters, pressing irons, soldering irons and special applications of heat, and the central station must make it possible for them to get the power readily; in other words, he must go after the heating business.

Fig. 3. Exhibition Room of Grand Rapids-Muskegon Power Co.

I could name a score of central station managers who have told me, with considerable boasting, that they have made a canvass of their likely customers, with the result that an iron has been placed in one out of every ten homes. They seemed perfectly well satisfied to drop aggressiveness in pushing for further sales, taking it for granted that the remaining 90 per cent. would never think later of following the example of their neighbors. Then there are some of our good friends who "skim the cream" of their community and pay no further attention to keeping the devices sold in working condition, condemn the manufacturer, and turn to another and another; until the customer, and they as well, are dissatisfied, and can see nothing in electric heating

In such a city or town one would see a lack of lamp renewals, and plenty of reasons for dissatisfaction on the part of the consumer Such a central station man needs to learn that a *satisfied customer helps a public corporation pay dividends.*

There are central stations, however, that contrast sharply with the ones we have had in mind. At Webster Groves, Missouri, much heating business has been obtained through the use of a demonstration wagon shown in the cut above. The arrival of this wagon was announced a day in advance by postal or letter, and the demonstrator would cook and iron, with a good audience at each stop.

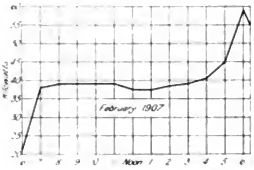
One Chicago supply salesman, in Iowa alone, has induced nine small towns without day circuits to operate this summer on Tuesdays (ironing day), with the result that they find it a paying proposition which will soon make it lucrative to operate every day in the week. Each of these towns now have from fifty to one hundred and fifty flat irons, which have been placed in service since about July 1st. At Washington, Iowa, fifty irons were put out on approval in one day; forty-one of them stayed in service, and several of the nine customers, who returned the irons then, came back for them later. The superintendent of this plant says he cannot see that this flat iron trade has affected their gas business in the least. Their customers, and customers in other towns, have increased their bills for current by amounts of from forty cents to one dollar, but all seem to be perfectly willing to incur the added expense for the con-

Fig. 4. Demonstration Wagon at Webster Grove, Missouri

veniences provided by the electric current.

In another small town in Iowa, the gas and electric company would not handle the the irons; a local plumber then bought fifty irons, and sold all of them at $5.00 each. We hope that the central station will not be outdone by the plumber next summer, but that it will help him place more current consuming devices on its lines. The rate charged is 15 cents per kilowatt hour, and the lighting company realizes that the revenue derived from the use of flat irons is nearly all clear profit.

The reader's attention is called to the load curves above, where Curve 1 shows the kilo-

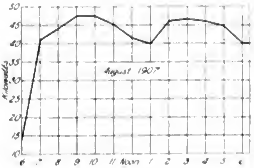


Curve 1

watt load over a period of 12 hours, from 6 a.m. to 6 p.m., for February, 1907, in a city of 19000 inhabitants. Curve 2 shows the load for the following August, after one hundred and twenty-five flat irons, (the equivalent of eighty-four horse-power) and one hundred horse-power in motors had been installed on the circuit. The writer was very glad to get such a good illustration showing the desirability of installing electric cooking apparatus to make the curve more nearly approach the ideal straight line.

At conventions central station men have discussed the effect of this cooking load on their lines, and the majority of them believe that the station peak will not be increased in summer, and not to a prohibitive extent in winter. It seems, from the curve of Figure 2, that in this particular town it would be very desirable to have a cooking load of at least fifty kilowatts, to correct the curve; this would represent some twenty-five or forty families using electricity exclusively to cook with. The advisability of carrying a cooking load above this value would depend upon the ability of the plant to carry load above its present peak. With the exception of baking, nearly all cooking is done between the following hours:

Breakfast	5 to 7:30 a.m.
Lunch	11 to 12:30 p.m.
Dinner	5:30 to 7 p.m.



Curve 2

with dinner usually at noon in the smaller towns.

The reader is referred to the October number of the Review for data on current consumption for cooking for a family of three.

Central station men need all the help the manufacturers can give them, and they are glad to see the salesman when he calls, for they expect to hear the news — to learn of new developments and experiences of other stations. I am aware that the greatest help the manufacturer can render the central station man is to make him prompt deliveries of apparatus; and next in importance to this is to secure for him men who are expert heating solicitors, who will spend a month or two in organizing his heating department, and in training men to carry on the business along the lines mapped out by himself. The writer hopes that the General Electric Company will soon be able to furnish a number of such expert solicitors to central stations at reasonable salaries, so that they can carry on their heating business in an intelligent and aggressive way, and thus gather in some of the profitable revenue that is waiting for the wide-awake ones.

I know of some stations that would be compelled to discontinue their day service if they were deprived of their electric heating load, and it is gratifying to know that the central station managers throughout the country are planning to get all the electric heating business they can. In a letter from a local lighting company at Adrian, Mich., the manager states that they have erected on the roof corner of their building, a seven foot electric sign which reads, "Now is the time to use electric flat irons," and in the space between the words "flat" and "irons," a General Electric flat iron is represented in outline by two-candle-power incandescent lights. This sign happens to stand directly over the center of the street, due to an angle in the latter, and can be seen from far and near.

Fig. 5. Corn Carnival Exhibit of the Oklahoma City Gas & Electric Co.

Central station managers are spending much money in fitting up attractive demonstration and exhibition rooms, in order to show their customers electrical conveniences in operation. They consider money spent

Fig. 6. Six Room Cottage Completely Equipped with Electrical Devices, in Display Room of Union Electric Co., Dubuque, Ia.

in this way well invested, with the belief that it will bring them abundant returns.

The domestic science department of women's clubs is enthusiastically taking up and advocating cooking by electricity, and in many cities the local lighting companies co-operate with these clubs by furnishing lectures and demonstrators, as well as space and attractive exhibits, with the result that their heating business is greatly increased.

Another article will appear in a subsequent issue of the REVIEW, containing several illustrations of demonstration and lecture rooms, where well attended sessions have been held, and much interest shown in the display and operation of heating devices.

Fig. 7. Exhibit of Electrical Devices, Dubuque, Iowa

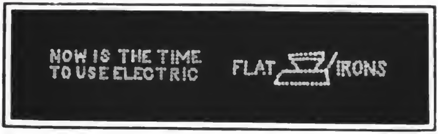


Fig. 8. Electric Sign on Roof of Local Lighting Company, Adrian, Mich.

TRANSIENT ELECTRIC PHENOMENA *

PART I

By Dr. C. P. Steinmetz

When electric power flows through a circuit, power is consumed in the conductors of the circuit by their resistance; and this loss of power takes place as long as the current flows, and equals i^2r; where r is the resistance of the conductor. Accompanying the flow of power through the circuit, a magnetic field, and also an electrostatic field exist in the space outside of the conductor; these are essentially as much a part of the phenomenon as the loss of power in the resistance. The lines of magnetic force surround the conductor in closed circuits; the lines of electrostatic force radiate from the conductor and terminate in the return conductor. The magnetic field is proportional to the current, and equals iL—where L is called the *inductance* of the circuit. The electrostatic field is proportional to the voltage, and equals eC—where C is called the *capacity*.

No power is consumed in maintaining the magnetic or the static field, but energy is required to produce them, and this energy is stored in the space outside of the conductor as magnetism, or as electrostatic stress; and is returned, or dissipated, when the magnetic, or static field is destroyed.

The magnetic energy is $\frac{i^2L}{2}$; the static energy $\frac{e^2C}{2}$, just as in a moving mass the mechanical energy is $\frac{v^2m}{2}$.

In an alternating current circuit, where current and voltage periodically vary, the stored energy of the electric field also varies; its magnetic component reaching a maximum at maximum current, and its static component at maximum voltage.

Since the flow of current necessitates storage of energy as magnetism, it follows that a current cannot start and reach full value instantly—just as a fly-wheel cannot instantly reach full speed. The current, when closing an electric circuit—like the speed of a fly-wheel—starts from zero and gradually rises to full value; and during this period of acceleration, not all the power which flows into the circuit is delivered at the other end or consumed by the resistance, a part is stored as magnetism. For the same reason, a current cannot stop instantly; its magnetic energy must first be dissipated or returned to the electric circuit, just as a fly-wheel cannot stop instantly. Just as an attempt to instantly stop a fly-wheel, by a rigid obstruction, results in the momentum of the fly-wheel exerting a practically infinite force upon the obstruction—that is, in breaking it—so the attempted instantaneous stoppage of the current, and thus the instantaneous dissipation of its magnetic energy, would induce an infinite e.m.f. in the circuit, that is, would result in disruption.

Therefore any change of current due to a change of circuit conditions, is not instantaneous, but gradual; there being a transient period during which magnetic energy is stored—if the current be rising,—or returned to the circuit—if the current be decreasing. During this transient period the current has not the normal value that would correspond to the circuit conditions, but there is a transient term of current which connects the previous value of current with the value of current that follows after and that corresponds to the changed conditions.

If then in a circuit carrying current i_0, the conditions—such as resistance, voltage, etc.—are suddenly changed so as to produce a current i_1, the actual current i does not instantly jump from value i_0 to value i_1, but gradually approaches it; first rapidly,

* Lecture presented before the Schenectady Section, A.I.E.E., October 18th.

and then slower, as shown in Fig. 1. Instead of saying that during this transient period the current does not have the normal value i_1, but has the value i, we can say that during this time the current in the circuit consists of the current i_1 plus the current $i_2 = i - i_1$, hence we have:

$$i = i_1 + i_2$$

the current i_1 is produced by the impressed voltage of the circuit. The current i_2 therefore, has no voltage back of it, but is merely a survival of the change; it results from the fact that at the moment of the change, the current in the circuit is different from what it *should* be to correspond with the changed conditions; and consequently this current i_2 gradually dies out, that is, it may be called the "transient current of change of circuit."

If the impressed e.m.f., and therefore the current, are alternating (as in Fig. 2), and if at the moment of a change of the circuit, the current has the instantaneous value i_0, but *should* by reason of the changed condition of the circuit, have the value i_1, then the actual current i will gradually approach

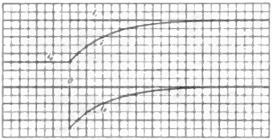


Fig. 1

the normal current curve I_1 from the previous value i_0. That is, it consists of the two current components $I_1 + i_2$; where I_1 is the alternating current produced by the impressed e.m.f. under the new circuit conditions, while i_2 is the dying out of the difference $i_0 - i_1$, with no voltage back of it; that is, it follows the same curve as in Fig. 1. In other words, the transient current i_2, merely depends upon two things; first, the discrepancy between the *actual* current i_0, and the current i_1 which *should* exist after the change; and, second, upon the circuit conditions. It does not depend upon the character of the power flow, whether continuous or alternating; it has no voltage back of it, and can be investigated as current flowing in the circuit at zero impressed e.m.f.

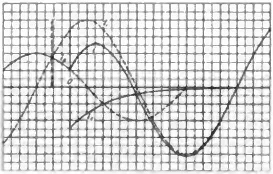


Fig. 2

The change of current with a change of circuit conditions, that is, the readjustment of the circuit to the changed conditions, --which is the dying out of the transient term i_2— is the slower, the higher the inductance L of the circuit and the greater the difference between the previous value i_0 of the current, and the after value i_1, that is, the more magnetic energy there is to be stored or returned. Hence, in a highly inductive circuit, as a motor field, it may require several seconds before the current becomes normal; while in a practically non-inductive circuit, as in an incandescent lamp, the change is practically instantaneous. If at the moment when the change in the circuit occurs, the current which *should* flow in the circuit, under the changed conditions, happens to be of the same value as the current *actually* flowing—as for instance, at the point x in Fig. 2—no transient term appears, but the current immediately follows the normal value.

Upon closing an alternating current circuit at that moment of the e.m.f. wave when the current should be zero, no transient term appears; while upon closing the circuit at the moment when the current *should* be maximum, the transient term is a maximum since the actual current is zero.

These transient currents are rarely of practical importance as currents, but their importance lies in the voltage which may be produced by them, especially in the extreme case when the current is decreased to zero, that is, upon opening the circuit.

When opening a circuit, the stored magnetic energy must be dissipated during the opening of the circuit, or, while the current is decreasing to zero; and if we attempt to open the circuit instantly, that is, infinitely fast, the magnetic energy must be dissipated at an infinite rate, *i.e.*, at an infinite e.m.f. The faster an electric circuit is opened, the higher, therefore, is the e.m.f. induced at the opening switch by the decreasing magnetic field of the circuit; and if the magnetic energy is considerable, as in the case of a motor field, and the circuit is opened with a quick-break switch, the induced voltage of the magnetic field discharge may easily reach disruptive values.

Where the currents are very large, and are normally of high voltage, as in high power alternating current systems, a sudden opening of the circuit is liable to be destructive, if it does not take place at the zero point of the current wave; that is, at that point where no transient term appears. A break in open air, with a long flaring arc, is dangerous in this respect, in that the arc frequently has a tendency to rupture when near the maximum value of current, thus giving disruptive induced voltages. Thus the transmission and distribution of very large power has become practically feasible only by the development of the oil switch, which has the characteristic of opening the circuit at the zero point of the current wave, due to the opening occurring through an arc at high vapor pressure—that produced by the momentum of the oil column.

In addition to that stored in the magnetic field, energy is also stored by the electric circuit as electrostatic energy, by the electrostic field of the circuit; or as is usually said—in survival of the ancient theory of electricity as a fluid—by the electrostatic charge of the conductor.

In most circuits, such, for example, as the low voltage lighting circuits, the 550 volt direct current railway circuit, and the 2200 volt alternating current distribution circuit, the electrostatic energy, $\frac{e^2C}{2}$, is so small, compared with the magnetic energy $\frac{i^2L}{2}$, that the former can usually be neglected (except when dealing with extremely high frequencies, as in lightning) and the circuit considered as having resistance and inductance only, and no capacity, that is, as storing energy only magnetically.

The static energy is comparable with the magnetic energy, or of the same magnitude, in only two types of circuits:

1. The long distance high potential transmission lines, or high potential underground cable systems. Here the voltage e is so high, or the capacity C so great, that $\frac{e^2C}{2}$ is of the same magnitude as $\frac{i^2L}{2}$, that is, in overhead lines of 30,000 volts and over, and in underground cable systems of 6,600 volts and over.

2. The telephone circuit. Here the currents are so small and the frequencies so high that $\frac{i^2L}{2}$ is of as low magnitude as $\frac{e^2C}{2}$.

The long distance transmission line and the telephone circuit thus show many similarites in their electric phenomena, resulting from the storage of energy in two forms, as magnetic and static; the effects obviously are vastly different, due to the negligible power in the one type of circuit, and the very large power, high voltage, and large current in the other type of circuit.

In these circuits in which energy is stored in two forms, statically and magnetically, any change of circuit condition usually requires a readjustment of both forms of energy. That is, two transient terms exist, one resulting from the change of current from the value i_0 (corresponding to the previous conditions), to the value i_1, required by the changed conditions; the second transient term corresponding to the change of e.m.f. from e_0 to e_1, or of electrostatic charge from q_0 to q_1.

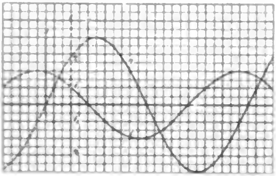


Fig. 3

For instance, if in Fig. 3, i is the current and q the electrostatic charge, and thus the voltage of the circuit; and if the circuit is closed at the moment marked x; at this moment the current *should* be i_1, but is in reality zero; and the static charge should be q_1, but is also zero. Thus starting from zero at x, the actual current and voltage gradually approach the permanent values i_1 and q_1; hence they can be considered as consisting of two terms:

$$i = i_1 + i_2$$
$$q = q_1 + q_2$$

where i_1 and q_1 are current and static charge, produced by the impressed e.m.f under normal circuit conditions, and i_2 and q_2 the transient terms of current and static charge, backed by no e.m.f., and consequently gradually dying out.

If the circuits are closed at that moment y where the current is zero, a transient term would still appear, due to the voltage, which at this moment is not zero; and if the circuits are closed at the moment z of zero voltage, the current, which is not zero, produces a transient term. Therefore upon closing (or opening) such a circuit, containing inductance and capacity, the transient term can only disappear if both current and voltage pass zero at the same moment; that is, if they are in phase, or the circuit in resonance condition. The disapperance of a transient term would therefore require that capacity and inductance of the circuit have such values as just to neutralize each other, and also that the circuit be closed at just the proper moment of the wave; and since the coincidence of so many conditions is highly improbable, it can be said that in general: "in a circuit containing inductance and capacity, upon closing or opening the circuit, or in any other way changing the circuit conditions—as by a change of load—a transient term always appears, due to the readjustment of the magnetic energy or the static energy, or both."

If the circuit is closed at the moment y, where the current should be zero, the magnetic field of the current produces no transient term, but the electrostatic field of the voltage does. The transient term (Fig. 3) produced by the latter, however, comprises not only voltage, but current also. At the moment of closing the circuit, the static charge on the conductor should be q_1; it is, however, 0. That is, the circuit represents an uncharged condenser thrown across the e.m.f., and in the first moment, the condenser acts as a short circuit on the supply voltage. That is, short circuit current rushes into the condenser and charges it to the required voltage e_1. At the moment where the condenser is charged to its normal value, the charging current still is excessive, and consequently its magnetic energy is also excessive; hence, it cannot instantly disappear, but continues flowing into the condenser, thus overcharging it, until all the magnetic energy of the current has been stored as static energy in the condenser, charging it above the voltage which it should have, that is, to about twice line voltage. As soon as the current has been stopped by the rising counter e.m.f. the latter begins to discharge, causing a reverse current to flow. This current is a maximum when the condenser has discharged down to its normal voltage; the current continues to flow, discharging the condenser, and again causing the current to reverse and to recharge, and so on.

The same phenomena appear when closing the circuit at zero e.m.f. (point z of Fig. 3). At this moment the current should have the value i_1, but instead, is zero, and so a transient current appears. This, flowing into the condenser, charges it to a voltage beyond the normal, causing the reverse discharge current to flow, with its accompanying phenomena outlined above.

Thus, in the case of inductance and capacity, the adjustment of the circuit at a change of conditions does not occur gradually, but is effected by a series of oscillations (shown in Fig. 4), during which the energy surges between magnetic and static energy until it is gradually dissipated in the resistance. These oscillations, representing the adjustment of the circuit to the changed conditions, last the longer the greater the inductance and capacity—that is, the greater the amount of energy stored. On the other hand, these oscillations die out the faster the greater the resistance of the circuit: the energy is therefore more rapidly dissipated with a large resistance, and if the latter is sufficiently high, the surge of energy may not develop at all but the energy be dissipated in the resistance during the first transfer from magnetic to static energy, or the reverse.

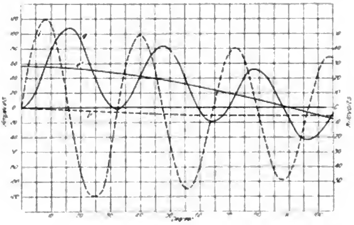


Fig. 4

We may compare a circuit, containing resistance and inductance only, to a pipe line through which water flows; and a circuit containing capacity in addition, may be compared to an open trough. In the water pipe, energy is stored by the momentum of the moving water only. When opening the pipe, the water does not immediately rush out with full velocity, since the water column has first to be set in motion, and this consumes the pressure. When the opening is reduced, the flow does not fall off immediately, because the momentum of the moving water column (the magnetic field) supplies sufficient pressure at the first moment to keep up the same flow of water through the reduced opening. This momentum gradually gives off its energy, and the water slows down to normal conditions of pressure and flow, corresponding to the reduced opening. If we suddenly close the opening and stop the flow, the pipe is liable to burst, just as the insulation of an inductive circuit is liable to be punctured if the circuit is abruptly opened, and the current stopped.

If, in an open trough or canal, we suddenly open the gates, the water rushes in at full head (the short circuit current), and fills the trough. Due to its momentum (the magnetic energy), it continues to flow, and so raises the water level above the normal (overcharges the capacity), to twice its height before it stops, if there is no frictional resistance; the current then rushes out again, empties the trough, rushes in again, and thus in a number of oscillations, or waves, gradually comes to rest at normal height and normal current. If, however, the resistance is very high, due to a long and narrow channel, the water never reaches such velocities when filling it, as to raise the level beyond normal; that is, no return flow or oscillations occur,

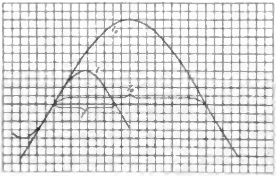


Fig. 5

just as no oscillations appear in an electric circuit of very high resistance.

When closing a circuit containing inductance and capacity, the capacity during the first moment acts as a short circuit on the supply voltage; that is, the current i rises at the same rate as the short circuit current i_0 (Fig. 5). This current i, however, does not last throughout the whole period of impressed e.m.f., as does the short circuit current i_0, but stops when the condenser is charged; *i.e.*, when it has stored the energy $\frac{e^2C}{2}$. The condenser then discharges again with current i, and when fully discharged, it has given off all its energy to the current, where it is stored as magnetic energy $\frac{i^2L}{2}$. During the oscillations, the static energy must therefore be equal to the magnetic energy; or

$$\frac{e^2C}{2} = \frac{i^2L}{2} \qquad (1)$$

and the current i rises at the same rate as the short circuit current i_0; hence we have, from Fig. 5

$$\frac{i}{i_0} = \frac{T}{T_0}$$

where T = duration of one half wave of the oscillation, and T_0 = duration of one-half wave of the supply voltage: that is

$$\frac{T}{T_0} = \frac{N_0}{N}, \text{ and thus}$$

$$\frac{i}{i_0} = \frac{N_0}{N} \qquad (2)$$

where N_0 = impressed frequency, and N = frequency of oscillation.

The short circuit current of a system, when neglecting resistance, is, however

$$i_0 = \frac{e}{x} = \frac{e}{2\pi N_0 L} \qquad (3)$$

where $x = 2\pi N_0 L$ = reactance:

Hence

$$\frac{i_0}{e} = \frac{1}{2\pi N_0 L}$$

and, by combining this with (2)

$$\frac{i}{e} = \frac{1}{2\pi NL} \qquad (4)$$

From (1) it follows that:—

$$\left(\frac{i}{e}\right)^2 = \frac{C}{L} \qquad (6)$$

hence, by substituting (5) in (4) we get:—

$$N = \frac{1}{2\pi\sqrt{LC}} \qquad (6)$$

= frequency of oscillations.

In a long distance transmission line, with distributed capacity and inductance, due to the difference in phase of the different parts of the line, the resultant capacity and inductance, or the arithmetical means of a half cycle, $\frac{2}{\pi}C$ and $\frac{2}{\pi}L$, have to be used instead of C and L, and equation (6) then assumes the form:

$$N = \frac{1}{4\sqrt{LC}} \qquad (7)$$

we have then, from (4):

$$i = e\sqrt{\frac{C}{L}} \qquad (8)$$

or:

$$e = i\sqrt{\frac{L}{C}} \qquad (9)$$

the equations relating the transient term of current, i, and of e.m.f., e.

That is: if $e = e_0$ is the supply voltage, the oscillating charging current is given by (8) as:—

$$i = e_0\sqrt{\frac{C}{L}}$$

If i_0 = the instantaneous value of the short circuit current, and the short circuit is suddenly ruptured, thus causing an oscillation, the e.m.f. of this oscillation is given by (9) as:—

$$e = i_0\sqrt{\frac{L}{C}}$$

or, by (3):

$$e = \frac{e_0}{x}\sqrt{\frac{L}{C}} = \frac{e_0}{2\pi N_0\sqrt{LC}}$$

where e_0 = impressed e.m.f., N_0 = main frequency.

The latter e.m.f. may reach enormous values.

It thus follows, that whenever in an electric circuit a change of circuit conditions takes place, the corresponding adjustment of the stored energy of the circuit occurs by a transient term which, if the circuit can store energy in one form only, is a gradual approach from the previous to the changed conditions. If, however, the circuit can store energy in two different forms, magnetically and statically, the transient term usually consists of a series of oscillations, which gradually die out by the dissipation of their energy in the resistance of the circuit.

Some causes of such change of circuit conditions are:

1. Change of load, as starting the circuit, opening it, or short circuiting it.

2. Abnormal currents entering the circuit, as by electro-magnetic induction from a lightning flash parallel to the circuit; or a short circuit on a parallel line; or abnormal voltages entering it, as by static induction from the clouds.

3. Sudden changes of static charge on the circuit, as by spark discharges, or arcs from the circuit to the ground or to other conductors.

The latter class of disturbances has the tendency to become recurrent, since the spark discharge from the circuit is usually the result of a defect in its insulation, and during the oscillations caused by it, the voltage of the circuit doubles, and at this increased voltage a second discharge takes place, etc.; thus the disturbance may continue indefinitely.

Some of the more interesting cases of such transient phenomena will be discussed in a later paper.

OPEN VERSUS ENCLOSED AND SEMI-ENCLOSED CAR LIGHTING*

By G. H. Stickney

Representing W. D'A Ryan

The primary purpose of lighting a car is to provide for the comfort of the passengers, and it is with this end in view that the skill and experience of illuminating engineers are enlisted. Considerable attention has been given recently to the subject, and numerous suggestions and changes have been made, but there still seems to be room for improvement.

In taking up any lighting problem, the physiological aspect should never be lost sight of, for it is necessary to consider the eyes of the people who are using the light. Outside of the questions of ventilation and heating, the only way in which the lighting affects the passengers is through their eyes. Perhaps the most common defect in car lighting is the glaring effect of lights of high intrinsic brilliancy. This is particularly noticeable to a passenger when he is occupying one of the rear seats, so that there is a line of lights in front of him which comes within his range of vision and shines in his eyes. Of course, the low decking of the car makes it necessary to locate the lights relatively low, so that the lamp is unavoidably within sight. The light enters the eye at such an angle that the physical properties of the eye render it incapable of protecting itself. This point is illustrated by snow blindness, which affects the eye, not because the intensity of the light is stronger than the light which comes from above, but because it enters the eye from a direction at which the eye is powerless to shield the optic nerve.

Now, the intrinsic brilliancy of a light source may be defined as the intensity of the light divided by the area of the source; that is, if we have two lights of equal intensity, that one which has the smaller area is the more brilliant, and is the one which will produce the greater tiring effect on the eyes. If we can enlarge the area of the light source, and without changing its volume, make the light come from a large surface, you can see immediately that it will be much easier on the eyes. If this dispersion be carried far enough, one can even look directly into the light without being nearly so much affected as by a casual glance at a light of great intrinsic brilliancy. Fortunately, increasing the source of light produces several other improvements. It improves the diffusion of the light around bodies, cuts down harsh shadows, and aids in making distribution over all points equal in intensity. It is very unpleasant, when reading, to have the lights situated so that the shadow of one's head, for instance, comes directly on the page. I think passengers have been troubled with this defect quite seriously.

Now, to come to the question of proper intensity. In nearly all illuminating engineering problems we find quite a wide range of variation in opinions among those who are using the light, as to the intensity of light that is necessary in order to perform a certain work, or to see with a certain degree of fineness. Outside of the requirements of different conditions, this variation of opinion necessitates our making an extended study of the subject in order to determine an intensity which is a compromise between the desirability of strong illumination and the matter of cost. For economic reasons the intensity of artificial illumination almost always falls far below that of daylight. In car lighting there is a demand for quite a variation of intensity in a single car; for instance, a person who

* A paper read before the Western Railway Club, Chicago, on Sept. 17, 1907.

is reading requires considerable intensity of illumination, while another person, who is whiling away his time and trying to sleep or rest, would prefer a relatively low intensity. So, outside of the cost of illumination, we desire to secure easy reading with as low an intensity of light as possible. This condition is also facilitated by properly diffusing the light.

About a year and a half ago, in connection with lighting one of the large stations of the country, Mr. Ryan ran a series of experiments for one of the railroads, in which he lighted a high room by arc lamps suspended in the top of the room, and also by arc lamps concealed so as to reflect the light on the roof, and then downwards into the room, no lamps in this case being visible. Of course, the latter method was a great deal more extravagant of light, but a committee of railroad officials who looked at the installation decided that the diffused illumination, which was only two-thirds as intense as the direct illumination, permitted them to see objects and to read more easily than the direct illumination, while the general effect was much more pleasant.

Another quality of illumination which should be considered in connection with the eyes is the color of the light. It is not absolutely essential that the light should be perfectly white, or daylight in color, but it should approximate this color as nearly as possible; and if there is to be a variation, it should be in the direction of the warm colors; such as yellow, for instance, to which people are accustomed, both in their ordinary indoor lighting and in the waning of daylight. The eye has been developed to its present state through the action of daylight, and to some extent through the action of artificial lights to which the people have been habituated, and is therefore better able to perform its functions by such lights. An excessive distortion of color should always be avoided — you could hardly expect the public to tolerate an extreme monochromatic light.

In selecting an illuminant for a particular lighting problem we have found it desirable to make the power and capacity of the lighting unit bear some definite relation to the area to be illuminated. In a high room of considerable size we would use a large powerful unit, and in a small low room a correspondingly smaller unit. In cases of armory lighting, as an example, we make a practice of grouping several arc lights together to form a single unit, while in order to obtain even illumination in a moderate sized room, the lighting unit must be relatively small. So of all the electric lamps available, the incandescent lamp lends itself most readily to car lighting.

Within the past few years there has been some very extensive developments going on in the construction of incandescent lamps; new materials have been discovered which have made it possible to increase the efficiency of an incandescent lamp very considerably. Up to about the present time it has been necessary to use a carbon filament which required the expenditure of from three to four watts for every candle power, whereas it may soon be possible to use a tungsten filament consuming approximately 1¼ watts per candle power; that is, per horizontal candle power. This increased efficiency will be of great aid to all classes of illumination where the incandescent lamp is applicable. The tungsten lamp is particularly adapted to low voltage; in other words, the electrical characteristics of this lamp are such that it can be manufactured more easily for voltages of from 20 to 30, than for 110 volts, the latter being the voltage at which the ordinary incandescents are run. To produce the proper electrical resistance, the relation between the length and the diameter of the filament is the determining factor. The hardest thing that we have had to overcome in constructing tungsten lamps has been the brittleness of the material, and for this reason the short, heavy filaments are the most substantial and suitable for car lighting work.

The great point of advantage of the tungsten lamp is its high efficiency as compared to ordinary incandescent lamps. This is due to the fact that it is possible to run tungsten at a higher temperature than any other material which has yet been available for the manufacture of filaments. If carbon, for instance, were run at this temperature the carbon would evaporate away from the filament, and in a short time the filament would burn out at some point and the lamp would be rendered useless.

Tungsten is a metal which has a lower resistance than carbon, so that a longer and more slender filament is required for the same voltage. In most of these lamps there are two filaments connected in series, each of which is about the size of an ordinary looped incandescent filament for 110 volt circuit; while the tungsten lamps are intended for only 30 volts. Another advantage of the tungsten lamp is that with a slight increase of voltage the temperature does not increase so rapidly as with the carbon lamp, and hence it is not so liable to be burned out by variations in voltage. The explanation of the relation between temperature and efficiency of lamps may be interesting. When we heat a solid material, for instance a lamp filament, up to a certain temperature, no light rays are given off. As we increase this temperature, we come to a point at which a very dull red ray is emitted, and the efficiency is then very low. As we increase the temperature still further, the material becomes brighter and brighter, the color becoming first yellow and then white. With increasing temperature, the percentage of useful light rays increases very rapidly. We have not as yet been able to produce pure white light in any incandescent lamp without cutting down the life of the filament to such an extent that the cost of replacement becomes too great for ordinary commercial conditions. The tungsten lamp, however, approaches more nearly to this ideal, and at the same time shows a correspondingly higher efficiency. In the electric arc it has been possible to produce practically a white light, because here carbon is maintained at the boiling point. As the electrode used is comparatively inexpensive, it can be allowed to boil away and be replaced without excessive expense. The electric arc, however, is not adapted to the small units we desire to use for car lighting.

Another point in connection with the incandescent lamp is the question of whether clear or frosted bulbs should be used. The light from a frosted lamp is undoubtedly much easier on the eye than that from a clear lamp, when run without a protecting shade, but the frosted lamp falls off in candle power much more rapidly than a clear lamp, with or without an outer shade. This subject has been worked out theoretically and practically, and a number of papers have been written on the subject, but we have found it best to use a clear incandescent lamp and protect the eyes by means of a separate shade.

Fig. 1. Three-light, Train-Lighting Ceiling Diffuser

Mr. Ryan's car lighting fixture consists of a steel diffusing screen placed above a row of incandescent lamps, the steel being finished with a white enamel, so as to give a highly efficient reflecting and diffusing surface. This design renders the lamp, to a large extent, independent of the finish of the car, whether this be dark or light, and at the same time permits enough light to fall on the deck of the car to prevent its appearing dark or gloomy. Beneath the row of lamps is placed a long trough shaped shade of art glass. The purpose of this is to cut off the direct light of the lamps from the eyes of the passengers, and to reduce the intrinsic brilliancy, in order to conform to the conditions which we have previously outlined. This form of reflector provides a large area for the source with a low intrinsic brilliancy, so that passengers may sit in a car without experiencing the tiring and even injurious

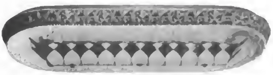


Fig. 2. Six-light, Train-Lighting Ceiling Diffuser

effects of a harsh lighting. It also provides for an even distribution of light throughout the car, so that no seats have advantages over other seats, and harsh and disagreeable shadows are eliminated. In constructing the reflector, all parts are mounted upon a light metal framework, which is attached to the deck of the car. The ornamental casting around the diffusing surface finishes off the reflector and gives it a neat appearance, and also prevents an open space existing in which the dust and dirt would accumulate and spoil the appearance of the installation. The diffuser is of stamped steel and is made in sections, so that the size of the unit may be varied for different conditions; for instance, in the body of the car a long reflector may be used varying anywhere from about two or three feet up to the entire length of the car. This design was made to provide flexibility, in anticipation of the likelihood that it might be desirable at some time to use one continuous reflector for lighting the car. The designs, as adapted at present, are merely the oval and the oblong shapes. The shade is a trough of art glass, which conceals from view the separate individual lamps. When it is desired to turn down the light, or reduce the intensity, part of the lamps may be cut out without its being noticeable that some of the lamps are not lighted. Each fixture is just one general source of illumination, whether all or only part of the lamps are in service. The dimensions of the light reflector are 48 inches long by 20 inches wide, and 10 inches deep. The weight of the reflector as constructed is about 37 or 38 pounds. The advantages of the reflector may best be stated as follows:

1. Softness and general diffusion of light eliminating strong shadows.

2. Clear bulbs can be used, thereby materially increasing the life of the lamps and diminishing the initial and maintenance cost. It is a well-known fact that the difference in useful life between a clear and a frosted lamp is somewhere between 30 and 40 per cent. On railway trains, particularly, frosted lamps accumulate a very large amount of smoke and dirt, so that the use of a clear bulb is a decided advantage which cannot be obtained by any other form of illumination with which I am personally familiar. For example, if the lamps are

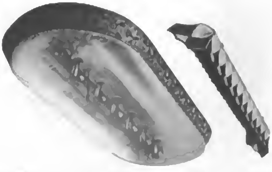


Fig. 3. Six-light, Train-Lighting Ceiling Diffuser, with shade removed showing lamps and diffusing screen

enclosed in a prism glass globe, aside from the usual disadvantages of this glass, you have a high intrinsic brilliancy in streaks.

3. The apparatus can be made attractive in appearance, with a possible saving on first cost as compared with some of the quite elaborate fixtures now used in Pullman cars.

TWO DOLLARS A YEAR TWENTY CENTS A COPY

GENERAL ELECTRIC REVIEW

VOL. X, No. 2
PUBLISHED MONTHLY BY
GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU
SCHENECTADY, NEW YORK
JANUARY, 1908

Station No. 3, Niagara Falls Hydraulic Power & Mfg. Co., in Process of Erection

(See page 51)

GENERAL ELECTRIC REVIEW

VOL. X, NO. 2 | JANUARY, 1908

CONTENTS

Booth at Pure Food Show, Rockford Edison Company, Rockford, Ill.
(See page 63)

Vol. X, No. 2 SCHENECTADY January, 1908

GENERAL ELECTRIC REVIEW

THE NIAGARA FALLS HYDRAULIC POWER & MANUFACTURING COMPANY *

By Geo. R. Shepard

The design of a power station is influenced, first of all, by the local conditions, and that design which develops the water power and gets it from the power house in the simplest manner is the most successful development, from all points of view. As engineers of the company, our endeavor has been to do this, regardless of appearances to some extent.

Fig. 1. Forebay of Station No. 3 while Building

The original plant of the company, which we call our No. 2 plant, was begun in 1895 and finished in 1900. There are several points regarding this plant of which I wish to speak, particularly the ones which illustrate what should not be done in power house construction. The water for this plant comes through two raceways, running down into

* Lecture delivered before the Schenectady Section A.I.E.E. November 21, 1907.

the forebay. Several pipes leave the forebay at an elevation of about 550 ft., and run over the edge of the cliff into the station, which is at an elevation of 340 ft., giving approximately 210 ft. effective head on the wheels. These pipes run the entire length of the station in a subway. The wheels are set directly above the pipes, and there is a separate opening from the pipe into each wheel, which is a very bad arrangement. The really proper method is to have a separate pipe for each unit.

Fig. 2. Generator Room, Station No. 2

The prime feature, from the hydraulic point of view of the power station, is to see that the water gets to the water wheels and away again by turning the fewest possible corners, and any turns in the direction of flow of the water should be as moderate as possible. These corners mean a loss of efficiency in the water power, and in our first station I presume we lose in this way between five and ten per cent. of the available power.

In the forebay of our new station, which was built this summer, the concrete has been curved where the water enters the mouth of the penstocks, forming a bell-mouth opening. This is the proper design for a place of this kind, as these bell-mouths allow the water to have a uniformly increasing velocity from the entrance to the pipe proper; that is to say, a uniform acceleration from the bay into the pipe; which, of course, means we lose less head than in any other way. This station brings out another feature which was neglected in the first plants; that is, the depth of the forebay from the top of the water. This is about 15 ft. in the old plant, and 30 ft. in the new. We found in the old station, at times of very low water—and we do have low water at Niagara, as well as at other places—that there was a tendency to suck air into the penstocks, which was very injurious to the pipes, as the air set up vibrations, and at times we have had grave fears for their safety. In each of these new pipes, which are 9 ft. in diameter, we have a sluice-gate, and around this sluice-gate there is an 18 in. by-pass valve. The penstocks are filled while the sluice-gates are closed, and the gates are then raised with pressure on both sides.

This is important in the design of a power house under any great head, as it is extremely difficult to get valves to operate satisfactorily under these conditions; but by placing them at the top of the penstock we can operate them under a head of 25 ft., and in case of necessity they can be closed under full head. This would be extremely difficult to do if they were under a head of some 205 or 210 ft. When for any reason we want to get the penstocks dry, we have a drainage system which takes care of any water which may leak through the valves. We have found that the least bit of water falling through the vertical height of these pipes, 150 ft. or more, produces a sort of pump action, forcing cold air and spray into the wheels and out through the man-holes, so it is almost impossible to get into the wheels to make repairs, or do cleaning. It is essential, for the proper maintenance of the plant, to be able to get the wheels absolutely dry, and on this account the drainage system was established. A slot is embedded in the concrete, and between this slot and a guide-piece on each side, we drop two 9 ft. stop-gates, which shut off the water sufficiently to enable us to get at the sluice gate inside. This is only used in cases of emergency.

The racks or screens which take the sticks and debris from the water, are made of bars ⅜ in. x 3 in., spaced with about 2 in. centers. The sections from the bottom to within about 5 ft. of the top of the water are made removable, so that they can be pulled out at any time. This has been found necessary on account of the slush ice which we have in certain seasons of the year, notably in the early winter, just after the water reaches freezing temperature. Water at that time is full of slush ice, which adheres to the bars and in an hour or so, if not watched and prevented, it would close up the passages between the bars, and cut off the water from the station. We keep a record of the temperature of the water and air from day to day, and have plotted a curve of water temperature, running through the entire year. By this curve we are able to determine, about two days in advance, when the water will reach 32 degrees, and when we will have slush ice. We keep our eye on this curve, and when it reaches the proper point we pull out enough rack sections to give a clear passage of the water and ice, and await developments. We have had this slush ice within twenty-four hours of pulling out the bars, and then again a week has passed before it came, but this has been the greatest length of time, which shows the efficacy of the curve. We leave the racks in as long as possible, to prevent sticks and debris from getting into the wheels, and this curve enables us to determine pretty closely the proper time to pull them out.

Fig. 3. Site of Station No. 2, Showing Difficulties of Winter Construction Work at Niagara

The forebay proper is on the outside of the racks, and a space between the racks and the entrance to the penstocks is necessary for the water to quiet down after it has passed through the narrow openings of the racks. From a velocity of 1½ ft. per second at the racks, it increases to its maximum, and when it reaches the wheels, is running at a velocity of 10 ft. per second. This increase is made uniformly in the curved opening.

A vent pipe running from the main pipe up to the top of the wall is extremely useful. It allows the air to enter the pipe in case of sudden shut-down, or when draining the water from the pipe. In our original installation we had a 9 ft. pipe under 125 ft. head, in which there was a somewhat similar opening about 6 in. in diameter. On one occasion we had to shut down very suddenly, and neglected to see whether the vent pipe was in operation. As a matter of fact, it was frozen up, the penstock collapsed, and we had to put in 50 ft. of new pipe. You can therefore see the importance of the air vent.

Turning our attention to the ice in the water, we started in with the theory that we ought to get water into the canal without any ice. After several years we made up our minds this could not be done, and the next question was, how to get rid of it. The water comes in in a direction parallel to a boom, which is simply a steel frame running across the forebay, and extending about 10 ft. below the surface of the water. On the extreme left of this boom we have a gate leading into a raceway off at one side. This gate is lowered, instead of being raised, allowing the water to fall over the top of the gate and creating a surface current. The floating ice naturally follows this surface current, is spilled over the top of the gate and runs off. The water goes in underneath the steel boom and flows into the wheels. This arrangement was worked out for our No. 2 station several years ago. In that plant we found it difficult to run the ice off without its jamming in our long raceways. It jammed continually, until our Superintendent conceived the idea of bringing his tug, which was laid up for the winter, to the mouth of the raceway, and there making it fast. The propeller was started up, and acted as a sort of pusher, and we had no more trouble. The next winter we put a propeller in the raceway and

Fig. 4. Station No. 2 while Building

connected it to a motor, and there has been no further ice clogging, the propeller doing the work of about 30 men.

To protect the power house of our No. 2 station from the ice in the river, we built a wall 5 ft. thick outside of the end wall of the power house, and have found this an ample protection. The masses of ice which form here every winter reach almost to the top of the bank—something over 100 ft. of solid ice, which lasts usually until about the first of June.

We figured that it cost $1000.00 to install this apparatus, and by running it after working hours, by the time it was too dark on summer days we found this removed anywhere from six to seven hundred cubic yards per day. Figuring $5.00 for operating expenses, the cost was about one cent a yard, which is very cheap excavating.

Our No. 3 station was built of concrete, with the exception of the wall facing the river, which the Commission, appointed by Secretary Taft, insisted on having built of

Fig. 5. Landing an Armature and Car from Cliff Above

rubble masonry to match the bank. The architect's explanation of this was that a concrete building decreases the apparent height of the cliff, and this is extremely important to preserve—therefore the rubble masonry was used.

From the face of the cliff to the water is a space 150 ft. wide on which there was debris of every kind, which consisted of boulders of all sizes, and other material dumped over the bank from time to time. We took all this loose stuff out with an hydraulic jet. Water was brought down from the top of the bank in a pipe 12 in. in diameter, the lower end of which was fitted with a nozzle having a four inch opening, and this was turned onto the bank. I think this is about the cheapest form of excavation ever devised.

We have a traveling crane, of a capacity of 65 tons, located on the top of the cliff, and all material shipped in is lifted directly from the cars, carried over and dropped below the bank, all in one operation.

Fig. 5 illustrates part of quite an interesting operation. It shows the landing of the armature of one of our big generators at

Fig. 6. Penstock Construction

the bottom of the cliff, by means of our 65-ton crane. These armatures arrived from the General Electric Co. on General Electric cars, and they were very well put on. The track shown runs some 450 ft. from the base of the cliff to the part of the station where these generators were to be installed, and our superintendent conceived the idea of lowering the armature, car and all, without unloading. We picked up the whole thing, and after landing it below, ran the car into the station, unloaded the armature, and then sent the car back. I might add that the car checker of the railroad appeared, and not finding the car, nearly had nervous prostration looking for it. We took particular pains to take it back when he was not around.

Fig. 6 is interesting only in showing penstock construction. It shows the notch cut in the bank, and the penstock hung up on a steel frame. It is difficult to set this steel frame properly, and even more difficult to secure the penstock to the frame. On account of the water rusting the pipe rapidly, we found it necessary this summer to encase the pipe in concrete, making a shell about 12 in. thick, completely enclosing it. We have discovered that concrete is an absolute protection for iron; in fact, it not only protects the iron, but when put around rusted iron, this will clean up and stay clean. We removed some concrete from iron which had been enclosed for perhaps five years, and although the concrete was put on when the iron was rusty, the latter was as bright as if it had been polished.

The illustration on the front page of the cover shows Station No. 3 in process of erection, one penstock completed, and the other partly so. These penstocks were shipped in sections of about 30 ft., which were lined up and then riveted with the little riveting platform shown in the cut, which was made to go around the pipe, and slide up and down. The power house itself is in two sections—the water wheel or hydraulic compartment, and the generator or electrical compartment. It is almost impossible to keep our water wheels dry, and we have had leaks develop of more or less magnitude, which have been disastrous to the generators right next to the water wheels. For this reason we put in a concrete wall, provided with a hole for the shaft, between the water wheel and generator, and in case anything goes wrong in the water-wheel room, the water cannot get to the generators. We have had a demonstration of the efficacy of this arrangement, although the station has not been in operation for more than two or three months.

The two white streaks running up between the penstocks are the aluminum bus-bars which carry the current from the station to the top of the bank. The Aluminum Company of America expects to take about 40,000 h.p. through these bus-bars, and unless I am mistaken, that figures roughly about 40,000 amperes, at their voltage. There is quite a perceptible field about these bars when they are in operation, but we have experienced no trouble from electrolysis. shall have as few sharp turns as possible, and that in the runners the velocity shall increase from that of the penstock up to a certain well-defined, fixed percentage of the velocity due to the head. From the wheel it slows down until it finally leaves the draft tubes at a velocity at which it will not eat out the concrete tailrace. This is accomplished by gradually restricting the cross section of the water passages and the runner openings. We are forced to use draft tubes on our wheels, as the extreme variation in the elevation of the lower river is about 20 ft. Our power house floor must therefore be 20 ft. above the low water mark, or about 15 ft. above the mean low water. We usually average 22 ft. of draft tube, and find that this works satisfactorily.

Fig. 7. Installing Water Wheels in Station No. 3

The bus-bars run up over the forebay on an overhead construction directly into the Aluminum Company's building. The current is all turned into heat, and the best kind of ventilation is necessary in order that the men may live at all in the pot room.

Fig. 7 shows the water wheels in our new station. The penstock coming in through the wall turns an angle of 90 degrees and runs around in a snail-shell form. The theory of efficiency of a water wheel is that the water

STEAM TURBINES*

By W. L. R. Emmet

The reasons for the existence of the steam turbine are many. One of these is that it is a mechanically simple machine, involving less complicated mechanical elements, and having certain practical features which have made the electric motor great and successful. Another reason is that it works in a field which the reciprocating engine cannot occupy, as it gives us the possibility of good efficiency of action in a wider range of pressure.

The reason why we use steam as a motive fluid is that water is cheap and common. It affords the most available method we have of turning heat into motion. Other fluids than water might be employed, for certain sets of conditions, to make a vapor which could be used instead of steam; it has been proposed to use such other fluids, and this has been done to some extent. It is possible that there are other fluids than steam which would give higher efficiency than steam gives and make possible greater thermal range.

Roughly speaking, the efficiency of a machine depends upon the range of temperature through which it can be worked, and this range with steam is quite small. The upper range of temperature in steam processes is limited by the pressure which is practicable, say 200 lbs. to the square inch, corresponding to a temperature of say 380° F. This temperature is not nearly so high as we might work, but the pressure becomes prohibitive as we go higher. With superheated steam we go up to 700° F., but the superheated process is simply a very small increment upon the other process.

As the steam expands in the engine or turbine, it would, if dry, cool rapidly by expansion; the fact that it is a vapor prevents this, because as it cools it liquifies a part and gives up the latent heat of vaporization, and this action sustains the temperature. Thus temperature and pressure follow a different curve than that which would be followed if steam were gas. Thus we have a natural cycle of operation in every steam process by which the heat carried by the steam, whether dry or superheated, may be turned into energy; and this process bears a certain fundamental relation to a theoretically perfect engine process. If a steam engine were perfect, the possible efficiency of the process, working say from 200 lbs. down to good vacuum, would be 33 per cent., but what we actually realize is some fraction of this. Now this 33 per cent. of the total applies to a certain range of temperature, 370 or 380 degrees F. down to say 100 degrees F., which is what we may call the practical range of operation in a turbine. Of this our engine can recover a certain proportion, and the proportion recovered we call its efficiency. The question of efficiency in engines is one thing, and the question of net output is another. The efficiency of an engine is its ratio of energy recovered to energy available theoretically. If for any reason we work our steam through a less range of temperature, the amount of energy available is less; and although the efficiency may be the same, the net result will be less. This 33 per cent. that I have mentioned is the proportion which the steam cycle within the temperature range bears to the perfect engine working within that temperature range. If we diminish the temperature range, the perfect engine would give less output. We have two elements, one the efficiency, and the other the range of available energy. In order to explain the difference between the reciprocating engine and the turbine, I will say that one of the great advantages of the steam turbine is that it is capable of giving good efficiency, if properly designed, through a wide range of

* Lecture delivered before the Schenectady Section A.I.E.E. November 6, 1907.

pressure and temperature; whereas the steam engine has mechanical limitations which greatly reduce its effective range. The range of pressure and temperature, within which reciprocating engines are practically comparable with good turbines, is that from ordinary boiler pressure to the atmosphere. Below atmospheric pressure the performance of the reciprocating engine begins to fall away rapidly, and the efficiency for each addition to the range of the cycle becomes less and less; and finally, when we come into the higher degrees of vacuum, the amount of work recovered is very small; whereas in the turbine the efficiency throughout the whole range down to very high degrees of vacuum is practically constant, in fact it is even better in lower ranges where friction losses are less.

To get an idea of these possibilities, I will tell you what the available energy in steam amounts to under some different conditions of pressure. In working steam from pressure of 165 lb. absolute down to a 29 in. vacuum, the available energy is 271,000 ft. lb. per pound of steam. If we work to the atmosphere instead of to this vacuum, the energy available amounts to 136,000, which is one-half of the share, so we have used up one-half of our theoretical cycle when we have gone to the atmospheric pressure.

If instead of working to a 29 in. vacuum we worked to one of 24 in., we only use 76 per cent. of the energy which we would have with the 29 in. vacuum. That is, by changing our vacuum from 24 in. to 29 in. we add 33 per cent. to the possible output of the engine. A 24 in. vacuum is about the limit of important gain in the reciprocating engine, it will gain something with a better vacuum than 24 in.—possibly two or three per cent.—but it is practically at the end of its possibilities when it gets to that degree of vacuum. There is a limit to the size of the cylinders and the low pressure valves; and the immense surface exposed, together with high degree of expansion in the steam engine, involves loss through cylinder condensation. The principal difficulty is the weight and bulk of the necessary moving parts. Steam with a 28½ in. vacuum has a volume about 200 times as great as it has at 175 lb. gauge.

The idea of the steam turbine is a very obvious one, and naturally appeals to everybody. It is the simplest form of production of motion from pressure, and was used by the ancients. The whole difficulty has lain in the fact that the velocities to be dealt with were so high. Steam carries so much powe and weighs so little that it attains an enormous velocity when its work is turned into motion. In working steam of 175 lb. gauge down to 28 in. vacuum, it will impart to itself a velocity of about 4100 feet per second. The fastest turbine wheels used by the General Electric Company have a peripheral velocity of 460 ft. per second, only about one-tenth of the maximum velocity of discharging steam. At that velocity of 460 ft. per second, the rim tension in a revolving steel ring amounts to 25,000 lb. per square inch. This is the elastic limit of ordinary steel. You see, even at this very low velocity, (only one-tenth that of the steam), we are near the practical limit of construction.

DeLaval, who built one of the first successful turbines, did not attempt to go further than the application of the simple jet to the single wheel. He designed a wheel with thin edge and thick middle, so proportioned that it could be run up to speeds possibly in the neighborhood of 10,000 ft. per second, and although that speed was not as high as it should be in proportion to the velocity of his jet, he got very good results and made a very clever design to make those results mechanically available.

In the Parsons turbine he has made a drum construction with a great number of buckets, and the steam passes through various rows of stationary and moving blades. In these rows of blades the steam keeps expanding from one to another, and drives the rotor by impact upon the moving blades and reaction from the velocity of discharge from the moving blades.

The difficulty about DeLaval's process is that he cannot use a high enough velocity to get a high efficiency, and using the velocity he does it is hard to get mechanical application. The speed is too high to use without gearing. DeLaval tried to make his turbine with more than one stage, and put his single wheels in several successive stages, dividing up the energy, reducing the velocity in each stage, and bringing it into more conformity with his wheels. The difficulty with this is that the pressure in these stages becomes high. With high pressure he got rotation losses and found he did not gain anything, so he kept to the single wheel.

Parsons had opposite ideas; he took up the multiple arrangement, and the difficulty about his process is that he is dealing with a fluid which at the beginning of his cylinder has one volume per pound, and at the end of the cylinder has a volume two hundred times as great. Since the cylinder turns at the same speed at one end as at the other, and since he wants conformity of speeds at both ends to use the fluid effectively, he is forced to rather extreme dimensions. His buckets at the upper end become extremely small and relatively inefficient, and at the lower end they become abnormally large; so that in order to keep his turbine within the bounds of possibility, he has had to sacrifice a good deal at both ends. Most of the Parsons turbines are deficient in the matter of dimensions in the low pressure end, and are too large at the high pressure end. Before the steam enters the turbine at all it is often largely expanded. It is governed by a throttling process, which reduces the initial pressure.

The idea of Curtis was to make a simple device by which a high velocity steam jet could be made to work more effectively than in the DeLaval simple bucket, and he conceived the idea of making the steam bounce at least three or four times in passing through one element of the turbine; that is, steam taken from the nozzle onto a bucket discharges from the bucket and strikes the stationary member, then to another moving element, and so on, repeating the process. By doing this a great deal is lost by friction, but a considerable proportion of the residual energy is saved and worked a second time.

This fractional abstraction of velocity gives conditions which make a great difference in the matter of mechanical construction, and with relatively simple means we can use these modified velocities, whereas we cannot use the higher ones. Mr. Curtis's first idea was to use three or four, or even more, blades on the same rotor in the same stage, with stationary elements between them; and he expected that the steam would pass through and give up work until it was all gone. Our experience very early convinced me that in this he was expecting too much, and for our second group of turbines, I adopted the two-bucket arrangement,—that is, two buckets to a stage,— and that is what we have confined ourselves to largely in our larger work; in smaller machines we are still using the three-bucket arrangement.

One very important element in the turbine is the question of the friction of the fluid itself. This limited the DeLaval operation in more than one stage; it also limits ours, but to a very much less degree, because we drop the pressure to a considerable extent in our first stage, and after that we have our wheels running at comparatively low pressures. Furthermore, we have built large turbines, and in large turbines the friction is relatively much less.

One of the great advantages of the Curtis type is that it is a multiple stage process in which a number of elements are used. The revolving element has no pressure behind it; the pressure of the chamber in which it operates surrounds it; it is simply blown around as a wind-mill is blown around, without any appreciable thrust. In the Parsons

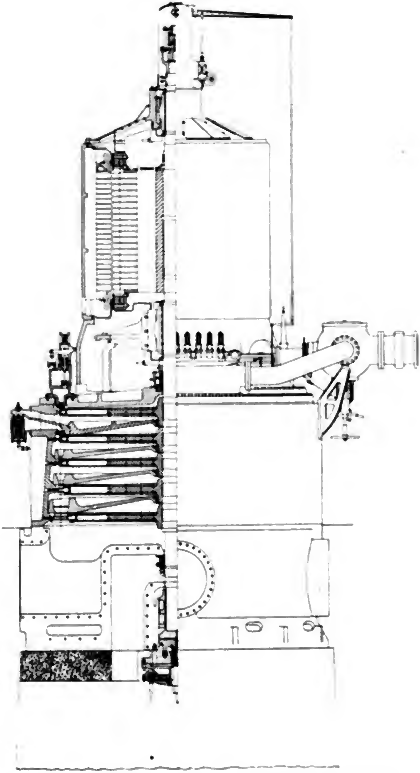


Fig. 1. 14000 Kilowatt Five-stage Curtis Steam Turbine and Generator

turbine, however, the pressure is behind the revolving element, and that pressure must be balanced by a similar revolving element which has no bucket and is simply a dummy that balances and removes the thrust. Now this dummy cannot be made steam-tight; in fact, is must necessarily have a considerable clearance, and that clearance involves a heavy loss, which loss is one of the serious limitations.

This is one of the great features of gain in turbines of the Curtis type. Nobody knows what the distortion of metal is until he begins to build rotating machinery. This is apparent as soon as you revolve the moving element. You cannot run close; you must have large clearances, and this is one of the important features of the whole turbine industry; and one of our great advantages is that we have a type in which we can use large clearances. In large turbines there is no clearance less than ⅛ in. in the axial direction, and radially possibly ¼ in., so they are turning in free space without anything to interfere with them.

The General Electric Company's present form of turbine, in its highest state of development, is shown in Fig. 1. It is a machine which is now rated at 14,000 kw. maximum, and is I believe, the largest that has ever been built, of any kind; it is also the most efficient machine ever built by a very considerable margin. This machine in Chicago has delivered to the switchboard a kw. hour at an expenditure of 12.8 lb. of steam; and that is the equivalent of something like 8¾ lb. per indicated horse-power. Its performance represents not only a very high efficiency of action, but very high range of action, the machine operating from 175 lb. down to a vacuum of 29 in. Other turbines have given as large a per cent. of the theoretical possibility, but no machine has ever given so large an output per pound of steam, and the reason is that this machine is both efficient and designed for a wide range of usefulness; whereas other machines, while efficient, are not suited for so wide a range.

Other machines which have been made by the General Electric Company, are almost equally efficient, and the 5000 kw. unit which has been tested in Boston showed only 0.3 pounds difference in efficiency from the unit in Chicago. All the smaller units, 1000 and 500, show satisfactory efficiencies for their size. These large turbines are five-stage machines, with very deep buckets in the last stage. The smaller machines are four-stage, very small and simple, yet very efficient.

One of the great problems in connection with the turbine industry has been the building of the generators, principally because there has been so much of it to do within a short space of time. An electrical design is something on which it is particularly desirable to have data and experience. It is very hard to foresee electrical conditions, particularly thermal conditions, eddy currents, mechanical strains, effects of vibrations, and other things. In generators for high-speed machinery, centrifugal strains are extreme, and since they are made up of copper and iron, it is necessary to devise all sorts of means for holding the copper and all parts together. The copper, under such centrifugal strains

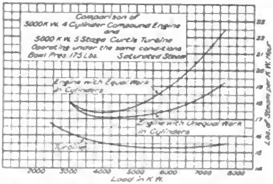


Fig. 2. Curves of Steam Consumption of Curtis Turbine and Reciprocating Engine

as here exist, will, if unsupported, flow almost like putty; it has to be bound, held and confined by strong steel structures in order to make it stay in place, and all this has to be taken care of in the rotating element. Furthermore, the machine, while highly efficient as most of the General Electric Company's generators are, involves losses like other electrical machines—possibly $3\frac{1}{2}$ per cent. in a machine like this 14,000 kw. turbine unit I have mentioned. Three and one-half per cent. of 14,000 kw. is a lot of power and represents a great deal of heat. I may roughly say that the heat represented by the losses in this highly efficient generator amounts to about the same that we would have in the furnace of a 60 h.p. boiler. If you imagine a generator about 10 ft. high, and 11 ft. in diameter, almost solidly filled with magnetic material—an extremely compact structure, with certain spaces through it for ventilation—and then imagine this structure having heat delivered into it as fast as a 60 h.p. furnace could put it in, you will see that the problem of keeping that thing cool is quite a serious one. To keep it cool, we must have 30,000 ft. of air a minute pass through, and keep that air uniformly distributed; so that in no part will it become very hot; otherwise we will have some part of the machine burning itself up. Most of this work on the generators has been splendidly done, and a vast amount of inventive ability, skill and foresight have been put into it; but naturally, some mistakes have been made, and every little difficulty with a generator tends to hold back the turbine industry as much as if it were in the turbine. These troubles, however, have been overcome and corrected. All this has been very expensive, but the result is, that in five years, we have made the largest and by far the most efficient steam engine ever produced.

PRACTICAL DEMONSTRATIONS ARE CONVINCING

By E. L. Callahan

In this day and age when so many new devices and labor-saving conveniences are being brought before the people, in order to call attention to any particular one, it seems necessary to show the buying public just wherein that one excels, is particularly desirable, or well adapted to their use.

This is especially true of electric heating devices, for so many people are satisfied if results can be obtained, regardless of whether they are accomplished under favorable conditions or under unfavorable ones with arduous labor. Central stations and electrical concerns that have devices for sale have therefore found it very advantageous to their business to show their customers, by means of demonstrations, just how cooking by electricity can replace cooking by other means—how much labor, time and expense can often be saved by using electric irons in the laundry, and electric heating appliances in the industrial field.

Throughout the last year or two there has been scarcely a food show held that did not contain booths with extensive displays of electric cooking and heating devices, and practical demonstrations of electricity replacing gas for heating. It has become quite the custom for electric light companies to have brilliantly lighted and tastefully arranged and decorated booths at these shows, with several demonstrators in white aprons and caps busily engaged in cooking and baking, and offering dainty bits of cake and coffee to the many interested visitors.

At one food show which I visited about two weeks ago, I found that, with two or three exceptions, every booth that needed heat was utilizing the electric current, and the management felt secure for the reason that the fire hazard was reduced to a minimum.

Many cities have an electric show annually, and since it is a recognized fact that things in motion attract attention, most of these shows depend upon electric novelties and electric heating devices for special features of the exhibitions.

These public demonstrations are not confined to the large cities, but have been taken up and carried through very successfully during the last year by many small towns and cities throughout the United States. In towns of ten thousand or over there is scarcely an electric light company that does not have an exhibition and demonstration room. In many cities these are not elaborate, but they are the nucleus for a new business department that will surely bring rich returns to the aggressive companies in the near future.

Fig. 1. Exhibition Room of the Detroit Edison Company

At State electrical conventions the managers of many lighting companies, who have given little time to pushing the sale of current-consuming devices, have been convinced, after hearing reports from those who have been pioneers in pushing the new business methods, that their plants are not earning what they should. They have gone home with the resolve that they would take steps to secure an exhibition and demonstration room, with someone in charge who would visit customers in their homes and show them twentieth century methods.

It has been learned that carefully chosen solicitors will be received in the homes of the electric light company's customers, as the latter are glad to learn of the new conveniences that are being offered.

The domestic science departments of the various women's clubs are enthusiastic on the subject, and are doing much to help the lighting companies to advertise electric heating devices. An example of this was shown early last spring in a town of about 40,000 inhabitants, where the domestic science departments of these clubs secured a renowned lecturer who had taken up electric cooking, with the result that about 20 per cent. of the inhabitants attended during the two daily sessions held for ten days. The electric supply companies and lighting company did everything possible to aid them in making attractive exhibits. The main feature was a six room cottage, complete to the smallest detail, which was located in the auditorium, and through which each visitor might walk and see what his or her home could be made like by the use of electric labor-saving conveniences, and proper lighting effects.

I am positive that the same success could be obtained in nearly every city in the United States, with excellent results and benefit to the electric company. At these lectures ladies secure valuable recipes for baking and cooking, having first seen them demonstrated, and those present are made to feel that they are being favored, rather than that they are conferring a favor on those in charge by attending.

A photograph of the cottage referred to above, which will give some idea of the completeness and care that was taken in building it, was shown in the December number of the REVIEW. It was demonstrated in this cottage that the week's washing, drying, and ironing could be done in from two to three hours time, and with almost no labor. To accomplish the drying, a rough board box about 4 ft. by 12 ft. by 6 ft. high was built, and the clothes quickly dried by electric heaters and fans.

Recently, in a city in Kansas where there had been little activity on the part of the local lighting and gas companies, the public was treated to a surprise through a change of management. The gas and electric companies combined, and tried to outdo each other in presenting the more interesting program at a practical cooking demonstration and course of lectures on domestic science. In the electric cooking demonstration, a comparison was drawn between cooking in the old way and in the new way.

Fig. 2. Demonstration of Electrical Heating Devices in one of Chicago's Leading Department Stores

The above illustration will show that the expense of providing the necessary equipment to carry on such a practical demonstration is not great. The smallest central stations can well afford to teach their customers to use current-consuming conveniences, for the money thus spent will come back to them through increased bills for larger current consumption by the satisfied customers.

In Grand Rapids, Michigan, a course of lectures by the eminent lecturer referred to above, has just lately closed. The lectures were held in the Press Building, and the Electric Light & Power Company were silent partners, although they were back of the whole scheme, and were the builders of the model cottage through which each visitor had to pass to reach the lecture hall. As a result it was the most popular attraction in town for two weeks, and was the means of demonstrating the practicability of electric cooking to just the class of people that the lighting company wished to reach.

This kind of advertising is effective, and when followed up by personal solicitation, brings profitable business.

The Edison Illuminating Company of Detroit, Michigan, has one of the most completely equipped demonstration and show rooms to be found anywhere. Nearly every current-consuming device, from a two candle-power lamp to a refrigerating machine, is installed ready to operate before the customer. A model electric kitchen in tile does not leave the inquiring customer much room for imagination, for everything is as it should and could be at home.

Demonstrators can better impress customers when they can show and operate kitchen devices in a kitchen, luminous radiators in a bath room, bedroom or living room, and ironing in a laundry. Nearly one million electric irons would not be in use to-day if the central station had not given the customer an opportunity to demonstrate that they would do the work.

Fig. 3. Model Electric Kitchen of the Edison Light & Power Co., Wichita Gas & Electric Show, Wichita, Kan.

A leading department store in Chicago, realizing that, with the extensive advertising of the lighting company and the desire of the people to buy new things, it would be to their advantage to put themselves in a position to supply the demand, arranged with the lighting company to have an exhibition and course of lectures on cooking by electricity held in their dining room. The hundreds of shoppers who patronized their restaurant, and those who came for the lecture, went away quite enthusiastic over the interesting subject, and were especially delighted with the electrically cooked dainties.

The best scheme that I know of for giving the people a correct knowledge of the cost of operating these various devices is shown in Fig 4. At one end of the demonstration room, and just outside of the fully equipped model kitchen, is a meter with a pasteboard dial having a circle described upon it, 12 inches in diameter and divided into twenty equal segments.

This is an old style five-wheel, or dial meter, the fifth wheel of which revolves once for each kilowatt registered. By extending the shaft three inches and attaching an aluminum hand, the current consumption in cents can be read by the observer at a glance, for instance, since the rate for cooking at Sault Ste. Marie is 2½ cents per kilowatt hour, if a broiler taking 1500 watts is used thirty minutes, the pointer will move 270 degrees around the dial, or show a cost of 1⅞ cents. The dial may be divided in any manner which best suits the rate in use.

It seems to me that the central station manager should make every effort to teach his customers the relative values of various apparatus as current consumers, compared with the best known standard. The custom of many stations is to use the 16 candle-power, 50 watt incandescent lamp as the standard. It is probable that this will not be a standard very much longer, but this standard is now more comprehensible to the layman than any other, and if he could see the relative current-consuming value of the 16 candle-power lamp and a two kilowatt air heater on a dial such as described above, the central station complaint department would not have so much work in adjusting customers' bills, and satisfying them that they had used all of the current with which they were charged.

Fig. 4. Exhibition and Demonstration Room of the Edison Sault Electric Co., Sault Ste. Marie, Mich.

If the customer is taught enough about electric measuring instruments to convince him that they measure the current accurately, and only when light, heat or motion is obtained, the central station man will relieve himself of the greater part of the complaints now received, and at the same time increase his revenue.

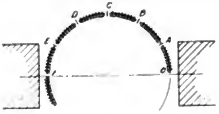
THE ROTARY CONVERTER

Part I

By E. J. Berg

In its general appearance the rotary converter resembles a direct current generator with two or more collector rings.

In its electrical characteristics it combines the features of the alternator with those of the direct current generator, and has many features of the stationary transformer.



Gram ring wound multiphase alternator

Fig. 1

In its action it is reversible, so that it can convert alternating current to direct current or *vice-versa.*

Depending upon the number of collector rings, a definite ratio exists between the direct current and alternating current voltage. As in the case of the transformer, this ratio is substantially constant at all loads and changes only by reason of the internal losses.

Voltage Ratio

With a sine wave of e.m.f. this ratio can readily be determined by referring to Fig. 1, which represents a Gramme ring wound, two-pole alternator, the armature of which is tapped at a number of points—O, A, B, C, D, E, and F.

Assume that the armature winding has t turns per pole, and that the effective alternating voltage generated per turn is E volts. In a single-phase alternator the voltage (represented in Fig. 1, as OF) would then be $\frac{2tE}{\pi}$, since the e.m.f's. generated in the individual turns are not in phase, their resultant being represented by the diameter instead of by one-half of the circumference.

In a three-phase converter the voltage is represented by the line OE, and is:

$$\frac{2}{3}t\,\frac{\frac{\sqrt{3}\,D}{2}}{\frac{\pi D}{3}}\times E = \frac{\sqrt{3}}{\pi}\,t\,E$$

In a four-phase converter (usually called two-phase converter) the voltage is represented by OC, and is:

$$\frac{2t}{4}\,\frac{\frac{\sqrt{2}\,D}{2}}{\frac{\pi D}{4}}\times E = \frac{\sqrt{2}}{\pi}\,t\,E$$

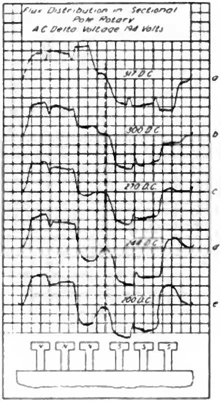


Fig. 2

In a six-phase converter the voltage is represented by OB, and is:

$$\frac{2t}{6}\,\frac{\frac{D}{2}}{\frac{\pi D}{6}}\times E = \frac{1}{\pi}\,t\,E$$

In a converter of m number of collector rings the voltage between adjacent rings is:

$$\frac{2tE}{m} \times \frac{m}{\pi} \cos \left(90 - \frac{180}{m}\right) = \frac{2t}{\pi} E \sin \frac{180}{m}$$

Since the direct current voltage corresponds to the maximum value of the single-phase alternating current voltage, its value is:

$$\frac{2\,t\,E\sqrt{2}}{\pi}$$

Assuming a fair flux distribution, such as is common in ordinary machines, the following relation exists, in general, between the alternating current voltage across adjacent collector rings of an m-phase rotary, and the direct current voltage:

$$\frac{\text{Alternating current voltage}}{\text{Direct current voltage}} = \frac{\frac{2tE}{\pi}\sin\frac{180}{m}}{2\frac{\sqrt{2}}{\pi}tE} = \frac{1}{\sqrt{2}}\sin\frac{180}{m}$$

This formula gives the following ratios for converters of the number of phases listed:

No. Phases	m	Ratio
1	2	.707
3	3	.613
4	4	.5
6	6	.353

With a greatly distorted flux distribution, such, for instance, as that shown in Fig. 2, the ratio changes very considerably. With a flux distribution as shown in a the ratio, three-phase to direct current voltage, was 0.615; as shown in b, 0.65; as shown in c, 0.72; as shown in d, 0.81; and as shown in e, 0.97. These diagrams are added to show how the ratio may vary. It is also of interest to note that in the first case, the ratio corresponds to that of a sine wave, although the flux distribution is far from such. We may therefore conclude that only very large distortions affect the voltage ratio.

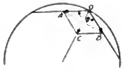
Current Ratio

In the following equations,

- i denotes the effective alternating current in the windings;
- i_a the effective alternating current in the lines;
- i_c the direct current in the winding;
- i_d the direct current in the lines;
- e the alternating e.m.f. between lines;
- e_d the direct current e.m.f. between lines.

The relation between the current in the winding and the current from a collector ring of a multiphase alternator is shown diagrammatically in Fig. 3.

Referring to Fig. 3, let $i = OA$, be the effective current in one side of the winding, and OB (also $= i$) the current in the other. Their resultant, which is the line current i_a, is then $2\,i \cos \frac{\phi}{2}$, where ϕ is the space angle between adjacent phases.



Relation between line current and current in a closed circuit winding of a multiphase alternator

Fig. 3

For an m-phase alternator, ϕ is $180 - \frac{360}{m}$, and therefore the line current i_a, corresponding to i amperes in the winding, is $i_a = 2\,i \cos\left(90 - \frac{180}{m}\right) = 2i \sin\frac{180}{m}$.

If e is the voltage between two adjacent collector rings, we get the total output = mie, which, when expressed as a product of line current and line voltage, may be written as:

$$\frac{mei_o}{2\sin\frac{180}{m}}$$

but e, as shown above, may be expressed as follows:

$$e = \frac{e_d}{\sqrt{2}} \sin \frac{180}{m} \qquad (1)$$

where e_d is the direct current voltage.

Therefore, in a rotary converter assuming 100 per cent. efficiency, we may write the direct current output the same as we do the alternating current input. Denoting the direct current line current by i_d, and the direct current e.m.f. by e_d, we therefore get:

$$i_d e_d = \frac{m e i_a}{2\sin\frac{180°}{m}} = \frac{m}{2}\, i_a \frac{e_d}{\sqrt{2}} \frac{\sin\frac{180°}{m}}{\sin\frac{180°}{m}}$$

or the ratio of currents in the alternating and direct current lines.

$$\frac{i_a}{i_d} = \frac{2\sqrt{2}}{m}. \qquad (2)$$

This formula gives the following ratios for converters of the number of phases listed:

No. Phases	m	Ratio
1	2	$\sqrt{2}$
3	3	.943
4	4	.707
6	6	.472

The relation between the alternating current in a closed circuit winding and the direct current for the same output is directly obtained from the previous reasoning.

We have i, the current in the winding =

$$\frac{i_a}{2\sin\frac{180°}{m}}, \text{ and } i_a = \frac{2\sqrt{2}}{m} i_d. \qquad (3)$$

Since in a two-circuit winding the direct current in the winding is one-half of the line current, we therefore get the following relation between the effective values of the two currents, where i_a is the alternating, and i_c the direct current in the winding.

$$\frac{i}{i_c} = \frac{i_a}{2\sin\frac{180°}{m}} \div .5\, i_d$$

$$= \frac{1}{\sin\frac{180°}{m}} \times \frac{i_a}{i_d} = \frac{2\sqrt{2}}{m\sin\frac{180°}{m}} \qquad (4)$$

and the ratio of the maximum value of the alternating current to the direct current, in the winding, is

$$\frac{i_{max}}{i_c} = \frac{4}{m\sin\frac{180°}{m}}. \qquad (5)$$

Thus, in a three-phase machine (m = 3)

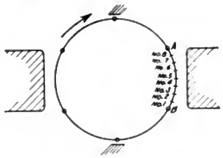
$$\frac{i}{i_c} = \frac{2\sqrt{2}}{3\cos 30} = 1.09$$

and the ratio between the maximum value of the alternating current and the direct current is $1.09\sqrt{2} = 1.54$.

In a four-phase machine $\frac{i_{max}}{i_c} = 1.414$, and in a six-phase converter, 1.333.

The armature heating, due to the I^2r losses, can best be studied by determining the instantaneous values of the resultant current in every coil during a revolution. Such analysis is given below for a six-phase converter with unity power factor.

Fig. 4 represents a two-polar, six-phase converter. The armature is assumed to consist of 48 coils, Gramme ring wound, and each phase has therefore 8 coils, displaced in space $\frac{360°}{48} = 7.5°$.



Two polar six-phase converter

Fig. 4

In the following analysis the condition existing in phase AB will be considered.

It is evident that when this phase is in the position shown in Fig. 4 its e.m.f. is a maximum; therefore, if the alternating current load is non-inductive; that is, if the rotary converter operates with such field excitation as to make the alternating current a minimum, the instantaneous value of the alternating current in this coil is also at its maximum at the same time. Let this maximum value of the alternating current be denoted by i_{max}, and the direct current in the winding by i_c. We then have, according to equation (5), the following relation between i_{max} and i_c.

$$\frac{i_{max}}{i_c} = \frac{4}{m\sin\frac{180°}{m}} = 1.333. \qquad (6)$$

(*To be Continued*)

RAILWAY SIGNALS

PART IV*

BY F. B. COREY

Signal Mechanisms

Having studied the fundamental principles of automatic block signalling and some of the elementary circuits used for its operation, we now come to the consideration of the signal mechanisms which drive the semaphore arm or other device, by means of which the proper visual indication is given to the crew of the train. This is an apparatus which must be designed and built with the greatest possible care, as failure to perform its proper function may lead to most disastrous consequences.

One of the earliest types of mechanism was the clock work signal, a few of which are still in operation, although such signals are not manufactured at the present time. This signal consists of a circular banner supported on a vertical shaft, the latter being turned by means of a weight and train of gears. An escapement releases this train of gears and causes the banner to revolve in such a manner as to give the proper indication. The weight is wound up from time to time, as the conditions of operation require. The banner

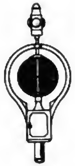


Fig. 1. Clock Work Signal

itself is largely made up of slats, like a blind; these slats being arranged to swing in the wind, so as to release the side strain that would otherwise occur. The mechanism is extremely simple, and the outward appearance of the apparatus is clearly shown in Figure 1. No new signals of this type have been erected since 1894.

The simplest of all signal mechanisms is the

Fig. 2. Disc Signal, Operated by Electro-Magnets

purely electrical device used in disc signals, a typical form of which is shown in Figure 2. This mechanism consists merely of peculiarly designed magnets, so arranged as to turn the signal from stop to clear position, and hold it there. Mounted on the armature shaft is an arm which carries two discs, the larger one of which is made of cloth, to secure lightness, while the smaller disc is of very thin glass. The large disc is for the purpose of a day indication, and the smaller one serves as a colored roundel for giving the night signal. Such a signal, assembled in its case, is shown in Figure 3, which gives a back view of the case, with the door open; above the door is seen the bracket, which supports the signal lamp.

* Part III of this article appeared in the September issue

Passing now to the consideration of the mechanism for operating the modern semaphore arm, we come first to the electro-pneumatic signal, which has come into very

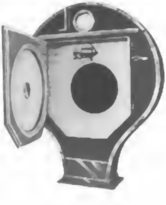


Fig. 3. Disc Signal Assembled in Case

extensive use. In this system compressed air is piped throughout the entire length of the road, and track circuit relays control electro-pneumatic valves for admitting air to the cylinder which contains the operating piston. It is arranged so that when the air is admitted to the cylinder, the signal is thrown to its clear position, and held there until the cylinder is exhausted by the release of the electro-pneumatic valve, or by failure of the air supply. A sectional view of such a cylinder and valve is shown in Figure 4, and a complete signal of this type is shown in Figure 5.

An interesting modification of the electro-pneumatic principle is the electro-gas signal, operated by gas pressure. In this signal the operating medium is carbonic acid gas (CO_2), which is stored in steel cylinders or tanks, where it is liquified by pressure. The storage tanks, which are similar to those used in the ordinary soda fountain, are placed in a battery chute of the usual type, close to the base of the signal. To absorb the moisture which is always present and thus prevent freezing, a small amount of alcohol is introduced into each cylinder, but this precaution does not entirely eliminate trouble from that source. A reducing valve is provided to regulate the pressure of the gas that is admitted to the operating cylinder. A small auxiliary reservoir, containing gas at the reduced pressure, is located in the mechanism case, and this serves for the direct supply to the operating cylinder, which is movable upon a stationary piston as shown in the section of Figure 6. An elevation of a two-arm signal of this type is shown in Figure 7. Large numbers of these signals have been installed and are in successful operation; at the present time, however, they are not being installed in as large numbers as formerly, as it is quite generally admitted that they are less satisfactory than the electric motor signal, which is now the most popular type.

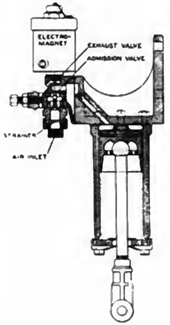


Fig. 4. Section of Cylinder and Valve, Electro-pneumatic Signal

The earliest form of electric motor signal to come into extensive use was the "Style B" signal, which is manufactured by the Union Switch & Signal Company, and is being built in large quantities at the present time, in practically its original form. The latest design of this signal is shown in Figure 8, which gives a good idea of its principal parts. The electric motor, through double reduction gears, drives a shaft which carries a sprocket wheel, while the upper part of the frame of the signal carries another sprocket, the two wheels being connected by means of an ordinary sprocket chain. To this chain is attached a roller, shown in the illustration near the upper end of its travel. The signal arm is operated by a vertical rod which is provided with a screw-jaw fastened to a casting called the "slot-arm;" this slot-arm carries a magnet, known as the slot-magnet, and the armature of this magnet is carried on a lever, the end of which engages a long hook attached to a bell-crank. This bell-crank engages another lever, which in turn is fastened to still another crank. This latter crank is so shaped as to engage the roller that is carried by the sprocket chain. When the signal circuit is closed the motor is started and the slot-magnet energized; with the slot-arm then in its lower position, the roller engages with the catch, raising the slot-arm, which in turn raises the rod, operating the signal blade. When the signal reaches its clear position the roller disengages the slot-arm and the latter drops back slightly, and is held by a lug on the frame of the mechanism. The motor circuit is then broken by the current controller, which is seen at the lower right-hand corner of the illustration, and the signal is held in its clear position as long as the slot-

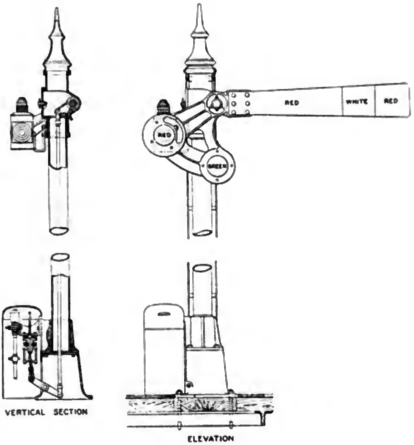


Fig. 5. Electro-pneumatic Semaphore

magnet is energized by the relays. The motor is stopped by means of a magnetically operated friction brake. When the signal is released the shock of its fall is absorbed by the dashpot, shown at the upper right-

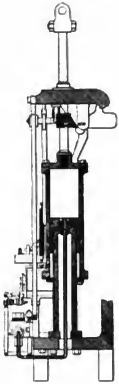


Fig. 6. Section of Operating Cylinder, Electro-gas Signal

hand corner of Figure 8. The mechanism illustrated is for a two-arm signal, and therefore carries two sets of sprocket wheels, two sprocket chains, slot-arms, etc. When this signal is used for a one-arm three-position signal the same mechanism is used, with the addition of two racks, each carried by a slot-arm, with a floating pinion between the two racks which is carried by the signal-operating rod. This signal is described in detail on account of the fact that there are now nearly 25000 of them in service.

It will be noted that all of the signal mechanisms above described are located at the bottom of the signal mast, and are connected to the signal arm by a vertical rod extending through the interior of the pipe mast. This arrangement involves the conversion of the rotary motion of the motor and gears to a reciprocating motion, and then again to a rotary motion at the semaphore bearing. In order to make a more direct application of the power, and thus avoid the difficulties and losses incident to such an indirect connection, a class of signals has been recently developed which are known as top-mast signals. In this class of signals the motor and other mechanism are located at the top of the signal mast, and in this way direct connection with the semaphore arm is secured.

All of the signals manufactured by the General Electric Company are of the top-mast type. With this arrangement it is

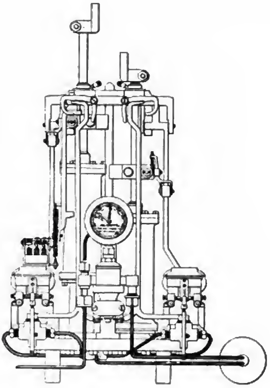


Fig. 7. Elevation of Two-arm Electro-gas Signal

possible to insulate the mechanism and its case from the signal mast and ladder, and this avoids, to a large extent, the possibility of trouble due to defective insulation of the mechanism parts, or to careless wiring when the signal is installed. The top-mast construction permits of the installation of a signal on any kind of pole with the least possible labor. The mechanism is located above the surface moisture and out of the reach of floods, and in locations where heavy snows occur, it facilitates the inspection and care of signals without the necessity of removing the snow from around the base of the pole. By doing away with the connection between the bottom and top of the pole considerable power is saved, and since such signals are usually operated from primary batteries any saving in power is of importance. The only objection that has been raised against the top-mast arrangement is that the maintainer is obliged to go to the top of the mast to inspect and care for the signals. In practice, however, those who have had experience with top-mast signals of the proper design are heartily in favor of this construction.

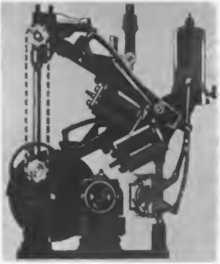


Fig. 8. Early Type of Electric Motor-Operated Signals

Figure 9 shows the General Electric Company's M-110 signal mechanism, complete in its case. This signal is of the three-position type. The motor is geared in such a way as to revolve the clutch wheel, which turns freely about the main shaft, while this shaft extends through the case for the reception of the signal arm. Mounted upon this

Fig. 9. General Electric Motor-Operated Three-Position Signal, Type M-110

shaft, and rigidly attached to it, is the sector casting which supports the clutch magnet, and which also provides, by means of the locking magnet seen at the top of the mechanism in Figure 9, a method of locking the signal in its caution and clear positions. The return of the signal to either caution or stop position is accomplished by gravity, without the movement of any of the gearing, thus avoiding all unnecessary friction. This gravity movement is retarded by means of a simple dashpot, shown at the lower right-

Fig. 10. General Electric Motor-Operated Two-Position Signal, Type M-113

hand side of the mechanism. For a complete description of this signal, reference is made to General Electric Bulletin No. 4484.

The General Electric Company has recently placed on the market a two-position, top-mast motor signal, which embodies a number of novel features, both electrical and mechanical, and is known as the M-113. The frame of the mechanism, which supports the main shaft bearing and the bearings for the reduction gears, is made so as to form a weather-proof case; and, with the door attached to it, this forms a complete protection for the working parts. This construction greatly reduces the number of parts required, and insures a more perfect alignment of the bearings than could be otherwise obtained. This mechanism is shown in Figure 10. The motor, by means of intermediate gears, drives the main gear, and to this latter gear are attached five steel driving pins which engage a pawl carried by the slot-arm. This slot-arm is secured to the main shaft, and serves to drive the signal to its clear position. The return of the signal to the stop position is effected by gravity, and this movement is cushioned by a buffer at the back of the driving gear. The stopping of the motor at the clear position is effected by converting the motor into a generator, and for this purpose a shunt field winding is provided, in addition to the series field. The electrical connections are shown in Figure 11. For a complete description of this signal, reference is made to General Electric Bulletin No. 4536.

The last two signals described above show the highest development attained, respectively, in these types of electric motor signals. It

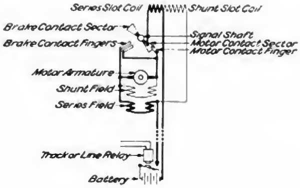


Fig. 11. Diagram of Connections, Type M-113 Signal

is believed that future development will be along the line of the top-mast construction, as it is universally recognized that reliability of operation is the supreme object of the signal engineer and of the signal manufacturer.

(THE END.)

NOTES ON THE DETERMINATION OF RAILWAY POWER STATION CAPACITIES

PART I

By E. E. Kimball

The object of this article is to outline briefly the general procedure followed by engineers in preparing estimates on the power required for the operation of proposed trolley roads, and also to present some interesting data in connection with train resistance and energy consumption which will be of great assistance to those who are frequently called upon to make technical recommendations on substation and power station apparatus, distributing system, size of motors, etc.

Requests for engineering recommendations are usually accompanied by a profile of the proposed road, showing grades, curves, location of stations, etc., and a description of the nature and volume of traffic the railway company expects to handle. Prior to the determination of the power station load, certain conditions more or less dependent upon each other must be definitely determined, and in order that these conditions may be properly emphasized and a logical procedure adopted, the following outline showing the steps in the calculations has been included:

1. Determination of schedule speed as governed by the frequency of stops, alignment, and profile of road.

2. Determination of car weight from seating capacity, motor weight, and maximum speed.

3. Determination of energy consumption of trains.

4. Determination of distribution losses.

5. Determination of headway, number of cars, and construction of train sheets.

6. Determination of station load diagram from train sheets, average kilowatt per car and distribution losses.

The determination of schedule speeds from the motor characteristics by the method of plotting *speed-time-energy* curves requires a knowledge of train resistance values, as well as the fundamental laws of force and motion. For this reason it seems advisable to show the development of certain fundamental constants which enter into the calculations of a great many railway problems.

Train resistance is that force which is directly opposed to the movement of a car or train, and includes rail and flange friction, rolling and bearing friction, wind resistance, etc. Within the past few years a great many tests have been taken, both in this country and abroad, to determine values of train resistance at various speeds with several different types of equipment, and under more or less favorable conditions of track, roadbed, etc., and after a very careful investigation of the conditions which existed in the actual tests, it was found that a single empirical formula could be derived which represents the test values very closely. This formula is as follows:

$$F = \frac{50}{\sqrt{T}} + .03V + \frac{.002V^2}{T} A\left(1 + \frac{N-1}{10}\right)$$

Where F = train resistance in lb. per ton.
T = total weight in tons.
V = speed in miles per hour.
A = end cross section in square feet.
N = number of cars in train.

$\frac{50}{\sqrt{T}}$ has been limited to a minimum value of 3.5.

It is unnecessary to enter into the method employed for deriving the above formula, since one is seldom concerned with the bearing, rail and flange frictions, etc., as separate items, but it is interesting to note that the last term represents the effective wind pressure upon the head-end and sides of the cars. Various tests have been taken to determine the variation of this pressure upon the front end of succeeding cars in a train and it was found to be about 10 per cent. of the total

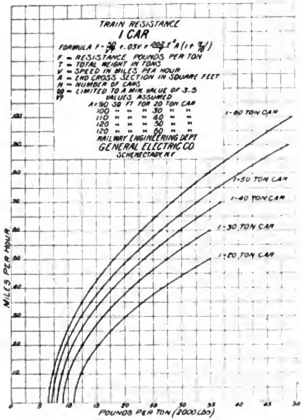


Fig. 1

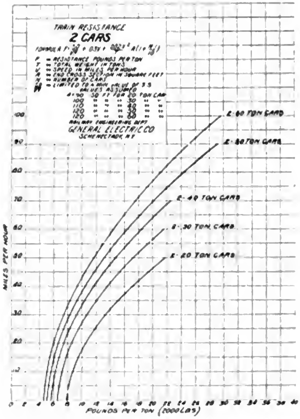


Fig. 2

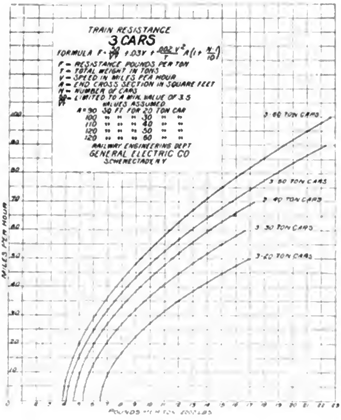


Fig. 3

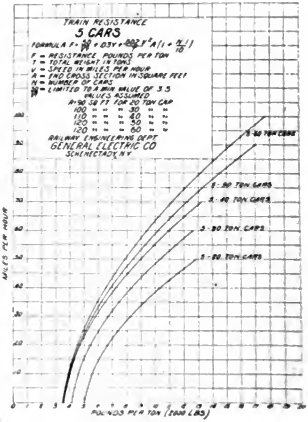


Fig. 4

pressure on the first car. It should be noted that the formula is perfectly rational in this respect.

In order to present the data on train resistance in the readiest manner for reference, the above formula has been worked up in curve form for various weights of car, area of end cross section, number of cars in train, etc. These curves form the basis of the calculations and tables which follow.

It is customary to speak of a grade as so many per cent., meaning thereby the ratio of the distance raised to the distance covered; hence, the component of gravity along the grade, and opposed to the movement of a train *up* is equal to 20 lb. per ton (2000 lb.) for every one per cent. grade.

Curves are rated in two ways; namely, by degrees and by radius. The first method is adhered to by steam railroad engineers, since here the curves are seldom greater than 10 or 15 degrees, which permits surveyors to easily line in a curve with a transit. A one degree curve is one so constructed that a 100 ft. chord will subtend, at the center of the circle, an angle of one degree. Hence the radius of a one degree curve is $\frac{360 \times 100}{2\pi}$ = 5730 ft., and the radius of any other curve

$$n° = \frac{5730}{n} = \text{feet radius approximately.}$$

Curves have, however, little bearing upon energy consumption of cars on account of their limited length, but it has been found that the *rail and flange friction while rounding a curve increases approximately at the rate of ½ lb. per degree of curvature.*

Frequently the distance between stops is so great that the equipment may be maintained running at constant speed over the greater portion of the run. Thus it is essential to know the power taken by a train when running at constant speed, in order to determine the size of trolley and feeder, and the drop between substations, as well as the load on the main station. During constant speed running the power supplied to a train is just sufficient to overcome the train resistance, and the losses in the motors and control, etc.

Hence,

Horse-power output at rim of the wheels

$$= \frac{T \times F \times \text{feet}}{33000 \times \text{minutes}}$$

$$= \frac{T \times F \times \text{miles} \times 5280}{33000 \times \text{hours } 60}$$

$$= \frac{T \times F \times V}{375}$$

When reduced to kilowatts the formula becomes

Kilowatt output at rim of wheels

$$= \frac{T \times F \times V \times 746}{375 \times 1000}$$

$$= \frac{2 \times T \times F \times V}{1000} \text{ approximately}$$

and kilowatt input to train $= \frac{2 \times T \times F \times V}{1000 \times \text{eff}}$.

Where T = total weight of train.

F = train resistance, including that due to grades and curves, in lb. per ton.

V = speed in miles per hour.

eff. = efficiency of the motors at the speed V.

The table on page 80 has been inserted to show the kilowatt input required by trains of different compositions running at various speeds, assuming standard cross sections for cars of various types.

The formula for energy consumption derived from the expression for kilowatt input is:

Watt hours per ton mile =

$$\frac{2 \times T \times F \times V}{\text{Eff.}} \times \frac{1}{T \times V} = \frac{2 \times F}{\text{eff.}}$$

The actual energy consumption in any service will always be greater than the value thus derived, but will approach this value as the distance between stops increases.

Speed-Time-Energy Curves:

It is quite evident that the problem usually met on the majority of interurban and city trolley lines requires further investigation, since the distances between stops are usually so short that the equipment has barely time enough to reach maximum speed before power is shut off and the brakes applied. This requires the construction of speed-time-energy curves, which consists in plotting instantaneous values of speed, current, volts and distances, corresponding to various sec-

TABLE I

KILOWATT INPUT AT TRAIN, CONSTANT SPEED RUNNING ON TANGENT LEVEL TRACK

MOTOR CAR SERVICE

SINGLE-CAR TRAIN

Speed in Miles Per Hour	10	20	30	40	50	60	70	80	90	100
20 Ton Car	6.5	16.2	32.0	56.7	93.5	....	....	....	....	....
30 " "	8.0	19.5	38.4	67.3	109.0	167.0	....	....	....	....
40 " "	9.4	23.1	44.1	76.2	124.0	188.0	276.0	....	....	....
50 " "	10.4	25.6	49.2	84.8	137.0	210.0	305.0	430.0	584.0	....
60 " "	11.5	27.9	52.8	90.2	144.0	218.0	316.0	442.0	599.0	792.0

TWO-CAR TRAINS

Speed in Miles Per Hour	10	20	30	40	50	60	70	80	90	100
2-20 Ton Cars	9.3	22.4	42.5	72.5	116.0	....	....	....	....	....
2-30 " "	11.5	27.4	51.4	87.0	137.0	206.0	....	....	....	....
2-40 " "	13.2	31.6	59.0	99.3	156.0	234.0	336.0	....	....	....
2-50 " "	14.8	35.5	66.3	111.0	175.0	261.0	374.0	520.0	699.0	....
2-60 " "	16.3	38.8	71.7	119.0	185.0	274.0	390.0	540.0	720.0	945.0

THREE-CAR TRAINS

Speed in Miles Per Hour	10	20	30	40	50	60	70	80	90	100
3-20 Ton Cars	11.4	27.2	50.9	84.1	136.0	....	....	....	....	....
3-30 " "	14.0	33.3	61.8	103.0	162.0	240.0	....	....	....	....
3-40 " "	16.3	38.7	71.5	119.0	185.0	271.0	391.0	....	....	....
3-50 " "	18.4	43.7	80.6	134.0	206.0	308.0	437.0	602.0	805.0	....
3-60 " "	20.1	48.0	87.4	144.0	222.0	326.0	460.0	635.0	925.0	1092.0

FIVE-CAR TRAINS

Speed in Miles Per Hour	10	20	30	40	50	60	70	80	90	100
5-20 Ton Cars	14.8	35.3	65.4	109.0	171.0	....	....	....	....	....
5-30 " "	18.3	43.5	80.0	133.0	205.0	303.0	....	....	....	....
5-40 " "	21.3	50.8	93.2	154.0	237.0	348.0	493.0	....	....	....
5-50 " "	26.2	61.9	112.0	183.0	279.0	406.0	568.0	773.0	1026.0	....
5-60 " "	31.3	72.8	130.0	208.0	312.0	448.0	622.0	835.0*	1100.0	1415.0

Constants Assumed

Efficiency at full speed taken at 75 per cent. and based upon the use of d.c. geared motors.

Train resistance obtained from formula $F = \frac{50}{\sqrt{T}} + .03V + \frac{.002AV^2}{T}\left(1 + \frac{N-1}{10}\right)$

Cross sectional area of cars as follows:—

20 Ton Car, Cross Section	90 square feet
30 " " " "	100 " "
40 " " " "	110 " "
50 " " " "	120 " "
60 " " " "	120 " "

onds of time after car starts from rest. See Fig. 6. It will be noticed that the speed curves can be divided into five parts, namely:

Acceleration, A to B;
Motor curve acceleration, B to C;
Constant speed running, C to D;
Coasting, C to E;
Braking, E to F.

Acceleration consists in bringing a car up to speed by notching up the controller, during which time the voltage impressed upon the motor terminals is always less than the line potential, or full voltage of the motors. During this period the rate of acceleration can be held approximately constant by cutting out resistance as the car speeds up. As soon as full voltage is impressed upon the motor, the rate of acceleration gradually decreases until the input to the motors is just sufficient to keep the car running at constant speed. This portion of the speed curve between constant acceleration and constant speed running is therefore designated as motor curve acceleration, since its shape depends upon the characteristics of the equipment employed.

In order that a motorman may make accurate stops, it is frequently necessary that the power be shut off some distance before the brakes are applied. During this period the momentum of the car is sufficient to keep it running at a constantly decreasing speed, which is designated as *coasting*.

Braking consists in applying a force opposed to the revolutions of the wheels, in order to produce retardation. The phenomenon is therefore the opposite of acceleration, and may be treated the same way.

Strictly speaking, *acceleration* or *retardation* is the rate of change of velocity, and is expressed in feet per second per second. In railway problems, however, acceleration is usually defined in miles per hour per second. Thus, an acceleration of one mile per hour per second means an increase in speed of one mile per hour during each second, so that in n seconds after starting from rest a train will be running at n miles per hour. The force required to produce a given acceleration is obtained from the formula:

Force = mass x acceleration,

where force is expressed in pounds, and acceleration in feet per second, per second;

$$\text{mass} = \frac{\text{weight}}{32.2}.$$

Hence,

$$\text{Pounds} = \frac{\text{weight in pounds}}{32.2} \times \frac{\text{feet}}{\text{seconds} \times \text{seconds}}$$

$$= \frac{2000 \times \text{tons}}{32.2} \times \frac{5280 \times \text{miles}}{3600 \times \text{hours}} \times \frac{1}{\text{seconds}}$$

$$= 91.1 \times \text{tons} \times \text{miles per hour per second}$$

Hence, an acceleration of one mile per hour per second requires a force of 91.1 lbs. per ton.

In accelerating a train it is also necessary to accelerate the revolving parts, which is equivalent to about 7 per cent. more weight. The following table gives the accelerating rates usually obtained in practical operation:

Accelerating Rates

	Miles per hr. per sec.
Steam locomotive, freight service,	0.1 to 0.2
Steam locomotive, pass. service,	0.2 to 0.5
Elec. locomotive, pass. service,	0.3 to 0.6

Motor Cars

	Miles per hr. per sec.
Electric motor cars, interurban service,	0.8 to 1.3
Electric motor cars, city service,	1.5
Electric motor cars, rapid transit service,	1.5 to 2
Highest practical rate,	2 to 2.5

For a comparison of acceleration tests with steam locomotives and electric motor cars, see B. J. Arnold and W. B. Potter's paper read before the American Institute of Electrical Engineers, June 19, 1902, Vol. 19.

For the same brake-shoe pressure the braking rate is greater for low speeds than for high speeds, on account of the decrease in the coefficient of brake-shoe friction. It is usual, however, to assume a braking effort of about 120 lbs. per ton gross for ordinary service applications on interurban lines. On steam roads the rate of braking of freight trains is considerably less on account of the time required to apply the brakes on all cars, and the necessity of reducing shocks to equipment and lading (caused by running in and out of the slack) to a minimum. A fair value to assume for the braking rate of freight trains is about 0.5 miles per hr. per second.

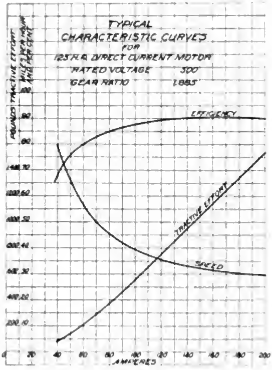


Fig. 5

The distance covered in a given time is equal to the product of the speed and time, where the distance is given in feet, speed in feet per second, and time in seconds.

Hence,

$$\text{Feet} = \frac{\text{feet}}{\text{seconds}} \times \text{seconds} = \frac{5280 \times \text{miles}}{3600 \times \text{hours}} \times \text{seconds} = 1.467 \times \text{miles per hr.} \times \text{seconds.}$$

Hence a speed of one mile per hour is equivalent to 1.467 feet per second.

During acceleration and braking the speed is uniformly changing; hence it is necessary to take the average speed, thus:

$\text{feet} = \frac{1}{2} \times \text{speed} \times \text{time} = \frac{1}{2} \times \text{acceleration} \times \text{seconds}^2$.

The above formulae are all that are necessary for the construction of speed-time-energy curves. The actual calculations, however, are best arranged in a table as shown on page 83 where a few points of Fig. 6 have been calculated to illustrate the procedure. The data assumed in these calculations is as follows:

Weight of car	40 Tons
Effective weight of car	42.8 Tons
Number of motors	4
Rated horse-power of motors	125
Characteristic curves of motor	Fig. 5

Accelerating current per motor $\frac{125 \times 746}{89 \times 500} =$ 210 amperes.

Accelerating constant per motor $\frac{42.8}{4} \times 91.1 =$ 975.

For other methods of calculating speed-time curves, see C. O. Mailloux's paper read before the American Institute of Electrical Engineers, June 19, 1902, volume 19.

The schedule speed is obtained by dividing the distance covered in miles by the time of cycle plus stops in seconds, and multiplying by 3600. It is also customary to allow

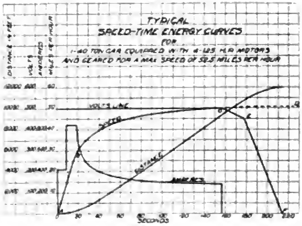


Fig. 6

about 10 per cent. leeway in the running time to allow for reductions in speed while rounding curves, and to enable the equipment to make up time in case of forced delays. If the lay-overs at the end of the line are long there is little need of allowing any leeway in the running time, as delays may be taken out of the lay-overs.

TYPICAL SPEED-TIME-ENERGY CURVE CALCULATIONS

1	2	3	4	5	6	7	8	9	10
From	Motor	Curves		(3)-(4)	$\frac{(5)}{975}$	$\frac{V_n - V_{n-1}}{(6)}$	$\Sigma(7)$	$\frac{V_n + V_{n-1}}{2} \times (7) \times 1.467$	
Speed V	Amperes Per Motor	Tract. Effort Per Motor	Train Friction Per Motor	Net Tract. Effort Per Motor	Accel. M.P. H.P.S.	Time in Seconds	Total Time From Start	Distance in Feet	Total Dist. From Start
1. 29.0	210	1650	130	1520	1.560	18.6	....	295	....
2. 30.0	185	1400	140	1260	1.290	.78	19.4	34	329
3. 35.0	123	800	160	640	.655	7.6	27.0	362	691
40.	98	540	180	360	.369	13.5	40.5	743	1434
45.0	81	385	205	180	.185	27.0	67.5	1685	3119
n-1 50.	70	290	235	55	.056	89.2	156.7	6200	9319
n. 52.5	65	250	250	0	....	....	....	....	....
Coasting From 50 M.P.H. to 45 M.P.H.									
45	....	....	235	-235	-.241	20.7	177.4	1440	10759
Braking 120 Pounds Per Ton Gross									
....	....	....	....	-1200	-1.23	36.6	214.0	1210	11969

For the figures enclosed in parentheses, substitute the constants from the corresponding columns.

(To be continued)

THREE-PHASE—SINGLE-PHASE TRANSFORMATION

By W. S. Moody

The fact that it is impossible to take single-phase power from a quarter-phase or three-phase system by means of static transformers, and distribute this power over the several phases, was well demonstrated long ago. The desirability of accomplishing this result is so great however, that many persons who should know better frequently forget and ask if it is not possible. The following note on the subject is given to show the impossibility of securing this result.

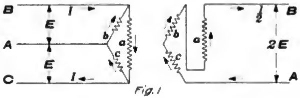


Fig. 1

The subject is perhaps most simply treated in Dr. Steinmetz's article, published in the Transactions of the American Institute of Electrical Engineers, for 1892. In this article Dr. Steinmetz shows that the difference between single-phase and polyphase systems is; that in the former the power delivered changes from maximum to zero and back to maximum every half cycle; whereas in the latter the rate of power delivered is constant. Therefore, any system, if it be capable of transforming from balanced polyphase current to single-phase current, must be capable of storing up energy during the interval of time when the power delivered to the single-phase side is less than the power received from the three-phase side.

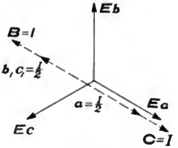


Fig. 2

The static transformer is evidently incapable of storing any energy, and therefore cannot possibly act as a means of transforming balanced three-phase current into single-phase current, or *vice versa*. To those who like to consider such problems in a mathematical way, the following demonstration, which was worked out by Mr. L. F. Blume at my request, will be interesting. In this he takes one of the suggestions sometimes offered for accomplishing the result; namely, the employment of three transformers, two connected in open delta and the third in reverse delta arrangement to the other two; and shows with diagrams that the whole combination is simply equivalent to a single transformer across one or two phases of the supply.

Fig. 1 shows a normal delta, and an open delta with the third phase reversed. Fig. 2 gives the voltages and current relation of the primary side, and Fig. 3 the same for the secondary side.

If E is the primary three-phase voltage, then, with a ratio of unity between coils, the voltage AB of the secondary will be 2E, as shown. Suppose a non-inductive receiving circuit takes a current x from the secondary; then, to balance the fluxes, the primary coils must each supply currents x in phase with the current in the respective secondary coils. Therefore, having only a single-phase current x in the secondary, the currents in the primary coils are equal in amount, and in the same direction as that in the secondary—except in the reversed coil, which merely turns the current vector through 180 degrees.

The current in main A will be the vector sum of the currents in coils b and c, or zero. In main B, the current will be the vector sum of the currents in coils b and a, or 2x; and similarly the current in the main C will also be 2x.

If I is the maximum effective current permissible in any primary main, then the value of x is $\frac{I}{2}$. Therefore the maximum effective secondary current is $\frac{I}{2}$, and the amount of power delivered to a non-inductive load is $2E \times \frac{I}{2}$, or EI.

Results just as good are obtained by simply using one single-phase transformer connected across two of the mains. In this case the maximum power delivered to a non-inductive load would be EI, the primary current being I in two of the legs, and zero in the third

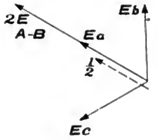


Fig. 3

leg. It is therefore seen that nothing is gained by the suggested method, while much is lost in simplicity and efficiency.

Other combinations have been investigated in the same manner, and in no case has it been possible to obtain a better result than that secured by using one transformer across two legs.

CELLULOSE ACETATE COVERED WIRE

By R. Fleming

Insulated copper wire is such a ruling factor in the design and manufacture of electrical apparatus, that any process which reduces either the cost of the insulated wire, or the amount required, is of great commercial importance.

Silk and cotton are about the only materials which have been used in the past for insulating purposes. The former is relatively expensive, while the latter, though cheap, occupies an unfortunately large proportion of the winding space, especially when the wire itself is small.

Various chemical solutions have been applied to wires in the attempt to secure a thin, though permanent insulation, which would be more economical to use than silk or cotton.

Cellulose acetate, enamel, collodion, casein, albumen, glue, rubber, silk solutions, etc., were tried with more or less favorable results, but for commercial purposes cellulose acetate and enamel have proven to be the substances best adapted to the insulation of copper wires.

The mechanical properties of the cellulose acetate film make it a desirable insulating medium for very fine wires. Its elasticity permits of considerable stretching of the wire before rupture takes place, thus insuring continuous insulation between wires on the finished coil. Its specific resistance is very high, so that the film, even though thin, provides ample insulation between turns and between the layers of superposed wire. The evenness of the coating, and the regularity with which the film can be applied to the wire, are important advantages; the finished wire is free from imperfections of coating, and presents an attractive appearance.

This insulation can be colored any desired shade to harmonize with the surroundings. In case of very fine wire, a bright green makes a satisfactory color, rendering it easy for the operators to see the wire, and to detect irregularity in the winding; but if these fine wires are colored a neutral tint, they are practically invisible, and winding them is a difficult operation.

The sizes of wire best suited to this process are from 0.003 in. in diameter, or even finer, to those as large as .005 in. For larger sizes, the enamel coatings are more suitable.

Fig. 1. Acetate Wire-Coating Machine in Operation

Cellulose acetate has been used for a number of years for the windings of meter armatures, where light weight is of great importance.

The following tabulation shows some of the more important comparisons of data:

.003 Diam. of Copper	Acetate	Single Silk	Single Cotton
Thickness of insulating film	.0005	.0009	.00175
Wire space factor	.442	.313	.167
Wt. per thousand feet (lbs.)	.033	.036	.049

With acetate coated wire the greatly improved space factor means, that for a given number of turns on a given form, the mean length of turn and total weight of wire is greatly reduced. This is shown in the following tabulation, which is drawn up on the basis of a perfect winding

Diameter of spool	1 in.
Length of spool	1 in.
Number of turns	100,000
Diameter of copper	.003 in.

Insulation of Conductor	Outside Diam of Coil (Inches)	Resistance (Ohms)	Wt. of Coil (Lbs.)	Price per pound to give same cost of coil
Acetate	4.20	71300	2.22	$7.50
Single silk	5.53	89500	3.04	5.50
Single cotton	9.50	144000	6.73	2.50

These coils are shown in Figure 3, which illustrates the great reduction in size made possible by the use of film-coated wire.

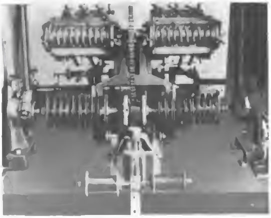


Fig. 2. Acetate Wire-Coating Machine

The great decrease in size shown in the above tabulation, would, in itself, be enough to warrant the use of acetate wire for many kinds of coils.

Another great advantage of acetate wire is that it is not affected by ordinary atmospheric conditions, whereas all fibrous materials absorb large quantities of moisture. Complete drying and impregnating processes are necessary for fibrous insulations, if long life is to be expected of them.

Manufacturers of telephones and other specialties, who use fine wires, will find film-coated wires of very great service in reducing the cost, and also the size, of their apparatus.

In the Lynn acetate wire-coating machines the solution automatically passes from the mixing reservoirs to the coating portion of

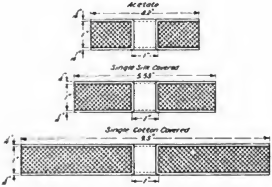


Fig. 3. Relative Sizes of Acetate Coated, Silk and Cotton Covered Coils of the Same Number of Turns

the apparatus. Here, by a system of transfer wheels, the solution is applied to the revolving coating roll, which, in turn, deposits it on the moving wire. The quantity of solution placed on the wire must be adjusted to a nicety; therefore mechanical scrapers are employed, which remove the excess and leave just the proper amount to be deposited on the wire.

After receiving its coating of solution, the wire passes through the oven at the rate of several hundred feet per minute. The volatile solvent is here driven off and the coating hardened, after which the process is repeated until numerous coatings have been applied. This method insures an even distribution of the film over the whole surface of the wire.

To keep the fine wire moving at such a high rate of speed, a very delicate adjustment of the moving parts is required, for the slightest unevenness of motion is sure to break the wire. This is prevented by friction drives and friction tension devices, which insure a perfectly uniform motion.

THE GENERAL ELECTRIC COMPANY'S PRINTING PRESS EQUIPMENT WITH PUSH BUTTON CONTROL

By F. E. Vickers

The application of the electric drive to large printing presses requires a nicety of control which is not often needed in other lines of work. In the case of a large sextuple press requiring a 50 h.p. motor to drive, with the heavy pressure of the plates against the blankets, the dragging of the ink rollers, and the stickiness of the ink, a very large starting torque is necessary to put the press in motion; once in motion, the torque required is greatly reduced. It is necessary that the press be started off very slowly to prevent breaking the sheet, should there be a little slack between the paper roll and the cylinders, and it is also necessary that a very slow and uniform speed be maintained for perhaps two or three minutes at a time for threading in the paper. After the paper has been threaded in, a uniform acceleration of the press is necessary up to its maximum speed, as any sudden change from one speed to another is almost certain to break the sheet, causing delays as well as waste of paper.

The modern method of push button control, with push button stations located on various parts of the press for the convenience of the pressman, requires absolute reliability on the part of the push button stations, as well as upon the controller itself. This problem of electric drive has been very satisfactorily solved by the General Electric Company in a number of press equipments furnished the San Francisco Chronicle. In addition to a CLB-50 h.p. compound-wound main drive motor, and a CQ-10 h.p. series-wound auxiliary motor, these equipments include a C-30 master controller, operated from the push button stations, and the well-known Type M control contactors.

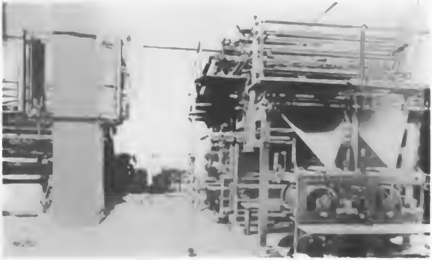


Fig. 1. Cylinder Press of the San Francisco Chronicle, General Electric Push Button Control

The sextuple Hoe presses of the San Francisco Chronicle are equipped with six or more push button stations, each push button station consisting of a "start" button for accelerating, a "slow" button for decelerating, a "stop" button for stopping the press quickly, and a "safe" and "run" switch for preventing the starting of the press when the "safe" button is in on any one of the push button stations. Also, when any "safe" button is in while the press is in operation, it is impossible to accelerate the press, but the deceleration or stoppage of the press in the regular way is not interfered with.

A solenoid-operated master controller, operated from the push button stations on the press, is mounted on a suitable switchboard panel with an ammeter, switches, etc., and this master controller operates Type M contactors, which are mounted in the motor pit, together with the motor resistances.

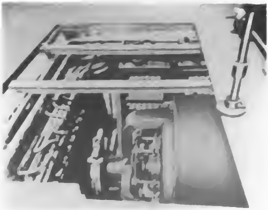


Fig. 2. Motor and Rheostats Located in Pit under Press

The main motor is geared direct to the main press shaft, and on this main press shaft is mounted a magnetic clutch, the loose portion of which is geared to the auxiliary motor, by which it is operated through a worm gear and intermediate spur gears. The auxiliary motor is series-wound, and the magnetic clutch is also in series with the auxiliary motor.

The master controller on the switchboard is so arranged that when the starting button is pressed in, and the controller is notched up to the first or second point, and the starting button then released, the controller will drop back to the off position. When notched up to the third point or beyond, it will remain stationary when the starting button is released. If the starting button be held in continuously, the controller will be slowly notched up until the motor attains its highest speed. The slowing-down button operates the controller in the same manner, but in the opposite direction, the controller slowly notching down as long as the slowing-down button is held in

The auxiliary motor is so connected on the first three controller points, that on the third point the auxiliary motor is in full operation. The main motor, being geared directly to the press, runs with the small motor, but without current. When the controller passes to the fourth notch the current is cut off from the auxiliary motor and clutch; the clutch opens and the auxiliary motor comes to rest. At the same time current is thrown on to the main motor, which then takes the load, and can be speeded up to any desired speed by notching up the controller.

A by-pass switch has been provided which permits the operation of the auxiliary motor and clutch during the upward or accelerating motion of the controller, but cuts them out of service on the return stroke of the controller, thus avoiding any danger of stripping the worm gear of the auxiliary.

On the controller panel a red signal lamp is provided, this lamp being lighted at all times when current is on either of the motors. The lamp circuit is opened when the controller is at the bottom of its stroke, and the pressmen can thus make sure at a glance that the power is off before entering dangerous places about the press.

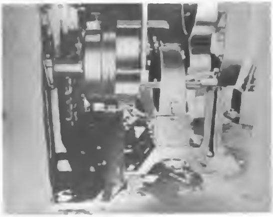


Fig. 3. Series Motor, Worm Gear and Magnetic Clutch

Where several presses in the same room are in operation at one time, it may be difficult for the pressmen to determine, from the sound of the controller, when the third point has been reached; this being the position of the controller for threading in the paper. Under these conditions, an arrangement can easily be provided to light a small signal lamp at each push button station on the press, to indicate when the controller is on the third notch, these lamps being operated through a switch which is closed only when the controller is on the third point.

The acceleration of the press is very uniform and smooth, and the breaking of the sheet has been reduced to a minimum. The auxiliary equipment is so speeded that when the pressmen wish to get a "turn-up" in order to put plates on the cylinders, they can do so by "jogging" the cylinders a half inch, or even less, with accuracy and ease. Moreover, the plate cylinders can be given a half turn, and stopped at any desired point with great accuracy, thus reducing delays in "spotting" to a minimum. The auxiliary motor gives a speed of about ten revolutions of the press cylinder per minute, which is a very satisfactory one for threading in the paper. A still slower speed can be obtained, if desired, by jogging the press along on the first and second notches of the controller.

Figure 1 shows the first press installed by the Chronicle since the great fire. A portion of the second press may also be seen in the photograph. Two controlling panels are shown mounted on a column at the left of the picture, and are so placed as to give a clearance of seven feet from the floor, in order that the floor might be left clear for the handling of paper. The column is of structural iron surrounded by brick work, and the panels are mounted on iron straps clamped around this brick work. Two push button stations are shown, one on either side of the folder of the press. The 50 h.p. main driving motor is in a pit, which is covered by the planks appearing just at the left of the press.

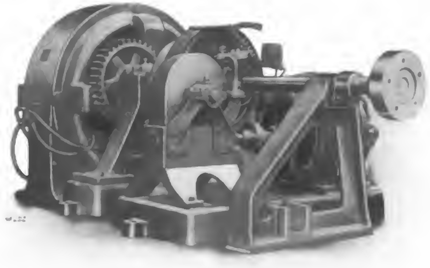


Fig. 4. Self-contained Set for Driving Cylinder Press. Push Button Control

Figure 2 shows the 50 h.p. motor, with contactors and rheostats, in the pit beside the press.

Figure 3 shows the auxiliary equipment, which is mounted on the shaft driven by the main motor, and gives a very good view of the magnetic clutch and its brush-holders, while the worm gear and a portion of the motor are also plainly visible. The gear which meshes with the motor pinion is just through the wall shown on the left of the picture.

Figure 5 shows a self-contained set for the San Francisco Examiner, consisting of a 60 h.p. main driving motor, and a 10 h.p. auxiliary motor, mounted on a common base. This differs from the Chronicle equipment in the assembly only. The entire set is mounted in a pit outside the frame of the press, and a section of this frame, included in the picture, shows the location of the apparatus with respect to the press, the coupling on the shaft being underneath the latter.

The controller has been very carefully developed, and it is thoroughly "fool-proof," so there is no possible way of causing any damage to the press or electrical equipment by pushing a wrong button. The entire outfit has proven very reliable and thoroughly satisfactory.

MILL TYPE ENCLOSED ARC LAMP FOR 220 TO 250 VOLTS D. C. CIRCUITS

By G. N. Chamberlin

Some of the most severe operating conditions met with in the field of arc lighting are found in the case of the nominal 220 volt power circuit as generally used in iron and steel mills. The varying potential of such circuits as have a large percentage of motor load, together with the high temperature, extreme vibration, and the presence of large quantities of fine metallic dust, makes it necessary that a lamp be designed specially to meet these requirements.

This new lamp, as shown in the accompanying illustrations, is of the well-known two-rod type. The lamp top is the General Electric standard casting, with large porcelain insulator suspension, such as is used for high potential series circuits. This top is equipped with large two-screw cast binding posts, each insulated with porcelain bushing, thus avoiding any possibility of grounds or short circuits from collection of metallic dust. Within the lamp casing similar precautions are also taken against grounds by the use of large lava and porcelain bushings.

The windings are of the bare wire edgewise-wound type, insulated with non-combustible material. The series lifting magnet being of copper wire, and series resistance of German silver. There being no inflammable material, the destruction temperature is the melting point of the German silver wire. This is a very important consideration in the adoption of a lamp for 220 volt circuit, as with 3.0 amperes current, there are 660 watts

Fig. 1. Mill Type Enclosed Arc Lamp

energy to be dissipated; and with maximum current possible (short circuited arc) there are about 1800 watts energy to be dissipated. For 235 volt and 250 volt circuits the wattage is correspondingly higher.

That portion of the heat which radiates from the arc is separated as far as possible from the heat of the lamp windings which are attached to the lamp cover. An air space between the gas cap and the lamp base frame, together with the open air space between the globe ring and casing, quite effectually keep the heat of the arc away from the lamp mechanism.

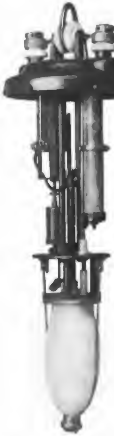


Fig. 2. Mill Type Enclosed Lamp, Casing Removed

The dashpot is the 1 in. standard graphite plunger type, equipped with a phosphor-bronze cap to exclude all dirt and dust. The placing of dashpot below and directly in line with the operating magnet, allows of large clearance between shell and plunger. This arrangement assures close current regulation, aside from being the coolest place within the lamp mechanism.

There is but one wire or lead used in the lamp, this being the German silver, glass bead insulated flexible cable connecting the magnet to the movable upper carbon holder.

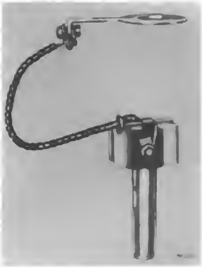


Fig. 3. Upper Carbon Holder, Cable and Terminal

Fig. 3 shows the method of attaching the cable, both to the magnet winding and the upper carbon holder. The terminals, attached without solder, and the special supports which avoid sharp bending of the cable, together with the material used, assure permanent connections.

The main body of the casing is black oxidized solid copper 7 in. in diameter. The lower portion, for supporting the globe ring, is 5 in. in diameter; thus furnishing an open space between the two for ventilation of the mechanism chamber. The increased draft, together with the large radiating surface of the 7 in. copper casing, facilitates the dissipating of a large amount of heat.

While such abnormal tests of lamps are not recommended, and at best do the lamp no good, it may be interesting to note that lamps have been connected to a 250 volt circuit with carbons short circuited for three days, 12 hours per day, and then operated normally for several weeks. Aside from a discoloration of the casing and internal parts, the lamps were in no way damaged.

While nearly all enclosed arc lamps have, in past years, been equipped with switches, it is a recognized fact that only a small percentage of these switches are ever used. Many of the larger arc lamp users are now specifying that their lamps be furnished without switches. The lamp top without switch is shown in Fig. 2, and is recommended, though the lamp can be furnished with a switch if required.

The enclosing globe support is the same, with the exception of length, as that used on standard series alternating GE lamps. It consists of a phosphor-bronze bail and phosphor-bronze spring at the bottom of the globe. The spring allows of sufficient compression to admit of the use of globes furnished commercially, and its position at the lower extremity of globes assures its remaining at a safe temperature.

Outer globe, Cat. No. 26393, globe ring Cat. No. 3568, enclosing globe No. 46, and carbons 12 in. x ½ in. upper, 4½ in. x ½ in. lower are used, these being the types used on any closed base type enclosing globe, D. C. Multiple lamps of GE standard type. Any standard combination of globes, shades, reflectors or diffusers are applicable.

A NEW SWITCH INDICATOR

By B. F. Corey

The General Electric Company has just completed the development of a new switch indicator for use in connection with automatic railway signals. This indicator, known as Type SI-104, is of a novel design which is the outcome of suggestions of well-known signal engineers who have had wide experience in the operation and maintenance of this class of apparatus. The front view of this indicator is shown in Fig. 1.

Fig. 1. Switch Indicator, Type SI-104

Fig. 2. Switch Indicator with Back Open Showing Mechanism

For those not familiar with this class of apparatus, it may be stated that a switch indicator is a device placed along the side of the track close to a switch, to indicate to the train crew the presence of a train in the vicinity of the switch. In case the track is clear, the operating coil of the indicator is energized, and the miniature semaphore is held in "clear" position, indicating that the switch may safely be opened. Provision must be made to open the signal circuit when the switch is thrown so as to give protection to the train which is using the switch. Such indicators are used in large numbers by railroads equipped with automatic signals.

Fig. 2 shows a back view of the SI-104 indicator, with the door open. Fig. 3 is a diagram of the internal connections. The advantages of this indicator are as follows:

With the indicator "clear," a resistance equal to double that of the operating coils is connected in series with them, thus reducing the current consumption to one-third. With the indicator at "danger," this resistance is cut out by a "back contact" carried by the armature, as shown in Figs. 2 and 3. The operating torque of the indicator is strong, and its release, effected by gravity, is positive.

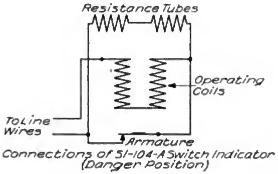


Fig. 3. Diagram of Connections

The case of this indicator is made absolutely weatherproof by means of a gasket of elastic felt surrounding the door opening. This elastic felt has proved to be far more satisfactory than the tubular rubber gaskets used by other manufacturers, as rubber deteriorates rapidly, causing a leaky joint, and is frequently torn when opening the case, due to its sticking to the cover. The case projects well over all operating parts, affording the greatest possible protection when it is necessary to open the door in stormy weather. The connecting wire enters the bottom of the case through an insect barrier of elastic felt, similar to that used for the gaskets around the doors; while the dial is so designed that it is impossible for spiders or other insects to gain access to the blade.

The terminals are mounted on moulded insulation similar in composition to that used in General Electric signal relays. The magnets are wound with enameled waterproof magnet wire. The resistance tubes are of substantial construction.

The armature and shaft bearings are cylindrical, the journal being made of hard-drawn german silver. Provision is made inside the case for the attachment of a two-way General Electric Lightning arrester, which is furnished when required.

The indicators are manufactured with four different resistances, as follows:

Resistance of Operating Coils	Total Resistance
250 ohms.	750 ohms.
500 "	1500 "
750 "	2250 "
1000 "	3000 "

QUESTIONS

(This section is open to inquiries upon engineering subjects. The questions will be submitted to the respective departments and such as are of general interest will be answered in this column, while those of less importance will be answered by letter.)

Q. Will two 150 kw. transformers of given voltage, frequency and temperature characteristics connected in open delta on three-phase system, give 300 kw. output in three-phase current with the same temperature rise as three 100 kw. transformers of the same characteristics connected in closed delta on three-phase system? If not, what will be the difference in output at normal temperature rise?

A. Let us carry the assumption a trifle further and assume that the secondary voltage is 1000. Then, when three 100 kw. transformers are connected in closed delta, the current in each transformer is 100 amperes. The current in the line is $100 \times \sqrt{3}$, or 173 amperes Under these conditions the transformers will give normal temperature rise.

Assuming that two 150 kw. transformers are connected in open delta, the line current is, of course, the same as the above, or 173 amperes. Normal current of the transformers is but 150 amperes, and each transformer is therefore overloaded the difference between 173 and 150 amperes, which amounts to 15 per cent. The proper load for normal heating on each of the 150 kw. transformers, when connected in open delta, would be 150 kw., minus 15 per cent. or approximately 130 kw.

NOTES

EMERGENCY SHIPMENT FOR THE GREAT NORTHERN RAILWAY LINE

On Friday night, November 8th, Elevator C, one of several owned by the Great Northern Railway at Superior, Wisconsin, was destroyed by fire. On Saturday morning, when it became possible to approach the ruins, it was found that the power house which supplied electric power for these elevators had been totally destroyed, although Elevators S and X were undamaged. Owing to the near closing of navigation on the Great Lakes it was of extreme importance to the owners to get these elevators into service at the earliest possible moment.

Arrangements were made with the Great Northern Power Company of Duluth, and the Superior Water & Light Company, to furnish about 600 kw. in 60 cycle, 2300 volt current. The induction motors in the elevators were 400 volt three-phase machines, and it was therefore necessary to obtain suitable transformers for reducing the voltage. In the emergency, the Railway Company shipped to Superior the transformers which were in use in St. Paul on the transmission line between the Railway Company's Jackson Street power house and Dale Street repair shops. These were received at the Elevators by special car on Sunday morning.

Meanwhile, Mr. R. A. Swain, representative of the Power and Mining Department of the General Electric Company at Duluth, had been appealed to by the railway officials to get some transformers to replace those taken from St. Paul, in order that the Dale Street shops might not be shut down any longer than necessary.

On Saturday evening Mr. Swain telephoned the Assistant Manager of the Chicago Office of the General Electric Co., at his residence, and explained the situation; and he in turn telephoned the Sales Manager of the Transformer Department, Schenectady, who, before noon on Sunday replied that the transformers could be shipped, and that a special express car had been secured. Mr. Swain was then advised and took the matter up with the railway officials at Superior, and these in turn were obliged to telephone to St. Paul for the necessary authority. Upon receiving word that this was secured, the Assistant Manager at Chicago again got into communication with Schenectady, at about three o'clock in the afternoon, and ordered shipment. In order to load the transformers it was necessary to secure a gang of men and a train operator. These, however, were obtained, and Sunday night the special express car containing the transformers was attached to the Lake Shore passenger train No. 37, and reached St. Paul at 8 a.m. Wednesday morning, November 13th. The following day the Dale Street shops were in operation at the usual starting time.

This illustrates what can be accomplished in a real emergency, when those to whom appeal is made rise to the occasion, and the customer's interests are made paramount to personal comfort and convenience.

The Public Service Commission of the State of New York, 2nd District, have expressed their approbation of General Electric Portable Instruments, Type P-3, by placing an initial order for four voltmeters and eight wattmeters. Additional orders will undoubtedly follow as the commission extends the scope of their tests. These instruments will be used by the Inspector of the Commission as working standards to check the standards of the central station, and also in the testing of integrating wattmeters. The order was given the General Electric Company solely on the basis of merit.

* * *

Since the above item was written, an order has been received from the Commission for ten additional instruments and one potentiometer outfit.

* * *

The following letter from Mr. Boisen, of the Board of Public Works, Holland, Mich., describes a novel use made of General Electric flatiron heating units:

"We had to renew a crank pin on the high pressure side of a 500 h.p. cross-compound engine. The new pin was made 6 in. in diameter, $\frac{1}{64}$ in. taper, to be shrunk in a disk 43 in. outside diameter, 5 in. thick. To do this we had to expand the disk by heating. The engineer wanted to use blow torches below, and pieces of iron brought to a white heat in a blacksmith forge, which would burn the paint and make an all-around dirty job. Having some General Electric 6 lb. flatirons on hand, I thought it would be an easier and cleaner job to heat the disk with the heating units from the flatirons. I therefore placed a row of heating units in the 6 in. hole in the disk, and an iron core 3¼ in. in diameter in the middle to hold the heating unit in place. The current was then turned on for four hours, after which the disk was sufficiently hot. The heating units were at about white heat all the time, and during the last hour I expected to see them melt any instant; in fact, two of them did melt on one side. The brass tubing melted, but still there was no short circuit. The heating units were afterwards replaced in the flatirons, and put out in service. I have kept track of them ever since, and they have not given any trouble after three months use, one of them being in a laundry, and used forty hours a week."

* * *

SUPPLY PARTS—LYNN WORKS

The advantage of a decentralized system in a large business has been clearly shown by the reorganization of the Supply Parts business.

In 1906, 4,000,000 supply parts were shipped representing in value 6 per cent. of the entire output of the Lynn plant. This year the business has actually doubled, but notwithstanding this phenomenal increase in business, shipments are made more promptly than ever.

Six months ago the department was reorganized to the present system, where each manufacturing department carries stock, and fills its supply parts requisitions, as well as those calling for completed apparatus.

Approximately 30 per cent. of the orders are shipped the day they are received, and at least 90 per cent. of them are filled within one week's time from that date. It is anticipated that the careful study of the situation now being given the subject will still further increase this percentage.

* * *

A large single order of direct current motors and controlling equipment has recently been closed by the New York Office of the General Electric Co.

The apparatus will be installed in the Hudson Companies' Church Street terminal building.

The motors, which aggregate 635½ h.p. are, with one exception, of Type CLB; they will be used to operate ventilating fans, an air compressor and various pumps.

All of the motors had to conform to very rigid specifications, inasmuch as no part of the machine should show a temperature rise by thermometer of more than 47° C. when operating under maximum rated output at maximum speed.

Another important feature of this order is the fact that all the controlling apparatus for these motors, both automatic and non-automatic, will be of the General Electric type, instead of that named in the specifications; for the customer, after a thorough examination of General Electric controlling apparatus, decided in its favor.

The automatic controlling apparatus consists of a compound speed regulator, and automatic starting and stopping device, in connection with pressure regulator and relay, while the non-automatic controlling devices will be the standard General Electric Co. R. F. O. and S. F. O. hand-operated rheostats

PATENTS

The following Patents were issued to the General Electric Company during the months of October and November

867,415	Oct. 1,	F. W. Richey	Rail Bond
867,416	"	"	Electrical Conductor
867,456	"	W. S. Weedon	Electrode for Arc Lamps and Method of Making the Same
867,475	"	E. R. Carichoff	Motor Starting Rheostat
867,476	"	"	System of Control
867,481	"	F. P. Cox	Prepayment Meter
867,482	"	A. S. Cubitt	Locking Machanism for Controller Handles
867,486	"	S. T. Dodd	Electric Locomotive
867,496	"	H. Geisenhoner	Fuse
867,509	"	E. Johnson	Electric Switch
867,519	"	J. T. Marshall	Electric Furnace
867,533	"	H. N. Ransom	Air Brake System
867,543	"	F. H. Weston	Filling for Thermal Cut-outs
867,547	"	W. C. Yates	Starting Device for Alternating Current Motors
867,561	"	Davis & Haskins	Measuring Instrument
868,171	Oct. 15,	F. Eichberg	Control of Alternating Current Motors
868,190	"	C. D. Knight	Dynamo-Electric Machine
868,362	"	E. D. Priest	Motor-Driven Pump
868,379	"	E. Weintraub	System of Electrical Distribution
868,380	"	"	System of Electrical Distribution
868,381	"	H. E. White	Motor Control System
868,419	"	W. L. R. Emmet	Turbine Bucket
868,464	"	A. S. Mann	Control System
868,481	"	H. N. Ransom	Air Brake System
868,569	"	O. Junggren	Elastic Fluid Turbine
868,592	"	C. E. Barry	Air Brake System
868,723	Oct. 22,	D. W. Taylor	Control of Motor-Operated Doors
868,752	"	R. E. Barker	Variable Reactive Coil
868,787	"	O. Junggren	Elastic Fluid Turbine
868,889	"	R. H. Rogers	Trolley Operating Valve
869,058	"	J. G. Callan	Speed-Changing Device
869,138	"	W. L. R. Emmet	System of Lubrication for Elastic Fluid Turbine
869,185	"	M. Latour	Self-Exciting Alternating Current Dynamo
869,186	"	"	Shunt-Wound Self-Excited Alternator
869,187	"	"	Compounded Self-Excited Alternator
869,300	Oct. 29,	R. Fleming	Arc Lamp Electrode
869,301	"	"	" " "
869,314	"	C. Macmillan	Resistance Unit
869,352	"	M. W. Day	Motor Control System
869,356	"	W. Fiedler	Motor Controller
869,359	"	M. Fuss	Relay for Circuit Breakers
869,364	"	L. A. Hawkins	Air Brake System
869,365	"	"	Block Signal System
869,413	"	W. S. Bralley	Frequency Changer
869,442	"	W. D. Litchfield	Apparatus for Measuring Speed of Rotation
869,444	"	G. Macloskie	Air Brake System
869,459	"	W. B. Potter	Electric Railway System
869,464	"	G. E. Stevens	Electric Heater
869,465	"	S. B. Stewart	Third Rail Contact Shoe
871,097	Nov. 12,	M. H. Branin	Sealing-in Machine
871,160	19,	"	Stem-Making Machine
871,171	"	O. O. Kruh	Vapor-Rectifier System

TWO DOLLARS A YEAR TWENTY CENTS A COPY

GENERAL ELECTRIC REVIEW

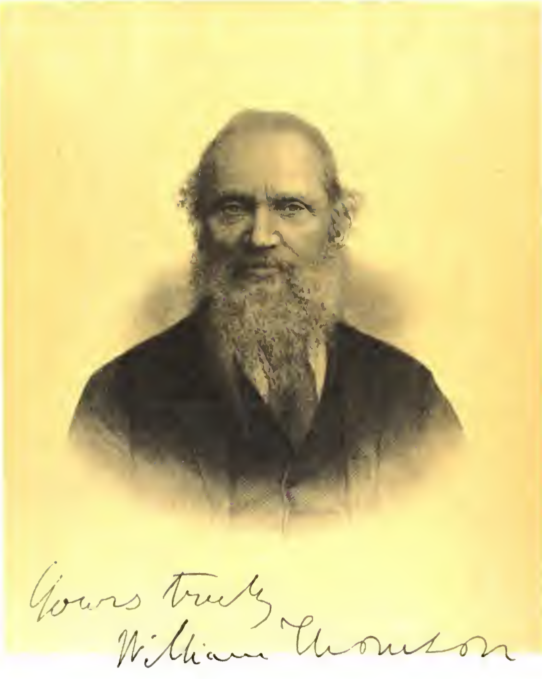
VOL. X, No. 3
PUBLISHED MONTHLY BY
GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU
SCHENECTADY, NEW YORK
FEBRUARY, 1908

Electrical Illumination of Niagara Falls
Concentrated Aurora

GENERAL ELECTRIC REVIEW

VOL. X, No. 3 | Copyright, 1908 by General Electric Company | FEBRUARY, 1908

CONTENTS


Yours truly
William Thomson

Vol. X, No. 3 SCHENECTADY February, 1908

GENERAL ELECTRIC REVIEW

LORD KELVIN

Lord Kelvin (William Thomson) one of the greatest scientific men of the 19th century died at Glasgow, Scotland, on December 16th, 1907, at the age of eighty-three years. Like so many of Great Britain's most brilliant men, he was by birth an Irishman, and was born in Belfast on June 25th, 1824.

When William Thomson was only eight years old, his father, Dr. James Thomson, was made Mathematical Professor at Glasgow University, and the education of young Thomson was carried on in the College of Glasgow, where he won many prizes, including the University prize for an essay on the "Figure of the Earth," written when only fourteen years old. At sixteen years of age he entered St. Peter's College, Cambridge, England, but did not take his degree until 1845, when he was twenty-one years old. He was then placed Second Wrangler and also won the coveted distinction of Smith's Prizeman, which is generally considered a more noteworthy achievement. Thomson was by no means a bookworm only, but devoted himself to athletics, especially to rowing, winning the Colquhoun Sculls and rowing in his college boat when it was second on the river. He was also President of the Cambridge Musical Society.

Soon after taking his degree, he was made a Fellow of his college, and at the age of twenty-two became Professor of Natural Philosophy in the University of Glasgow, which post he occupied for the unprecedented period of fifty-three years.

Lord Kelvin was married in 1852 to Miss Margaret Crum, who died in 1870; in 1874 he was again married to Miss Frances Anna, Lady Kelvin, by whom he is survived.

Lord Kelvin's genius was not confined to any one branch of engineering or science, and it can be truly stated that he combined in himself three different kinds of intellectual attainment, any one of which would stamp him as remarkable. He was not only a great mathematician and wonderful scientific discoverer, but also had the extremely rare faculty of applying fundamental scientific principles and recondite speculations to practical inventions; in addition, he was an acute business man. Endowed with such parts, it is not wonderful that he illuminated everything he touched, or that he enriched the human race with commercial inventions of the most epoch-making character.

Professor Thomson was knighted in 1866 by the Lord Lieutenant of Ireland for his services in connection with the laying of the first two trans-Atlantic cables completed in that year. Not only did he investigate the question of the retardation of telegraphic signals in submarine cables, enabling him to design them in the most scientific manner, but he was also the first to devise a sufficiently sensitive instrument, the mirror galvanometer, for receiving the signals. In this instrument, the operator must continuously observe a spot of light and automatic records were not possible. Nine years later Sir

William Thomson improved on his former instrument and gave the Syphon Recorder to the world, which is now practically universally used with all long distance cables. He is also responsible for many other inventions in connection with submarine cables, and he vastly improved deep sea sounding devices. In fact, he was deeply interested in all questions of navigation, partly, no doubt, owing to his being a keen yachtsman. The most fruitful result of his inventive ability in this direction was perhaps his improvement of the Nautical Compass, first patented in 1876, which was brought about by a request to write an article on this subject for *Good Words*. The type of compass which he then invented is now used almost exclusively in all parts of the world.

J. R. Lovejoy E. M. Hewlett E. A. Carolan
John McGhie T. C. Martin W. B. Potter Lord Brassey J. P. Ord

C. P. Steinmetz E. W. Rice, Jr. Gen. Eugene Griffin S. Dana Green
A. L. Rohrer G. E. Emmons Elihu Thomson Lady Kelvin Lord Kelvin Spencer Trask Alanson Trask Geo. Foster Peabody

From photograph taken at Schenectady Works of the General Electric Company, upon the occasion of Lord Kelvin's visit, September 24, 1897.

Sir William Thomson has also made many valuable inventions in reference to electrical instruments, amongst which the following may be mentioned: the quadrant electrometer, electric balances, and electrostatic voltmeters, as well as numerous types of ammeters, voltmeters and wattmeters.

Lord Kelvin was made chairman of the Board of Experts convened to study the first Niagara Falls water power scheme, and he visited the plant of the Niagara Power Company in 1897. He was elevated to the peerage in 1892, taking his title of Lord Kelvin from the name of a small stream which flows into the Clyde near Glasgow. In 1896 he completed the jubilee of his Glasgow Professorship and received a wonderful tribute of admiration and affection from the whole of the scientific world.

His work in connection with an absolute thermometric scale of temperature, and the relations existing between heat and mechanical power were of fundamental importance; and his researches into the nature of the atom, the age, constitution, etc., of the earth and tidal phenomena, by which he was led to construct a harmonic analyzer and tide-predicting machine of the highest utility, well illustrate his extraordinary versatility. With all his great attainments, he possessed a simple, loyal and generous nature, never governed by jealousy or envy; but perhaps his most wonderful attribute was his extreme modesty.

The honors both English and foreign showered on Lord Kelvin are legion. In 1893 he was elected an honorary member of the American Institute of Electrical Engineers. He was four times President of the Royal Society of London and at the time of his death was President of the English Institute of Electrical Engineers for the third time. Great Britain has now bestowed her last and crowning honor upon Lord Kelvin; he rests at the feet of Newton and next to Charles Darwin and John Herschel in Westminster Abbey.

A GAS-ELECTRIC CAR FOR RAILWAY SERVICE

By John R. Hewett

The accompanying text and illustrations will describe a gas-electric car which has been designed by the General Electric Company to meet railway service conditions.

The car is of the combination type, and comprises one ordinary passenger compartment, a smoking room, a baggage room, an engine room, a toilet and an observation compartment. The car is single ended, having the controlling apparatus situated in the engine room. The principal dimensions are as follows:

Length over all 50 ft.

Length of engine room 9 ft., 6 in.

Length of baggage room 5 ft., 8 in.

Length of smoker 7 ft., 11 in.

Length of passenger compartment 18 ft., 6 in.

Width over all 8 ft., 8 in.

Height over all 12 ft., 10 ½ in.

Seating capacity 44.

Total weight of the car and trucks fully equipped, 31 tons.

This car was designed throughout with special reference to the service required, the main object in view being to secure a maximum carrying capacity with a minimum weight; and at the same time to have a car of great strength. The shape of the ends is parabolic, in order to reduce the air resistance to a minimum when travelling at high speed. The general shape of the car will be seen by reference to the illustration. The roof and sides are made of T irons bent to the required shape and braced diagonally. The exterior of the car is of steel plate, while the interior is finished with selected Mexican mahogany. No wood is used in the engine compartment. The floors of the passenger and baggage compartments consist of two layers of wood with paper between, armored on the under side with steel plates. The roof, which is fireproof, is of a plain oval shape; the monitor construction was not employed as it would have needlessly added to the weight. Special attention has been paid to ventilation; twelve ventilators of the globe suction pattern are furnished in the roof. The under framing is of a very rigid construction; the center sills consist of six-inch I beams, and the outside sills are six-inch channels. These are braced diagonally to lend greater rigidity.

The gasolene engine is direct coupled to a 90 kw. direct current generator, which furnishes current at a variable potential. This current is fed to the motor through the medium of the control system; by which the voltage of the generator may be governed according to the requirements. The two motors are of the GE-72-A Type, each rated at 60 h.p.

The engine was designed and built by the General Electric Company with special reference to the requirements peculiar to gasolene electric cars. Very special attention has been paid to the simplification of the engine; and the number of parts and weight have been reduced to a minimum.

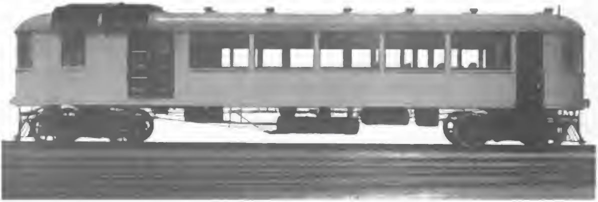


Fig. 1. Gas-Electric Car

When running at 550 r.p.m. the engine develops 100 h.p., and has a greater capacity at increased speeds. There are eight cylinders each of which is 8 in. in diameter and has a stroke of 7 in. The cylinders are placed at 90 degrees to one another, or at an angle of 45 degrees with the vertical. Each cylinder is composed of one piece, being a casting of very soft fine grain cast iron. Each casting is self-contained and

The seats are handsomely upholstered in green leather. The interior is lighted with individual lamps, there being one light for each seat, in addition to those in the vestibule, toilet, and engine rooms; while a head light is also provided. The steps are arranged in such a manner that the bottom one folds up automatically as the vestibule door is closed.

The car body was built by the Wason Manufacturing Co., Springfield, Mass., in accordance with the designs of the General Electric Company.

includes the water jacket; it is worthy of note that special attention was paid to provide a cooling surface around the valves to eliminate any excessive temperature at the valve seats. There is one admission and one exhaust valve for each cylinder, which are arranged in such a manner as to permit the inspection of both valves by the removal of two nuts. The pistons are of the trunk type; they are made of cast iron and are rendered gas-tight in the cylinders by the provision of three split piston rings. The connecting rods, which are made of chrome nickel steel, are connected to the trunk piston by means of a hollow pin shrunk into the body of the connecting rod. The crank shaft is made in one forging of 40 carbon steel; it is a four-throw crank having an angle of 180 degrees. All of the crank pins lie in the same plane; the two center pins occupying the same angular position; while the two outside crank pins are set at 180 degrees to the center crank pins. This arrangement of cranks with cylinders set at 90 degrees to one another, gives a very satisfactory system for balancing purposes. Two connecting rods are coupled to each crank pin.

Each cylinder is fastened to the engine base by means of six bolts. The engine base proper is made of one casting of Parsons manganese bronze, the form of which is clearly shown in the illustration. The crank casing, which is made oil-tight, is of aluminum.

All of the valves, both admission and exhaust, are actuated by one cam shaft, which is driven from the main engine shaft by two gear wheels with the customary two to one reduction. This cam shaft is entirely enclosed in a circular tunnel which runs the entire length of the engine base; the tunnel is formed in the main casting. The fact that the valve rods are operated from this one shaft, has greatly simplified the design of the engine.

There are two carburetors, of the float-feed type. The ignition system is of the high tension type; a separate coil is provided for each cylinder. These coils are energized by means of a small accumulator. The sparking at the correct instant in each cylinder is effected by means of a roller commutator.

Considerable difficulty has heretofore been experienced in starting gasolene engines of this size, but in the present instance a special breech block mechanism has been provided which fires a charge of black powder into one of the cylinders, and this has proved a most effectual way of overcoming these difficulties. This piece of mechanism is illustrated by Fig. 2.

The cooling system for the cylinders operates on a thermo-siphon principle. The radiator, which is situated on the roof of the

Fig. 2. Breech Block Mechanism for Starting Engine

car, is divided into four separate nests of radiating tubes, these, being of the spiral-finn pattern, give a maximum cooling area per unit length.

The total cooling surface amounts to approximately 1300 square feet. Each pair of engine cylinders is connected to one nest of tubes and the four nests are in turn connected by means of three copper pipes. The water jackets are connected to the radiator by means of pipes running vertically from the engine; these pipes pass through the roof and the circuit is completed by means of other pipes leading from the radiator to the engine cylinder jackets. This system forms the most simple cooling arrangement possible, as it entirely eliminates the necessity of using pumps or cooling fans, and it has the further advantage of being easily drained and of being filled from the side of the car.

It is of interest to follow the course taken by the gasolene from the storage tank to the carburetor. The gasolene is stored beneath the car, in a large steel tank having a capacity of 90 gallons and is raised to a small auxiliary tank in the cab by means of a diaphragm pump. The gasolene is filtered in transit from the tank to the pump. This auxiliary tank is provided with a float to register the height of the gasolene, and a glass tube somewhat similiar to a sight feed lubricator is provided, so that the operator can see if the diaphragm pump is working. The gasolene is fed by gravity to the carburetors.

The oiling system has been very carefully designed. Forced lubrication is used, and for this purpose there is a nest of pumps operated from the main shaft. One pump is provided for each of the main bearings, and another oils the cams and cam mechanisms, the duty of this latter pump being to keep the cam shaft tunnel filled with oil; the oil on leaving the tunnel flows over the reduction gears and thence to the crank chamber. All of the oil used for lubricating purposes similarly flows to the crank chamber, whence it can be drained. The big ends of the connecting rods are lubricated by scoops which dip into the oil in the bottom of the crank chamber, the oil being forced

Fig. 3. GE-8-100/125-550 Gasolene Motor

to the crank pin as the crank shaft revolves.

The generator is a General Electric 90 kw., 8-pole separately-excited unit, which has been specially designed with a view to procuring the lightest possible machine for the necessary output and at the same time keeping the temperature rise to within a reasonable figure. It is provided with commutating poles, which, in conjunction with the potential type of control, gives a great flexibility of current output.

The advantage of this arrangement will be readily appreciated when it is pointed out that at starting, the field excitation is weak, and that large currents are required to give the necessary starting torque. The normal pressure when running at 550 r.p.m. is 250 volts, at which time the current amounts to 360 amperes; but at starting, a current of 800 amperes can be secured at a corresponding decrease in voltage. It would be impossible to commutate so large a current in a machine with so large a kw. capacity per lb. without the use of commutating poles.

The total weight of the generator including exciter is only 2740 lb., while a standard machine of this output weighs 8800 lb. As is only natural, in a machine where the weight has been so materially reduced, the temperature rise is higher and the efficiency lower than in standard apparatus of the same output. The higher temperatures are fully provided for by the type of insulation employed; there is no paper or muslin used anywhere in the machine. The armature coils are insulated with mica, the interpolated pole coils with asbestos, and the field coils are wound with enamelled wire. The armature leads to the commutator are riveted as well as soldered, although the precaution

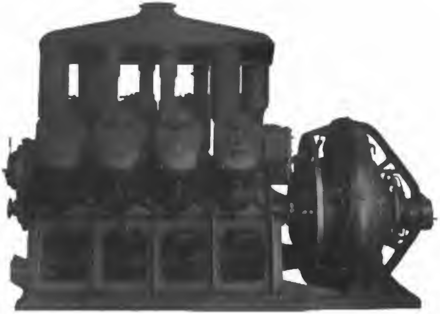


Fig. 4. GE-8-100/125-550 Gasolene Motor

has been taken to use pure tin for soldering, which has a melting point of over 200 degrees Centigrade. Air ducts of ample dimensions are provided to insure a large volume of air being circulated through the core. The efficiency is 88 per cent., being only about 3 per cent. lower than a standard machine having a temperature rise of 35 degrees Centigrade.

The exciter is a 3 kw. 70 volt, shunt-wound machine with its armature mounted directly on the armature shaft of the main generator and its field yoke supported by the bearing brackets, enabling it to fit under the back ends of the generator armature windings. The illustration of the engine, generator and exciter assembled shows far better than a written description the neatness and compactness of this generating set.

The speed of the motors is governed by a potential control, the generator being separately excited and the terminal voltage of the motors being varied by means of a rheostat in series with the exciting circuit. The simplest explanation of the controlling system is arrived at by considering the circuits separately. The armature circuit of the main generator comprises the armature, fuse, two contactors in series, reverser, and the two motors. The motors are connected in series or in parallel, according to the position of the controller handle, and they are grounded to the truck framework, while the solenoid coils for operating the contactors are energized by a storage battery floating across the field circuit. The reverser is operated as usual by a separate reverser handle on the controller.

The current from the exciter passes around the field of the main generator and through the rheostat; the function of the controller is to cut in and out this rheostat as occasion demands.

A storage battery which floats on the exciter circuit is used for supplying the lighting circuits, and its charging and discharging is controlled by means of a reverse current relay which permits of the lights being supplied directly from the exciting circuit or from the storage battery according to the voltage of the exciter circuit. A Tirrill regulator is employed for regulating the voltage on the lighting circuit. This arrangement enables the car lights to be used when the engine is at rest.

The master controller which has some unique features is of Type C-44, and gives seven steps with the two motors connected in series, and eight steps with the two motors connected in parallel. It is provided with four handles, three of which are mounted one above the other on concentric shafts. The function of the top handle is to advance and retard the ignition of the engine; the second controls the throttle of the engine; while the third handle controls the generator field resistances and the contactors, which establish the circuit for the motors, besides transposing the motor connections from series to parallel. The fourth handle operates the reversing switch and controls the direction of rotation of the motors.

The car is heated by passing part of the exhaust gases through pipes suitably located in the car body.

The car is provided with a straight air brake equipment, and the air is supplied by means of a compressor which is direct connected to the engine. The working pressure is 60 lbs. per sq. inch, and this is kept constant in the storage tank by a mechanical governor. Hand brakes are also provided.

The trucks were constructed by the American Locomotive Co. They are of the swing bolster type, and have wheels 36 in. in diameter. One motor is mounted on each truck. The journals are of the MCB standard pattern.

The interior of these cars can be designed to suit any requirements or service. Cars of this type are available for use as private cars, with sleeping and dining accommodation, as inspection cars, wrecking cars, and baggage cars, etc., etc.

ELECTRO-METALLURGY OF IRON AND STEEL

Part I

By Samuel A. Tucker
Adjunct Professor of Electro-Chemistry, Columbia University

Although a comparatively new industry, the processes for the production of iron and steel with the electric furnace have been so much perfected that it seems certain to find extended application in metallurgy. The investigation, which was made by the Canadian Government in 1904, of the processes in operation in Europe, has unquestionably done much to give a better understanding of the subject and to point out in which direction a process can best be applied from a commercial standpoint.

The methods which have so far been successful are those which effect the reduction of the ore, or produce steel, by means of heat generated electrically; and although an expensive source of heat, the fact of its application being within, and the ease of control, make it highly efficient.

The findings of the Canadian Commission have pointed to the fact that it is only profitable to smelt iron ores electrically when peculiar conditions exist. These conditions call for cheap power and localities where fuel is dear, or where the nature of the ore is such that it cannot be smelted by the ordinary blast furnace operations. But for the refining of steel in operations like the crucible process for the production of high grade steels, the electric methods can without doubt be applied to advantage.

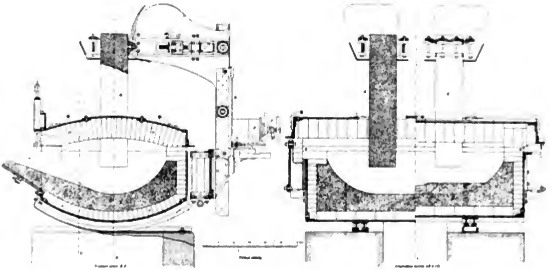


Fig. 1. Heroult Steel Furnace

How much further electricity will prove useful in metallurgical operations is difficult to say, but it must be remembered that the industry is a new one, and it seems only reasonable to suppose that as time goes on, with extended trials in actual practice, we shall have a greater application of electric methods. In some of the processes so far devised both smelting and refining may be conducted in the same apparatus; in others the intention is merely

The author wishes to express his thanks for the use of many of the illustrations to the editor *Electro-Chemical and Metallurgical Industry*, and to Dr. Eugene Haanel's report on the commission appointed by the Canadian government

to refine to a high grade steel, as is at present conducted in the crucible process. It will be readily understood that cheap power is of great importance to any of the processes to be described, but this does not mean that they can only be profitably applied in localities where cheap water power is available; for with the development of the modern gas engine, we have an economical source of power from the waste gases of metallurgical plants, and even where this cannot be used the gas producer can be utilized.

A further advantage gained by the electric methods in the matallurgy of iron and steel is in the production of ferro alloys of the more difficultly fusible metals, such as tungsten, titanium, vanadium and chromium. The high temperature which it is possible to reach in the electric furnace makes it possible to manufacture these alloys containing a very high percentage of the refractory metal, and to thus supply the market with the desired metal in very concentrated form.

HEROULT PROCESS

This is the invention of Mr. Paul Heroult, and was first put in operation at the Société Électro Métallurgique Française at La Praz, France.

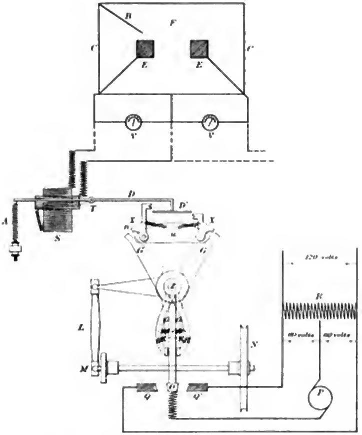


Fig. 2. Diagram of Automatic Regulator for Heroult Furnace

The Furnace

This consists of a tilting arc furnace with two vertical electrodes, and is illustrated in Fig. 1, which shows a vertical and longitudinal section.

The iron casing is first lined with dolomite bricks HH, and magnesia bricks about the openings. This brick work supports the hearth K, formed of crushed dolomite, which is rammed down to the form shown.

Two electrodes EE, of about 17 in. square section and 5½ ft. long, are made of retort coke and pass vertically through the roof of the furnace. In most cases it is necessary to water-jacket the electrodes for a short distance on each side of the place where they pass through the roof.

The passage of the current is from one of the vertical electrodes, through the narrow air gap, to the slag, through which it passes to the molten bath of metal beneath, and again through the slag and the second air gap to the other electrode. It will be seen that it is very necessary to have good control of the length of the arc, which is adjusted by changing the length of the air gap. Heroult accomplishes this by having a supplementary electrode, which consists of a metallic connection between the two vertical electrodes and the bath of molten metal. A voltmeter is placed in each of these circuits, which indicates any irregularity of the two; the adjustment of the electrode being effected by hand.

Fig. 3. View Showing Open-Hearth Furnace on the Right and Heroult Furnace on the Left.

Fig. 2 gives a diagram of the automatic regulator used to accomplish the above result. B is an iron wire connecting the casing C with the bath of molten metal. The current due to the difference of potential between the metallic bath and the electrode E, passes through the voltametric suction coil S; the movable outer coil of which (operating the rod D pivoted at T, and regulated by spring A), imparts motion to the horizontal staff D in a vertical plane with every variation of a difference of potential in the circuit.

Fig. 4. Measuring Instruments and Controlling Apparatus

A pulley N, which is operated by a small motor, actuates the crank M, which in turn causes another connecting rod L, to oscillate the part U, which is pivoted at Z. The dogs XX attached to U partake of the oscillation of U, but in their backward and forward motion fail to clutch the staff D as long as the variation of the voltage in the circuit does not exceed two volts; when this limit is exceeded either way, D′ either rises sufficiently high, or is depressed sufficiently low to be clutched by X or by X′, respectively. When this occurs the projection *n* of the respective dog is brought into contact with the corresponding side of the triangular plate GG, to which the prongs HH, pivoted at Z, are attached by the springs KK. This results in bringing the copper piece O, the suspending rod of which is pivoted at Z, into contact with the respective carbon block Q. From the diagram it will be seen that the direction of rotation of the motor P, which raises or lowers the electrode EE, depends upon the contact made by O with either Q or Q′, and hence upon the rise or fall of the voltage in the circuit beyond the limit of two volts.

At La Praz an alternating current of 4000 amperes and 110 volts was used on this furnace.

The whole furnace is mounted on two rockers which are operated by hydraulic rams, or electric motor, and admits of tilting,

Fig. 5. Side View of Heroult Electric Furnace

so that the charge of about three tons may be poured. It is designed for making steel and not for the smelting of iron ores, which operation is effected in a different furnace devised by Heroult.

The Steel Process

This consists in changing miscellaneous scrap to high grade steel, the material being usually fed into the furnace in the molten condition from a Willman furnace. A certain proportion of ore and lime is then added to produce a suitable slag, the arcs are struck, and the process carried on for a certain length of time, when the slag is removed and replaced by materials to supply a new one, this being repeated until the desired purity of the product is brought about.

Thus the production and removal of the slag is the means whereby the impurities are eliminated from the iron, the high temperature involved bringing about this result very actively. It is necessary to have the metal which is to be placed in the furnace "overblown" or suroxidized and free from slag. The metal under treatment is entirely protected from any oxidizing action of the air and from the influence of flame or gases, which fact has much to do with its resulting purity.

The proportion, composition, and number of removals of the slag depends upon the initial composition of the scrap to be treated.

The method of running for a high carbon steel, as conducted for the Canadian Commission, was as follows:

Charge:

Miscellaneous steel scrap	5733 lb.
Ferro-silicon	19 lb.
Iron ore	430 lb.
Lime	346 lb.
Ferro-manganese	3.3 lb.

Composition of scrap:

Carbon	0.110
Silicon	0.152
Sulphur	0.055
Phosphorous	0.220
Manganese	0.130
Arsenic	0.089

Before the current was turned on, the scrap and part of the lime was charged, the remainder of lime together with the ore

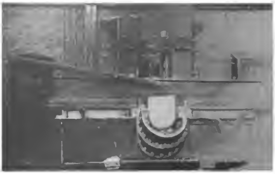


Fig. 6. Front View of Electric Furnace

being added during the melting. After the charge had melted completely, a new slag composed of lime, sand and fluor-spar was added, melted and removed, after which a finishing slag was added. The time consumed was now five hours and twenty minutes, and if the product desired had been soft steel, the furnace would have been ready to tap, but in order to bring the carbon contents to the right point, "carburite," or pure iron and carbon, together with the ferro-silicon was added; another heating was then continued for one hour and twenty minutes, when the charge was poured.

The product was 5161 lb. (equivalent to 2000 lb. of steel ingots for every 2230 lb. scrap and metal charged) and had the following composition:

Carbon	1.016
Silicon	.103
Sulphur	.020
Phosphorous	.009
Manganese	.150
Arsenic	.060
Copper	Trace
Aluminum	"

Fig. 7. View of Electric Furnace on the Platform

The energy used during the operations was 2580 kilowatt hours, which equals 0.395 h.p. years, and is equivalent to 0.153 h.p. years per 2000 lb. of steel produced. The steel thus made is uniform and compares very favorably with a high grade crucible tool steel, while the cost of production is much lower and is found to compare not unfavorably with a gas-fired Siemens furnace of the same capacity.

These furnaces may be constructed up to

Fig. 8. General View Showing Open-Hearth Furnace on the Right and Heroult Furnace on the Left

10 or 15 tons capacity and would be adapted to the production of special alloy steels without difficulty.

From work which has been recently carried on with the Heroult steel process, it is found more economical to remove most of the phosphorous in the preliminary open hearth treatment. This yields a metal which is in a highly oxidized condition but which lends itself well to the subsequent changes brought about in the electric furnace. Due to the higher temperature available, a very perfect deoxidation can then be effected in the electric furnace, resulting in a very fluid slag, the lime of the slag combining with the carbon to form calcium carbide, while the sulphur is largely eliminated. Such deoxidation is nearly impossible in the ordinary furnace operations, and it is necessary that it should be brought about for the higher grades of steel. The Figs. 3, 4, 5, 6, 7, 8, 9 and 10 are views taken of a Heroult steel plant which has been established in this country.

HEROULT PROCESS FOR SMELTING ORES

This operation is carried on in a furnace of very different construction from that just described, and one which takes the form of a vertical shaft more like the early carbide furnace of Willson. When the Canadian Commission inspected the Heroult Works

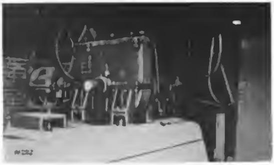


Fig. 9 Electric Motor for Tilting Electric Furnace

at La Praz, an experiment was made to demonstrate their ability to smelt iron ore directly by the electric furnace. At the time no furnace was available which was designed to meet the requirements, nor was the composition of the ore known for calculation of the necessary fluxes. With the adverse conditions existing, it is impossible, from this single experiment, to draw any conclusions of value as to the process, excepting that it was shown to be perfectly feasible to smelt iron ore direct with the electric furnace.

In order to ascertain whether the electric process could be advantageously applied to the direct smelting of ores, a series of experiments under the supervision of Dr. Eugene Haanel, were carried on in 1906 at Sault Ste. Marie, in a plant specially designed by Dr. Paul Heroult. The Canadian Government granted fifteen thousand dollars for these tests, as they had a very direct bearing on the commercial possibilities of iron metallurgy in Canada. The conditions in certain parts of that country are somewhat peculiar, from the fact that there are deposits of iron ore remote from the usual sources of metallurgical fuel, but where cheap power is available. Moreover, the quality of the ores is such as to render them unsuitable for the usual blast furnace treatment from the fact that they consist of magnetite containing a large proportion of sulphur. It was found that these ores could be smelted without difficulty in the electric furnace with very complete eliminations of the sulphur, and that charcoal and peat coke, of which there are abundant sources available, could be used as fuel.

The Furnace

This consisted of an iron casing bolted to a bottom plate of cast iron 48 inches in diameter, the bottom consisting of carbon paste

Fig. 10. Automatic Regulators for Electrodes

supporting a fire brick enclosure constituting the crucible. (See Fig. 11.) The principal dimensions of the furnace were:

Diameter of bottom crucible	24 in.
Height of lower cone	11 in.
Height of upper cone	33 in.
Diameter of joint base of the two cones	32 in.
Diameter of top of furnace	30 in.

The vertical electrode was composed of specially made carbon imported for the purpose and was 16 in. square by 6 ft. long. The current was furnished by one phase of a three-phase, 400 kw., 30 cycle, 2400 volt alternator, the voltage being lowered to 50 by a 225 kw. oil-cooled transformer.

Electrical connections were made to the vertical electrode and the iron casing of the furnace by aluminum cables ¾-inch diameter,

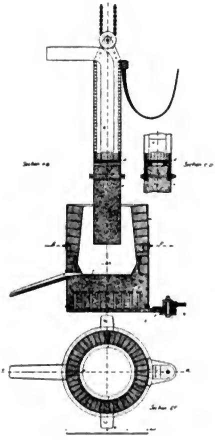


Fig. 11. Experimental Electric Furnace

of which 30 were attached to each of the two connections.

Some experiments were first undertaken to see whether it was possible to utilize some of the heat energy of the fuel; for this purpose an air blast was introduced a foot below the upper level of the charge. The furnace, however, was not found to work well with this addition, and it was abandoned. With a special design of furnace it was thought that the air blast would have been a valuable addition.

The fuel at first used was coke dust briquetted with fire clay, but charcoal was found subsequently to work perfectly and to be in every way preferable. Trouble was also expected in the reduction of magnetite, which is the principal ore to be smelted, from its being an electrical conductor. No difficulty was experienced, however, in the smelting of magnetite in respect to its electrical conductivity, nor was the inductance of the furnace increased by its presence. The following is a record of a run made on magnetite from the Blairton mine.

Raw Materials

Ore		Per Cent.
SiO_2	Fe = 55.85%	6.60
Fe_2O_3		60.74
FeO		17.18
Al_2O_3		1.48
CaO		2.84
MgO		5.50
P_2O_5 (P = 0.016%)		0.037
S		0.57
CO_2 and undetermined		5.053

Charcoal	Per Cent.
Moisture	14.06
Volatile matter	28.08
Fixed carbon	55.90
Ash	2.54

Limestone	Per Cent.
SiO_2	1.71
$Fe_2O_3 + Al_2O_3$	0.81
$CaCO_3$	92.85
$MgCO_3$	4.40
P	0.004
S	0.052

Charge	Pounds
Ore	400
Charcoal	125
Limestone	25
Sand	6

Products

Iron "Cast No. 80" grey iron

	Per Cent.
Total C	3.73
Si	3.53
S	.042
P	.034

Slag	Per Cent.
SiO_2	33.80
Al_2O_3	10.20
CaO	21.79
MgO	30.50
S	2.05
Fe	0.25
Length of run	65½ hours
Mean volts on furnace	36.03
Mean amperes	4987
Power factor	0.919
Watts 165125 or electric horse-power	221.34
Pig iron produced	11989 lb.

Output of pig iron per 1000 e.h.p. days = 9.92 tons e.h.p. year per ton of pig = 0.276.

In subsequent experiments it was found possible to smelt ores of high sulphur content not containing manganese, producing pig iron containing only a few thousandths of a per cent. of sulphur.

A further result brought out by the experiments was the possibility of smelting ores high in nickel and titanium, showing that it was quite feasible to smelt ores with the electric furnace that would be impracticable in the blast furnace.

The consumption of electrodes amounted to 17.98 lb. per ton of pig iron produced.

It is estimated that with a properly equipped plant, 12 tons of pig can be produced with 1000 e.h.p. days; and that the cost of a 10,000 h.p. plant to yield 120 tons of iron per day would be $700,000, inclusive of the charcoal plant and power plant, and figuring $50 as the cost of developing one e.h.p.

The cost of producing one ton of pig iron is figured as follows:

Ore, 55% metallic iron at $1.50 per ton	$2.70
Charcoal, ½ ton at $6.00 per ton	3.00
Electrical energy, amortization, etc.	2.43
Labor	1.00
Limestone	.20
18 lb. electrodes at 2 cents per lb.	.36
General expenses	1.00
	$10.69

From some small scale experiments made with a Heroult furnace by Albert E. Green and Frank S. MacGregor at the Mass. Institute of Technology, it was demonstrated that ores of a high titanium content (26.40% TiO_2) could be smelted with ease, producing a pig iron free of titanium. The furnace operated was of a 30 kw. capacity, and among the interesting features of the work was a determination of the temperature existing during the run. This was varied from 1375° C. to as high as 1922° C. without difficulty.

As a result of the Sault Ste. Marie experiments a Heroult smelting plant is now under construction at Welland, Ont., which will have a 3000 h.p. furnace with a capacity of 35 tons of pig per day, or of 40 tons if the hot gases are used for preheating the charge.

If this furnace is successful a larger one is to be built, together with a Heroult steel furnace, as the plant is to be used for producing steel castings. The location of this plant is not ideal from the fact that the power they will use is to be taken from the Ontario Power Co., which makes it expensive, and also because the location is removed from an ore supply. Nevertheless, the plant is expected to show economy in running even under these conditions. This will be still more convincing for electrothermic methods.

(*To be continued.*)

ILLUMINATION OF NIAGARA FALLS

By W. D'A. Ryan

The accompanying photographs, including that shown on the cover of this issue of the Review, illustrate some of the effects recently obtained at Niagara Falls under the rays of three powerful batteries of projectors.

Fig. 1. Bridal Veil Falls Illuminated by Searchlight

Plans and specifications for the illumination were prepared and submitted to Mayor A. C. Douglass and a sub-committee of the Niagara Falls Board of Trade. Subsequently the project was presented to the representatives of the various railroads centering in and around Niagara.

The estimated cost of the permanent installation was approximately $40,000. Considerable apprehension was expressed as to whether or not it would be possible to illuminate the Falls in the manner represented.

Furthermore, the universal censure which would naturally follow failure or unharmonious effects approaching desecration was a serious consideration.

In order to minimize the elements of chance, the Marine Department of the General Electric Company agreed to accept a nominal rental for a thirty days trial, during which approximately one-half the proposed battery would be used, with the understanding that if the experiments were satisfactory, the balance of the apparatus would be included in a permanent installation.

Mayor Douglass personally accepted the offer, and financed the required amount by local subscription.

The projectors were installed on the Canadian side, and located in three batteries.

Battery No. 1 comprised eleven 30 in. and ten 18 in. projectors installed on a platform 250 ft. long, located in the Gorge at a point midway between the American and Horseshoe Falls, 20 ft. above the water's edge, and approximately 1200 ft. from the center of Goat Island.

Fig. 2. Illumination of Niagara Falls from Canadian Side

Battery No. 2 consisted of four 30 in. projectors placed on what is known as the "spillway" of the Ontario Power Company, approximately 3500 ft. from the American Falls. These two batteries received current from a 300 kw. motor-generator set installed on a steel car stationed near battery No. 1.

The generator delivered 110 volts, and was driven by a 500 volt motor drawing current from the trolley circuit.

Battery No. 3 was made up of eleven 18 in. projectors located in Victoria Park, about 1500 ft. from the centre of the American Falls. The projectors at this point were arranged for series operation, and obtained current directly from the trolley circuit.

The lighting effects were controlled from battery No. 1, which was connected by telephone to the generator car and smaller batteries. The sub-division into three batteries was for the purpose of securing a wide sweep over both the cataracts, with a rising and a plunging light.

The Falls were illuminated every evening during the month of September, and while the volume of light was, as previously stated, only half the proposed strength, very good results were obtained, particularly on the American Falls. It was not possible, however, to properly illuminate both Falls simultaneously.

Fig. 3. Electric Aurora. Diverged

Under normal conditions, approximately 50 per cent. of the light was scattered or absorbed by the mist, and it was rarely that any discomfort was experienced in looking directly into a thirty-inch projector from Prospect Point, which was not over 2500 ft. distant. On one occasion, for a period of fifteen minutes, the light was completely shut out by the mist and rain, so that neither the Falls nor the light beams were visible. With this element to contend with, in conjunction with the enormous area over which it is necessary to evenly distribute the light, one can readily appreciate why a battery of

Fig. 4. Gorge Battery of Searchlights

searchlights giving approximately 2,000,000 candle-power, or practically double the amount of light used in the experiment, will be necessary to properly illuminate the American and Horseshoe Falls simultaneously.

It is the writer's opinion that the most beautiful effects were obtained by the use of white light. On this point, however, there appeared to be considerable difference of opinion. There is no question that the introduction of soft clear colors through suitable screens did not detract from the beauty of the Falls, but lent a pleasing variety of effects which appeared to be greatly admired and appreciated by the thousands of people who thronged the parks on both sides of the river every evening. An additional variation was introduced by noiselessly exploding loose giant powder in front of the main battery. This formed a blanket of pure white smoke, appearing as a cloud into which the colors were introduced. The sunset effects thereby produced in the water were beautiful beyond description.

Judging from the general comment and press reports, Niagara did not suffer from the experiments, and so pleasing were the results, as well as successful from a purely commercial point of view, that arrangements are being made to complete the permanent installation, which is expected to be in operation early next summer.

The following description of the illumination and the editorial on "Painting the Lily," appeared in the *New York Tribune* at the time of the display:

Magnificiently illuminated, the Falls were of a beauty that their daylight aspect has never equalled. For the first time since a factory was erected to draw its power from the rushing waters the garish outlines of the bleak brick buildings were gone, and in their place, * * * were the Falls in their old glory.

There was no moon when thousands of persons gathered on the Canadian side. Nothing could be seen of the Falls, but the mighty roar and the drifting spray told of their presence. Suddenly a flash shot across the river and danced for a moment alone on the American Falls before a dozen others joined it. In a moment more all the great searchlights were focused on the great mass of water, which truly shone in the light of its own glory, for it supplied the power used.

Then the lights swung up to the horseshoe in a rush of prismatic color. Every hue in the spectrum was used, and words fail to describe the magnificence of the spectacle. Some feared before the trial that there was to be a desecration of nature, but the natural wonder of the Falls was simply enhanced. The sordid sight of the factories and the hurdy-gurdies of the hotels and restaurants were banished. Presently the whole great stretch of the Falls was a mass of color; the whirling water beneath was like a pool of flame in the glow of the red searchlights.

Then the lights leaped into the air, to proclaim to Buffalo, to Toronto and even Rochester, the triumph of electrical genius.

PAINTING THE LILY

Man's audacity established a new record on Wednesday night, when the electric glare of fifty enormous searchlights were turned upon the tumbling waters and rising mists of America's noblest cataract. Prior to this incident, the championship medal for nature beautifying was held, we believe, by an enterprising Bavarian who, weary of the placidity of a mountain lake near his home, installed a surf machine which cast three-foot billows sluggishly upon the unaccustomed strand. It is hardly probable that the Niagara Falls champions can retain their lead very long, inasmuch moles, freckles and windmill ears, leaving the muddy countenance of the Night uncleansed and the jagged faces of the mountains without titanic cosmetics? It all depends upon the skill of the beauty doctor. In Shakespeare's day, perhaps, the bard's famous lines told the truth; before the invention of the spectroscope even a good artist might have been afraid to add another hue to the visible rainbow. But any college boy today could do the job very neatly. As for painting the lily, isn't it merely a matter of method? Instead of applying white lead mixed with turpentine to the pallid blossom, as an Elizabethan decorator might have done, the modern beauty doctor applies phosphates and water to the lily's roots, and, by other indirect methods, improves the natural flower

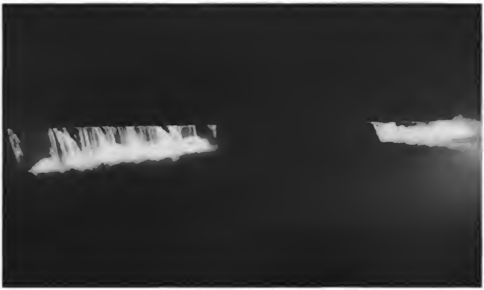


Fig. 5. Illumination of Niagara Falls. From Suspension Bridge

as the number of beauty doctors specializing in the treatment of nature's defects is increasing daily. It is not unreasonable to expect that some syndicate will soon be staining the upper crags and snow banks of Alpine majesties with colors more "effective" than those provided by nature. And perhaps even the thunderclaps of summer storms will some day be attuned and ordered most melodiously. All this will make many good folk weep, as the illumination of Niagara Falls has doubtless done. For is it not vanity and sacrilege to paint the lily and to add another hue unto the rainbow?

But was Shakespeare right? Should the beauty doctor confine his embellishing activities to warts, that once was thought perfect. In like manner, the searchlight has proved to be an instrument capable of lending to all of nature's mightiest monuments, save the inviolate stars, a new glory. It is said that the light effects produced upon the Falls held the thousands of spectators in almost utter silence. The nymphs of the rocky gorge and the naiads of the waters did profit, then, by the visit of the beauty doctor. Let Shakespeare continue to denounce the man who seeks "with taper light the beauteous eye of heaven to garnish." But the bard and his nature-loving disciples should absolve of sacrilege and folly all of nature's beauty doctors who are able to make more fair the face of Mother Earth.—*New York Daily Tribune.*

NOTES ON THE DETERMINATION OF RAILWAY POWER STATION CAPACITIES

PART II

By E. E. KIMBALL

The point has now been reached where one naturally asks, "Is the motor selected best adapted for the service in hand?" This can only be ascertained by determining the motor heating for the service under consideration, and it is evident that the calculations just outlined will serve to determine the heating as well as the energy consumption. The subject of motor heating has, however, been so well treated in A. H. Armstrong's papers presented before the American Institute of Electrical Engineers, June 20, 1902 and June 30, 1903, volumes 19 and 20, that it does not seem necessary to go into the method of calculating the motor capacity from the speed-time curves, but rather to include a table showing the horse-power required for cars of various weights when geared for a maximum speed of over 30 miles per hour, in order to facilitate the proper selection of motors for the service in question. The table gives the total horse-power rating of the equipment, and may be composed of either two or four motors, depending upon whether the conditions of service render it possible to run cars in trains or singly.

Table III gives a partial list of General Electric railway motors with their horse-power rating and weight, including gear and gear case, and also the weight of the necessary control apparatus. This table will be found convenient in estimating the weight of cars, after the seating capacity has been determined from the service contemplated.

It also seems advisable to include a list of various types of cars employed on American railways.

It is customary to estimate the passenger

TABLE II

HORSE-POWER MOTOR CAPACITY REQUIRED

STANDARD 500 VOLT D.C. MOTORS

SINGLE-CAR UNITS

Max. Speed of Car in m.p.h.	20 Tons	30 Tons	40 Tons	50 Tons	60 Tons
30	120 H.P.	155 H.P.	190 H.P.	225 H.P.	255 H.P.
35	145 "	190 "	240 "	280 "	315 "
40	180 "	230 "	295 "	345 "	390 "
45	215 "	275 "	350 "	405 "	455 "
50	....	320 "	410 "	475 "	525 "
55	....	....	465 "	545 "	600 "
60	....	....	525 "	620 "	690 "
65	....	....	....	710 "	790 "

TWO-CAR TRAINS

Max. Speed m.p.h.	2-20 Tons	2-30 Tons	2-40 Tons	2-50 Tons	2-60 Tons
30	190 H.P.	255 H.P.	315 H.P.	375 H.P.	440 H.P.
35	235 "	310 "	390 "	470 "	545 "
40	285 "	375 "	480 "	570 "	665 "
45	335 "	445 "	560 "	670 "	775 "
50	....	520 "	655 "	785 "	900 "
55	....	....	750 "	900 "	1030 "
60	....	....	850 "	1010 "	1160 "
65	....	....	....	1140 "	1320 "

THREE-CAR TRAINS

Max. Speed m.p.h.	3-20 Tons	3-30 Tons	3-40 Tons	3-50 Tons	3-60 Tons
30	255 H.P	350 H.P.	435 H.P.	530 H.P.	625 H.P.
35	310 "	430 "	540 "	660 "	770 "
40	370 "	520 "	650 "	800 "	920 "
45	440 "	610 "	770 "	930 "	1080 "
50	510 "	700 "	900 "	1080 "	1260 "
55	......	800 "	1030 "	1240 "	1430 "
60	......	......	1160 "	1430 "	1620 "
65	......	......	1310 "	1600 "	1830 "

FIVE-CAR TRAINS

Max. Speed m.p.h.	5-20 Tons	5-30 Tons	5-40 Tons	5-50 Tons	5-60 Tons
30	375 H.P.	510 H.P.	680 H.P.	840 H.P.	970 H.P.
35	460 "	640 "	830 "	1030 "	1230 "
40	560 "	770 "	1010 "	1230 "	1470 "
45	670 "	900 "	1180 "	1450 "	1710 "
50	770 "	1070 "	1370 "	1680 "	2010 "
55	......	1240 "	1570 "	1920 "	2300 "
60	......	......	1770 "	2190 "	2580 "
65	......	......	2010 "	2480 "	2910 "

weight from the seating capacity of the car, assuming that each passenger weighs 125 lbs.

After the schedule speed, size of motors, and total weight of car has been decided upon, it is possible to calculate the energy consumption from the speed-time-energy curves plotted from the characteristics of the motor selected.

Thus the energy consumption in watt hours is equal to the sum of the product of the instantaneous values of the current and voltage divided by 3600, or is proportional to the product of the area under the ampere curve times the area under the volt curve divided by 3600. In practice it is usual to assume the line voltage constant and equal to the voltage at which the motor characteristics are correct. During acceleration a considerable portion of the energy supplied to the train or car is used up in heating the starting resistance, which loss may be determined by referring to the diagram of losses in starting resistances, Fig. 1. The figures given in this diagram represent average conditions met in direct current practice, and vary but little with the size and voltage of motors. It is assumed that the derivation of the formulae will be obvious from an inspection of the figures.

Considerable time may often be saved, and the construction of the speed-time-energy curve avoided, by remembering that for similar speed-time curves the energy consumptions in watt hours per ton mile are equal (except for slight corrections for increased or decreased train resistance, due to higher or lower speeds); also, the distances covered are proportional to the square of the linear dimensions of the speed curves.

For example: Given a speed-time curve from which the schedule speed and energy consumption for a one mile run are 24 miles per hour and 66 watt hours per ton mile respectively, find the schedule speed and average kilowatt input to car, assuming that the speed time curves are similar, and the car makes a stop every 1¼ miles. Weight of car 40 tons.

Solution:

$$\text{Time of given cycle} = \frac{3600}{24} = 150 \text{ seconds.}$$

$$\text{Time of required cycle} = \sqrt{\frac{7290}{5280}} \times 150 =$$

184 seconds.

Required schedule speed $= \frac{3600}{184} \times 1.5 =$ 29.3 m.p.h.

Average kilowatt input per cycle =

$$\frac{29.3 \times 66 \times 40}{1000} = 77.7.$$

It is quite evident that the calculations just outlined require considerably more time than is warranted in preparing preliminary estimates of the power required for the operation of proposed trolley lines. An attempt has therefore been made to tabulate the energy consumption, or rather the average kilowatt input to trains of various weights and compositions, when operating under the most favorable conditions as regards schedule speed, maximum speed and stops per mile. In other words, the short table preceding the average killowatts input to trains, shows the maximum speed for which the equipment should be geared, as well as the schedule speed obtainable with the gear ratio and frequency of stops assumed. For instance, it has been found that very little advantage is gained in schedule speed by gearing for a higher maximum than 40 miles per hour, if the stops are as frequent as one per mile. At the same time, it has not been thought necessary to include in this table the average kilowatt input to trains when geared for a less maximum speed than here shown, as it would unnecessarily complicate the table without adding greatly to the value thereof.

The *efficiency* of *acceleration* depends

TABLE III
PARTIAL LIST OF STANDARD GE RAILWAY MOTORS

Trade Name	H.P.	No. of Motors	Type of Control	Weight of Control	Weight of Motors with Gear and Gear Case	Total Weight of Equipment
GE-80	40	2 4	K-10 K-28	940 1350	2800	6540 12550
GE-90	....	2 4	K-11 K-14	1015 2250	2875	6765 13750
GE-202	50	2 4	K-36 Type M	1225 2446	2600	6425 12846
GE-73	75	2 4	Type M "	1922 3158	4022	9966 19246
GE-204	75	2 4	Type M "	1823 3132	3280	8383 16252
GE-205	100	2 4	" "	2460 3600	3650	9760 18200
GE-66	125	2 4	" "	2715 3749	4376	11465 21249
GE-206	125	2 4	" "	2460 3600	4250	10960 20600
GE-207	150	2 4	" "	2946 4778	4740	12426 23738
GE-76	160	2 4	" "	3141 5385	5152	13445 25993
GE-69	200	2 4	" "	3379 5768	6230	15839 30688
GE-212	200	2 4	" "	3379 5768	6230	15839 30688

upon the ratio of the duration of control acceleration to the total time that power is on, and upon the efficiency of control, etc.

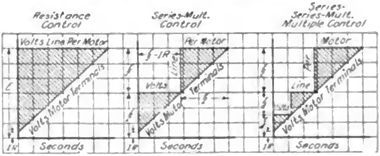
DATA ON TYPICAL ELECTRIC CARS

Type	Length Overall	Length of Body	Seating Capacity	Weight of Body	Weight of Truck	
Single truck, closed	26′	18′	18–20	6940	4400	City service
" "	28′	20′	20–24	7600	4600	" "
" " 8 bench, open	25′		40	4400	4600	" "
Double truck, closed	36′	25′	35	8400	6700	" "
" " "	37′	28′	42	10350	6700	" "
" " 13 bench, open	40′		65	11200	11400	" "
" " closed	41′	29′	40	17000	11400	Suburban
" " "	42′	29′	40	21000	11200	Interurban
" " "	49′ 1″	39′ 8″	56	26000	16000	"
" " "	51′	42′ 7″	52	33400	21000	"
" " "	55′ 4″	45′	64	37000	16000	"
" " steel body closed	60′	50′	70	85100	21000	"
" " combination	42′ 3″	31′ 4″		22000	11200	"
" " "	51′	43′	40	30500	23500	"

Above weights do not include weight of motor and car equipment

The control losses are confined to the period of acceleration, which renders them of little importance in runs of considerable length,

Diagram of Losses in Starting Resistances



Shaded Portions Represent Resistance Losses

	Resistance Control	Series-Mult. Control	Series-Series-Mult. Multiple Control
Ave. Rheo. Loss Per Motor Accel.	$\frac{E-IR}{2}I$	$\frac{(\frac{E}{2}-IR)^2+(\frac{E}{2})^2}{2(E-IR)}I$	$\frac{(\frac{E}{4}-IR)^2+5(\frac{E}{4})^2}{2(E-IR)}I$
Relative Rheostat Losses	100	50.3	39.7
Ave. Input to Train Per Motor	EI	$\frac{\frac{E}{2}(\frac{3E}{2}-IR)}{E-IR}I$	$\frac{\frac{E}{4}(\frac{11E}{4}-IR)}{E-IR}I$
Relative Input to Train	100	76.8	71.8
Input Per Motor	$\frac{E+IR}{2}I$	$\frac{E+IR}{2}I$	$\frac{E+IR}{2}I$
Control Efficiency	$.5+\frac{IR}{2E}$	$.65+\frac{IR}{2E}$	$.696+\frac{IR}{2E}$

IR Equals Volts Drop in Motor

Fig. 1

but when the runs are short, the acceleration should be higher in order that the period of acceleration may be made as short as possible and the efficiency increased. It is not wholly on account of the losses in the starting resistances that high accelerations are recommended for short runs, because it can easily be shown that the controlling factor in determining the schedule speed and energy consumption obtainable, when the stops are as frequent as one per mile, is the rate of acceleration.*

*See A. H. Armstrong's paper, Proceedings of American Institute of Electrical Engineers, 1898, volume 15.

The average kilowatt input values found in the main table agree very closely with results obtained from the construction of speed-time-energy curves, and can therefore be used as a starting point in making preliminary calculations of the power required for the operation of proposed trolley lines.

TABLE IV

TRAIN INPUT—FREQUENT STOP SERVICE

TANGENT LEVEL TRACK

Stops per Mile	1/8	1/4	1/2	1	2	3	4	5	6	7
Schedule Speed	50	40	32	24	18.5	15.5	13.7	12.5	11.7	11.0
Maximum "	65	55	45	40	30	25	23	21	20	19
Seconds Stops	30	20	15	12	10	9	8	7	6	5
Efficiency of Accel.	75	75	75	74	72	70	69	68	67	65
Accel. m.p.h. per Sec.	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7

The above data is common to all trains.

AVERAGE KILOWATT INPUT AT TRAIN

SINGLE-CAR OPERATION

Stops per Mile	1/8	1/4	1/2	1	2	3	4	5	6	7
20 Ton Car			51	36	29	26	24	23	22	22
30 " "		96	69	51	40	36	33	32	31	31
40 " "	176	119	85	63	51	45	43	41	40	40
50 " "	195	130	94	73	61	55	52	50	49	49
60 " "	200	140	106	82	70	64	62	60	59	58

TWO-CAR TRAINS

Stops per Mile	1/8	1/4	1/2	1	2	3	4	5	6	7
2-20 Ton			78	60	50	45	43	41	40	40
2-30 "		137	104	80	69	64	62	60	59	58
2-40 "	228	160	124	103	89	82	79	77	76	75
2-50 "	255	183	147	125	111	103	99	97	95	94
2-60 "	282	202	165	144	127	117	115	113	111	110

THREE-CAR TRAINS

Stops per Mile	1/8	1/4	1/2	1	2	3	4	5	6	7
3-20 Ton			102	76	67	63	61	60	59	58
3-30 "		173	135	112	97	90	88	86	84	83
3-40 "	280	200	164	140	127	117	115	113	111	110
3-50 "	300	236	198	172	155	145	142	139	137	136
3-60 "	342	263	219	191	175	167	163	160	158	157

FIVE-CAR TRAINS

Stops per Mile	1/8	1/4	1/2	1	2	3	4	5	6	7
5-20 Ton			144	124	110	102	98	97	95	94
5-30 "		238	196	171	154	145	142	139	137	136
5-40 "	370	292	246	216	197	188	183	180	178	176
5-50 "	438	350	302	270	250	236	228	225	222	220
5-60 "	497	400	352	314	290	280	275	271	266	263

The average kilowatts input to trains given in the above table takes no account of the loss in the low tension distributing system, substations, transmission lines, etc. These losses must be supplied by the power house, and are usually known as distribution losses. The determination of the losses depends upon combinations of the efficiencies of the apparatus forming various links in the system. Thus the efficiency of distribution for a typical interurban line may be determined as follows:

Efficiency of step-up transformers, power house	97 to 98 per cent.
Efficiency of high tension transmission line	90 to 95 per cent.
Efficiency of step-down transformers, substation	96 to 97 per cent.
Efficiency of rotary converters, substation	90 to 95 per cent.
Efficiency of secondary distributing system	85 to 90 per cent.
Net efficiency	64 to 77 per cent.
Efficiency of synchronous motor-generator sets	82 to 88 per cent.
Efficiency of induction motor-generator sets	82 to 88 per cent.

This determination of distribution losses is usually sufficient to permit of a preliminary estimate of the power required at the power house.

Main Station Capacity

To determine the capacity of the main station, it is usual to construct a train sheet which indicates the arriving and leaving time of all trains throughout the day, as well as their positions at any one time. In case of a regular schedule, it is unnecessary to show the entire train sheet, but only a section or possibly two sections showing normal and rush hour traffic. (See Fig. 2.) These sheets are usually constructed after a thorough investigation of the traffic conditions, density of population of the region served by the railway company, etc.; whereby a sufficiently frequent headway is determined to insure the greatest possible patronage, consistent with the cost of operation. From these sheets it is possible to ascertain the number of cars necessary to maintain the given headway, the load diagram showing the kilowatts required for every period during the day, the average load on the power station for 24 hours, the maximum power required, and the duration of this maximum load, etc.

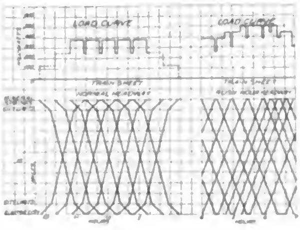


Fig. 2

The number of cars required to maintain a given headway may also be found by the following formula, without constructing a train sheet.

$$\text{No. of cars required} = \frac{\text{time of round trip, including lay overs in minutes}}{\text{headway in minutes}}$$

The load diagram is constructed by noting the number of trains on a section at any one time and multiplying by the average kilowatt input per train, as found from Table IV. The best method for constructing the load curve is to note the number of cars on a section at one time, then follow the train sheet through, noting the time when a train either enters or leaves a section, and adding or subtracting the kilowatts taken by it. The average kilowatt hours per day is proportional to the area of the entire load curve, and the average kilowatts, which usually determines the size of units to be employed, is obtained by dividing the kilowatt hours per day by the hours of operation.

The maximum average load dur ng the day is found from the load curve during maximum traffic, and the duration of this maximum load is usually noted, as well as the value. The momentary swings of power can seldom be estimated closely, but it is customary to assume about 1½ times the kilowatts shown in the load diagram as representing the probable maximum swings at these times. This figure is equivalent to assuming one quarter of the trains on the section accelerating, and the others taking average input. For very large systems, where the number of trains is considerable, the fluctuations in load are considerably less than this amount, but on systems where the power taken by a single car represents a considerable portion of the energy required for the system, the fluctuations are much greater than 1½ times the average value shown on the load diagram. These momentary swings of power should not exceed the momentary overload guarantees of the apparatus under consideration, and as a general thing, will not be the determining factor in selecting generating units.

The generating apparatus installed in the main station should therefore be sufficient to deliver the maximum power required for the operation of the entire road, with an extra amount to be used as a reserve in case of accident to one or more of the units, or in time of excursion traffic. The proper size of units to be installed in the main station depends upon a number of other considerations, among which may be mentioned:

Reciprocating engine
Gas engine
Water wheel.

1 Main Station
Old
New.

2 Type of Prime Mover
Steam turbine

3. Provision for present and probable ultimate capacity of station

4. Standard sizes of generators for direct connection to type of prime mover under consideration.

5. Efficiency of various sizes of prime movers and generators.

6. Flexibility.

7. Cost, etc.

In small installations it is usual to install two units, either of which is capable of supplying all of the power required for the operation of the road, thus providing means for transferring the load from one unit to another, for inspection and repairs. In large installations a greater number of units are installed, which enables the operation of a sufficient number during light loads to utilize the greatest maximum efficiency of the sets, and also renders it possible to reduce the reserved capacity 50 per cent. or more.

COVINGTON COKE EXTRACTOR

By M. R. Clarke

It is the purpose of this article to briefly describe one of the latest and most interesting applications of the electric motor in connection with the manufacture of coke. Electric haulage, both in the mines and in the propulsion of coke oven larries, has long been a common factor in the operation of coking plants, but there are many operations of considerable magnitude where, owing to the presence of gas in the mines, electrical power has not been used, except possibly for exterior lighting.

In the manufacture of coke, the "bee-hive" form of oven predominates. The coal is gradually converted into coke by a process of slow combustion of the volatile matter, which supplies the heat for maintaining the process of distillation. This action is conserved by the dome-shaped roof, under which the gas burns and generates heat. This heat is radiated from the dome of the oven to the mass beneath. At the end of 48 hours burning, the door in the side wall of the oven is uncovered, and the red hot coke is cooled by "quenching" with water. The coke is then a hard mass of columnar structure, and from three to four hours manual labor is required to break this apart and convey it from the interior of the oven.

It has long been the desire of coke operators to secure a machine which will displace the arduous and time-consuming hand labor required to draw an oven. The Covington extractor, manufactured by the Covington Machine Co., Covington, Va., is the successful survivor of various ingenious and powerful machines contrived to remove coke from a "bee-hive" oven.

Fig. 1. Covington Coke Extractor drawing Coke from "Beehive" Oven and loading into Car. This Illustration shows arrangement of Ovens at Typical Machine Plant

In the successful operation of a machine for drawing coke from the oven, electric drive is essential, on account of its flexibility in application and control. The pronounced success achieved by the Covington extractor has created a demand for electrical generating and motive equipments for a class of operations that otherwise might dispense with electrical apparatus altogether.

The Covington extractor consists essentially of a ram, armed at its extremity with a wedge having its lower side resting on the oven floor, and its thin end extending toward the face of the coke. Pressure on this ram forces the wedge under the coke, detaching it and causing it to fall back of the ram head. On the return movement, the vertical rear face of the ram head serves as a rake, drawing the coke from the oven. It will be noted from the cut that the ram arm is provided with a rack on one side. A cut steel pinion, driven through intermediate gearing by a CO-2002, 20 h.p. enclosed series motor, operates this portion of the mechanism. An R-28 controller, with 5 points forward and reverse, and reversing with a single handle, provides an effective control. The angular position of the ram advance is controlled by a handwheel, which pivots the ram guide about the pinion center. This enables the ram to traverse every part of the oven.

It will be noted from Fig. 1 that the coke drawn from the oven drops into a trough which is parallel with the oven wall and supported by the framework of the machine.

A conveyor chain, traveling at the bottom of this trough, carries the coke to the lifting conveyor, which then lifts it to a point above the car, where it is dropped into a trap. This trap at regular intervals of accumulation, drops the coke in bunches into the car. This method of loading has been found to insure a minimum amount of breakage. The operation of the conveyor system is effected by a CQ 15, 15 h.p. slow speed, compound wound motor.

The various parts of the apparatus are mounted together on a substantial truck, which is propelled parallel to the oven wall on a standard gauge track. This propulsion, occurring while the machine is idle, is effected by a clutch which detaches the motor from the ram and applies it to the axles of the truck.

The entire electrical equipment of these machines is supplied by the General Electric Company. There are now some 150 in operation, and new machines are daily being placed in service.

The main economy resulting from the use of the coke extractor is the saving of the expense of maintaining the large force of laborers necessary to draw ovens by hand. The following is a conservative estimate of the cost per oven for machine drawing:

Drawing	14 cts.
Cleaning out	5½ cts.
Watering	6 cts.
Leveling new charge	15 cts.
Total	40½ cts.

Allowance for repairs and other items brings this total up to about 52½ cts. per oven for machine work, which is a conservative figure. The average cost of hand drawing amounts to $1.17. The number of ovens drawn by one machine in a day varies from 35 to 50. The average amount of time required to draw an oven is about 20 minutes, whereas, with hand drawing, 3 to 4 hours are necessary.

Due to the rapidity of machine drawing, the oven walls have less opportunity to cool, and a larger amount of residual heat remains in the oven to ignite the new charge of coal. Each charge will therefore have a few more hours to burn, due to the saving in time, thus producing a more complete separation of the fixed carbon and the volatile matter.

In the construction of a bank of coke ovens it has formerly been the custom to place the ovens on an elevated masonry foundation. This foundation, or "wharf wall," is arranged to be on a level with the tops of the railroad cars in which the coke is to be loaded. This arrangement is necessary in a plant where the ovens are drawn by hand, in order that the laborers, gathering the coke in front of the ovens, may be able to dump their wheelbarrows into the car. With the advent of a successful extractor, a large number of new plants have taken full advantage of the conveyor system, and have dispensed with the construction of the wharf wall, the coke being loaded directly into the cars by the conveyor. The saving effected being both an abrasive and an excellent conductor

The motor equipment of these machines is giving excellent results, and this, too, in the face of extremely severe conditions. Every effort has been made to render the control equipment as simple and effective as possible. The starting rheostats of the conveyor motors are wired in accordance with the "BTH" method, which effectually

Fig. 2. Rear View of Covington Coke Extractor, Showing Controller for Ram, and Handwheel for Varying Angular Position of Ram Travel

in being able to dispense with the construction of a wharf wall practically halves the cost of building a bank of ovens Fig 2 illustrates the use of a Covington extractor in a typical "machine plant," where the oven walls are built on ground which is level with the railroad track.

The ever-present shower of dry coke dust has rendered it necessary to totally enclose both motors, in order to prevent the accumulation from forming "grounds," coke dust prevents the field "kick" from breaking down the armature insulation, a phenomenon which quite frequently occurs where shunt or compound wound motors are operated on a grounded circuit. The rapidity with which the machine drivers handle the controller of the ram motor is rather astounding at times, but the endurance of the motor seems to be up to the usual standard, notwithstanding the unusually severe treatment they receive.

THE ROTARY CONVERTER

Part II

By E. J. Berg

In order to study the distribution of heat in individual coils of the armature, the following arithmetic method has been used:

The armature will be assumed moving in intervals covering 7.5° in space. The original position will be that indicated in Fig. 4, when the alternating current is maximum. The next position will be designated by $\phi = 7.5°$, in which case the alternating current is $i_{max} \cos \phi$, etc. The direct current is $-i_c$ on the right-hand side of the center line, and $+ i_c$ on the left-hand side.

$\phi = 0°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$-i_c$	i_{max}	$i_{max}-i_c$	$.111\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.89\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 7.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$-i_c$	$.991\ i_{max}$	$.991\ i_{max}-i_c$	$.102\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	
4	"	"	"	"	$.816\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 15°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$-i_c$	$.966\ i_{max}$	$.966\ i_{max}-i_c$	$.084\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$671\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 22.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$-i_c$	$.923\ i_{max}$	$.923\ i_{max}-i_c$	$.0529\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.423\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 30°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$-i_c$	$.867\ i_{max}$	$.867\ i_{max}-i_c$	$.0256\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$205\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 37.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$-i_c$	$.792\ i_{max}$	$.792\ i_{max}-i_c$	$.003\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.024\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 45°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$-i_c$	$.707\ i_{max}$	$.707\ i_{max}-i_c$	$.003\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.024\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 52.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$-i_c$	$.607\ i_{max}$	$.607\ i_{max}-i_c$	$.036\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$287\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 60°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$-i_c$	$.5\ i_{max}$	$.5\ i_{max} - i_c$	$.111\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.89\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 97.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.13\ i_{max}$	$-.13\ i_{max} + i_c$	$.683\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$7.52\ i_c^2$
5	"	"	"	"	
6	$-i_c$	"	$-.13\ i_{max} - i_c$	$1.37\ i_c^2$	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 67.5°$

Coil	D.C. Amp	A.C. Amp	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$.38\ i_{max}$	$.38\ i_{max} + i_c$	$2.27\ i_c^2$	
2	$-i_c$	$.38\ i_{max}$	$.38\ i_{max} - i_c$	$244\ i_c^2$	
3	"	"	"	"	
4	"	"	"	"	$3.97\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 105°$

Coil	D C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current
1	$+i_c$	$-.259\ i_{max}$	$-.259\ i_{max} + i_c$	$.427\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$6.18\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	$-i_c$	"	$-.259\ i_{max} - i_c$	$1.81\ i_c^2$	
8	"	"	"	"	

$\phi = 75°$

Coil	D.C. Amp.	A.C. Amp	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$.259\ i_{max}$	$.259\ i_{max} + i_c$	$.181\ i_c^2$	
2	"	"	"	"	
3	$-i_c$	"	$.259\ i_{max} - i_c$	$.427\ i_c^2$	
4	"	"	"	"	$6.18\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 112.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.38\ i_{max}$	$-.38\ i_{max} + i_c$	$.244\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	
4	"	"	"	"	$3.97\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	$-i_c$	"	$-.38\ i_{max} - i_c$	$2.27\ i_c^2$	

$\phi = 82.5°$

Coil	D.C Amp	A.C. Amp	Resultant Amp	Current²	Σ Current²
1	$+i_c$	$13\ i_{max}$	$13\ i_{max} + i_c$	$1.37\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	$-i_c$	"	$13i_{max} - i_c$	$683\ i_c^2$	$7.51\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 120°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.5\ i_{max}$	$-.5\ i_{max} + i_c$	$.111\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.89\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 90°$

Coil	D.C Amp	A.C Amp	Resultant Amp	Current²	Σ Current²
1	$+i_c$	0	i_c	i_c^2	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$8i_c^2$
5	$-i_c$	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 127.5°$

Coil	D C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.607\ i_{max}$	$-.607\ i_{max} + i_c$	$.0362\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$289\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 135°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.707\ i_{max}$	$-.707\ i_{max}+i_c$	$.0036\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.029\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 142.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.792\ i_{max}$	$-.792\ i_{max}\ i_c$	$.003\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.024\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 150°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.867\ i_{max}$	$-.867\ _{max}\ i_c$	$.025\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.200\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 157.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.923\ i_{max}$	$-.923\ i_{max}+i_c$	$.053\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.423\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 165°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.966\ i_{max}$	$-.966\ i_{max}+i_c$	$.084\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.671\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"		"	"	

$\phi = 172.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.991\ i_{max}$	$-.991\ i_{max}+i_c$	$.102\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.816\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

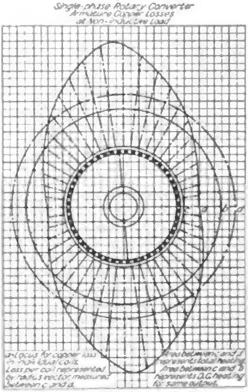


Fig. 5

The sum of the instantaneous losses at different positions of each individual coil is directly obtained as follows:

Coil No. 1........$8.75\ i_c^2$
" No. 2........$6.72\ i_c^2$
" No. 3........$5.34\ i_c^2$
" No. 4........$4.65\ i_c^2$
" No. 5........$4.65\ i_c^2$
" No. 6........$5.34\ i_c^2$
" No. 7........$6.72\ i_c^2$
" No. 8........$8.75\ i_c^2$

In a direct current generator, the loss in each coil would obviously be

$$\frac{180}{7.5}\ i_c^2 = 24\ i_c^2$$

Thus the coils nearest to the collector leads are subjected to the greatest loss; being, in this case, 1.87 times the loss in the coils

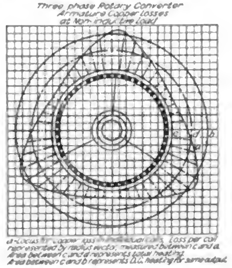


Fig. 6

midway between the leads, and about 36.5 per cent. of that in a corresponding direct current generator.

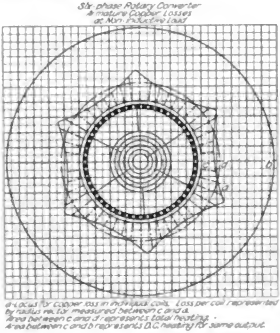


Fig. 7

Figs. 5, 6, 7 and 8 have been drawn to show how, with non-inductive load, the copper losses are distributed around the periphery of a single-phase, three-phase, four-phase and six-phase rotary converter, respectively. Fig. 5 refers to a single-phase converter, where the heating of the coil adjacent to the collector ring leads is about six times as great as in coils midway between the leads. The total heating is 1.43 times

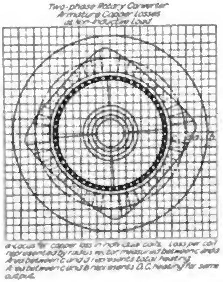


Fig. 8

that of a direct current machine of the same rating; therefore, for the same degree of heating, such a rotary converter can be rated at only 84 per cent. of its direct current output as a generator. The maximum current at any time for a given load is three times that corresponding to the direct current.

The curve sheets are self-explanatory, and show in a general way that the larger the number of phases, the less the total heating, and the less the difference in temperature between different coils.

(To be continued.)

SOME NOTES ON WIRING AND WIRING SUPPLIES FOR MINING SERVICE

By F. A. Barron

In deep shaft mining operations there are several systems of power transmission in general use; among these may be mentioned:

First, a copper wire transmitting electricity to electric motors;

Second, a flexible hose carrying air under pressure to air motors;

Third, iron pipes carrying steam under pressure to steam engines.

In some mines electricity is used for all important purposes; while in others it will be found that ropes or mules are used for haulage, and steam for all other purposes; while in still others, compressed air is used for coal drilling, and electricity for all other purposes.

In each case the result to be accomplished is the performance of the mechanical work necessary for the extraction and hauling of coal or ore. The essential characteristics necessary in the power transmission used in underground mining to meet the severe conditions of that service are flexibility, reliability, economy of space and cost, ability to transmit power to long distances with small loss, and facility of extension and repair. And it has been successfully demonstrated after years of service that in these important characteristics, electric power is so much the superior of the others, that it has found general adoption for most of the important operations in mining service, including main shaft hoisting, slope hoisting, locomotive haulage, ventilation, pumping, coal cutting and drilling, preparation of coal in breaker, and lighting.

The transmission of any power for the various operations in underground mining opens up a very interesting field for the solution of questions involving the economical relationship between the loss in power and the investment in transmitting mediums, for the reason that the most economical centers of distribution for underground operation are not always accessible from above ground. For example, the mine shaft has been used as a passage through which to carry the transmitting medium down into the mine, and it therefore becomes the fixed center of distribution. In mines, therefore, with long gangways, and numerous pumps, locomotives, coal cutters, drillers, etc., in operation, the loss in pressure becomes an important consideration. In addition to this, it is preferable to avoid, as far as possible, running bulky power transmitting mediums along the gangways, on account of the limited space and the nature of the roof and walls, and also on account of their liability to mechanical injury. Therefore, in order to effect the much desired economical relationship between investment in transmitting medium and loss in power, and in order to insure certain other desirable conditions, it is the practice to drill "feeder bores," or small pipe lined holes, down into the mine at appropriate points between the mine shaft and the end of the gangways, through which the power is fed into the mine.

Among other interesting features in connection with a power transmission system in underground operations are, the sulphurous nature of the moisture and water of the mines, involving corrosion and decay of materials; the necessarily limited head room and working space in the mines; the rough character of the work; the variable nature of the walls and roofs of gangways and chambers; the frequent blasting operations, requiring adequate provision for the protection of the system from mechanical and chemical injury; and the frequent moving of pumps, etc., making flexibility of transmission an absolute necessity. It is to these peculiarly severe conditions that electric transmission seems especially applicable, as offering a comparatively easy means of overcoming their difficulties.

In following a brief description of some of the features of the electric wiring system of mines, it should be remembered that no two mines are alike in details, and methods that will apply in one case may not fit the peculiar conditions found in others. The purpose of this article is, therefore, to describe but briefly a few of the essential devices used in the wiring equipment of coal mines in general. A tabulated list of the cables, wires, and wiring devices that are suitable for lighting and motor service in mines would be somewhat as follows:

Feeder cables from power station to mine shaft, and to trolley wires in gangway.

Lead armored feeder cables to run down mine shaft and feeder bores; as well as into pump chambers where wires are exposed to injury.

Feeder wires from power station to coal breakers and other buildings above ground, and to surface and tunnel trolley systems.

Trolley wire for locomotive haulage, with suspensions, frogs, ears, etc.

Insulated and bare circuit wires for lighting, above and below ground.

Metal conduit to protect wiring from mechanical injury in coal breakers, washeries, tunnels, shafts, etc.

Flexible steel armored conductors for coal cutters, drillers, etc.

Reinforced duplex flexible conductors for portable lamps, etc.

Weatherproof keyless lamp sockets, portable lamp guards, glass and proccelain insulators, knife switches, and porcelain receptacles for lamps on side walls where not exposed to mechanical injury.

In mines using alternating current supplied from a central station and fed to substations near the mine shafts, the only items which appear necessary to be added to the above list are the high potential feeder cables from central station to substation, which are sometimes bare, and sometimes insulated, depending, among other conditions, upon whether the transmission lines are, or are not, exposed to interference or public traffic.

Many of the electrically equipped mines of today use direct current of comparatively low voltage; *viz.*, 250 to 500 volts; but owing to the rapid extension of the mines, and the operation of extensive mining properties under a single progressive management, it is safe to predict that the alternating current will ultimately find general adoption in mining operations. This will be largely due to the fact that the economical transmission of direct current at standard voltages is limited to short distances and comparatively small loads by the cost of copper, while alternating current of economic voltages can be transmitted long distances at comparatively small cost for line construction, and the voltage easily and cheaply raised or lowered to suit conditions.

The coal mining department of the Delaware, Lackawanna & Western Railway Co. have a central station using Curtis steam turbines generating alternating current at 2300 volts, which is carried on overhead transmission lines to the substations situated at the various mines. The substations contain rotary converters for converting the alternating current to direct current for locomotive haulage, and step-down static transformers for feeding various alternating current motors down in the mine. Fig. 1 shows the front view of the central station switchboard, manufactured by the General Electric Co. A brief description of this switchboard may be interesting.

When installed in 1905, the switchboard consisted of seven blue Vermont marble panels, the first panel on the left controlling the two engine-driven exciters; the next three controlling the three turbine-driven generators; and the fifth, of 1500 kw. capacity, controlling the feeders for the motors in the water hoisting plant. Panels 6 and 7, of 500 kw. capacity each, are feeder panels, controlling the feeders to the substations. A recording wattmeter is placed on the back of each feeder panel, and triple conductor lead armored cables are run from these, under the floor and up the side walls of the station, connecting with the bare transmission lines leading to the substation.

Each of the substations contains a 200 kw. General Electric six-phase rotary converter for direct current light and power service (Fig. 2), and also three 75 kw. step-down transformers for alternating current motor service, in and around the mines. The switchboard consists of two panels; *viz.*, a 2300 volt A.C. panel, fitted with the usual fuses, meters and oil switch; and a D.C. panel, provided with a single pole circuit breaker, ammeter, field rheostat, and single pole single throw switch. The switch controls only the positive lead of the rotary, the negative side being grounded to the rails of the haulage system.

Fig. 1. Central Station Switchboard, Coal Mining Dept., Delaware, Lackawana & Western Railroad

When the mine shaft is dry, and no trouble is likely to occur from falling ice or coal, the power feeder leading into the mines consists of rubber covered wire supported on glass insulators fastened to the buntons. However, this condition is so seldom found that lead covered cables placed in iron pipes are generally used. This method has given good results, even in very wet shafts.

The following method of supporting feeder cables running down the shaft is suggested and used by the electrical engineer of the Delaware, Lackawanna & Western coal department, and has given entire satisfaction. A number of rubber pump valves about 6 in. in diameter are strung on a supporting rod to provide proper insulation, and the rod is then secured in place by strap irons fastened to the buntons, or some other convenient place. The lead of the lead armored cable is taken off for a distance of about 4 ft., and the bare cable is given one or more turns about the support just described, and then clamped to itself. The lead armor is stripped off to prevent the weight of the cable from crushing the insulation surrounding the wire and causing a short circuit between the conductor and the lead covering. Wooden bushings soaked in paraffin and then shellaced are fastened in the ends of the pipe to prevent the cable from being damaged or short circuited at this point. In cases where the depth of the shaft would produce excessive weight on the top support just described, the following arrangement is resorted to:

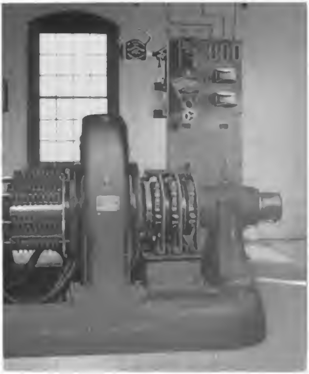


Fig. 2 Interior of Substation, Coal Mining Dept., Delaware Lackawana & Western Railroad

At the foot of the shaft, where the cable emerges from the iron pipe, through which it is carried down the shaft, a clamp is fastened to the cable and to the pipe; the cable, thus secured at the bottom of the shaft, is dropped down in the pipe to a certain extent, causing the cable to coil, or assume a wave like position, whereby a frictional support is secured against the sides of the pipe. This method of suspending feeder cables in shafts would also apply to those running down "feeder bores," the upper end of the cable, in some mines, being secured to a suitable wooden support. The feeders are looped into distributing bus-bars at each vein or gangway, and these feed the trolley wire, pumps, motors, lighting circuits, etc.

(*To be continued.*)

MOTOR DRIVEN DRAINAGE PUMP

A somewhat novel and interesting portable electric pump has been built by Yeomans Brothers of Chicago, for the Omaha Electric Light & Power Co., and is used by the latter for pumping out the manholes of their conduit systems. Rear and side views of the outfit are shown in Figs. 1 and 2.

The centrifugal pump is mounted on a

Fig. 1. Rear View of Portable Motor Driven Drainage Pump

bracket which forms one end of a long cast iron bed-plate designed to carry the motor and the inboard bearings of the pump.

The power is supplied by a direct current 10 h.p., 835 r.p.m., 500 volt General Electric motor. The pump has a capacity of from 450 to 500 gallons per minute against a maximum head of about 25 feet.

Below the flexible coupling which connects the motor shaft to the pump shaft will be seen a small secondary pump driven by a belt from the main shaft. The function of this secondary pump is to prime the casing of the main pump.

When it is desired to put the apparatus in operation, the main discharge valve is closed and the motor being started up, the small centrifugal vacuum pump exhausts the air from the casing of the main pump, causing sufficient water to rise out of the sump or manhole to prime the casing of the latter. As soon as this is accomplished the discharge valve of the main pump may be opened, and the speed regulated to suit existing conditions of head and flow.

The priming pump is fitted with a fast and loose pulley so that as soon as the main pump has begun to deliver water, its belt can be shifted onto the loose pulley, thereby permitting the smaller pump to come to rest.

Speed control is accomplished by means of a regulating resistance box which is shown in Fig. 2 on the left-hand side of the wagon. On the right is a reel carrying a flexible a ready access obtained to all parts of the connecting cord 200 ft. long, one terminal of which is permanently connected through the axle to the starting box, the other to be connected to a convenient source of electricity, which is to be found either in a manhole, in case of making connection with the underground system, or at a feeder or main junction box, in the case of a pole line.

The wagon-top is made removable so that in case of necessity it can be taken off, and apparatus.

Provision is made for carrying the suction hose on the side of the wagon body, in a manner very similar to that employed in connection with fire engines.

With the rapidly increasing use of underground distribution systems, it is evident that an apparatus of this kind will prove of the utmost utility, not only in removing the ordinary seepage and condensation which at times gathers in manholes and ducts, but it will prove especially effective and valuable in case of emergency or accident, such as frequently happens in underground systems when a conflagration or explosion occurs in their immediate vicinity.

F. M. K.

Fig. 2. Side View of Portable Motor Driven Pump

LUMINOUS ARC HEADLIGHT

By G. N. Chamberlin

An article in the October number of the General Electric Review described a new application of the direct current luminous arc; *viz.*, its use for street car headlights. This type of headlight is meeting with general favor among street car operating companies, and in every case where samples have been furnished, either additional orders have been received or assurance given that the luminous arc headlight will be specified if additional equipment is required. One company advises us that after trying two samples for a period of three months, they feel that they can no longer afford to use about 100 enclosed carbon headlights of a well-known make. Without taking into consideration the increased volume of light, and the fact that the arc is focusing, the decrease in operating expenses obtained by this particular company by the use of the luminous arc headlights, warrants the inquiry for prices for replacing all carbon headlights in use.

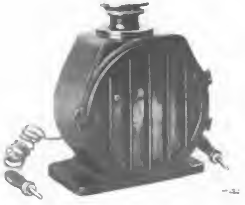


Fig. 1. Luminous Arc Headlight for Mining Locomotives Front View.

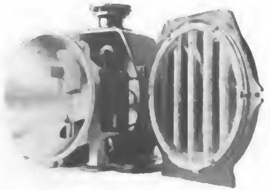


Fig. 2. Headlight Open for Inspection

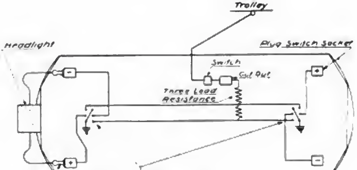


Fig. 3

Figs. 1 and 2, illustrate a type of headlight for mining locomotives which, while designed for this particular service, is available for use wherever a heavy cast frame of small dimensions is required. The internal mechanism and electrodes (upper copper and lower composition) are identical with those used for street car service, a full description of which will be found in the article referred to above.

Wiring diagrams for different connections of the headlight are shown in Figs. 4, 5 and 6

Without repeating the detailed information given in the article in the October REVIEW

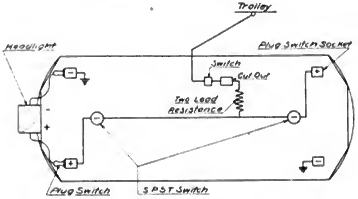


Fig. 4

entitled "Magnetite Headlight," the advantages of the luminous headlight as compared with the enclosed carbon headlight are as follows:

1. The higher efficiency of the magnetite arc, giving quantity and quality of illumination.

2. Arc maintained at focus of reflector, insuring permanent direction of rays.

The casing is of cast iron, including heavy cast iron bars for protecting the glass door. The casing complete weighs about 55 lbs. and is arranged for bolting to a horizontal surface; it is evident that this type of frame should be used where permanent installation may be made, and where increased weight is not objectionable.

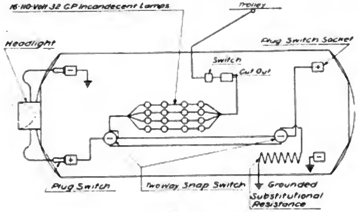


Fig. 5

For electric switching, mining and general railroad locomotives, and for stationary lighting where an efficient broad beamed semi-projector method of illumination is required, this type of luminous headlight is recommended. The headlight is furnished with two leads, plugs and receptacles, and is adapted for connection on direct current circuits of from 200 to 600 volts. A suitable resistance being furnished for any special voltage.

3. No enclosing globes used, thus eliminating greatest expense of enclosed headlight maintenance.

4. Long life of electrodes–2000 to 3000 hours for upper, 50 to 75 hours for lower showing a further reduction in operating expense.

5. Available means of quickly and effectually dimming the light—a modern method as compared with the use of screens hung in front of headlight door.

THE "INVINCIBLE" RENOVATOR

By Thomas Raddin

There has been placed on the market very recently a unique renovating device known as the "Invincible" Electric Renovator, which is manufactured by the Electric Renovator Mfg. Co., of Pittsburg, Pa.

This machine fills a long felt want in the cleaning field for house, church and hall renovating, and affords a most convenient method of disinfection.

The machine is operated on the suction principle, and is driven by a small direct connected motor. As may be noted by referring to the illustration, the front part of the machine is equipped with an aluminum casing, and inside of this is located a brush which is driven by a small belt connection from the fan shaft. This brush may be adjusted to the texture of the carpet to be renovated, and will therefore cause no undue wear on the nap of the carpet or rug. The inlet is 12 inches long by 13 inches wide at the point of contact with the carpet, and the suction is of sufficient strength and volume to remove the dust, grit and fluff from beneath the latter.

It is interesting to follow the course of the dust after it leaves the floor. It travels around the brush, past the removable trash drawer (designed to catch matches, string and other articles which might damage the fans) through the netting covering the inlet to the fans, and into the fan casing. This casing is divided into two stages by an aluminum diaphragm. The dust traverses these two stages and is driven upwards into the cylindrical dust collector, shown at the right of the machine in Fig. 1

The construction of this dust collector is worthy of brief mention. In consists of the finest woven muslin cloth, which catches all of the dust coming from the renovated surface, but allows the air to pass through and out into the room. The muslin collector is surrounded by a fine wire mesh.

The accumulated dust may be removed by lifting the collector by the handle at the top, having first detached the four wing nuts shown on the under side of the collector; while the bottom part, which is provided with lugs, may be unscrewed from its connection. By tapping the collector lightly the dust is discharged, and the collector is again ready for service.

The services of this machine are not limited to renovating carpets. The connection between the brush casing and the fan casing is provided with a two-way cock which enables

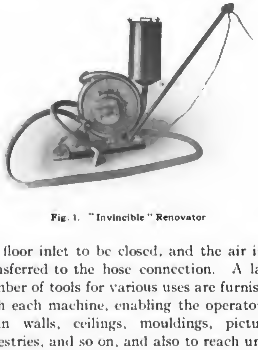


Fig. 1. "Invincible" Renovator

the floor inlet to be closed, and the air inlet transferred to the hose connection. A large number of tools for various uses are furnished with each machine, enabling the operator to clean walls, ceilings, mouldings, pictures, tapestries, and so on, and also to reach under radiators and other inaccessible places. By transferring the hose from the inlet to the discharge, and using an atomizer tool, a room may be disinfected in a most thorough manner. This machine affords an excellent means for renovating pillows and feather beds; first, by going over the outer surface with the suction tool, and second, by transferring the hose to the discharge outlet and "blowing up" the pillows, so to speak, with a special tool furnished with the machine.

In this manner the pillow is thoroughly cleaned, and the feathers are agitated and aerated.

The machine is built of aluminum with the exception of the motor, and is so light that a woman can operate it with ease. It is mounted on two rubber tired wheels, and

Fig. 2. Renovator Aerating Bedding

the amount of surface that comes in contact with the carpet is very small.

The motors are of the General Electric Company's semi-standard type, designed for this particular machine, and can be furnished for 110 or 220 volts, direct current or single-phase alternating current. The starting features of the machine are very simple, it being merely necessary to turn the small snap switch located on the motor, thus completing the circuit, and the motor will drive the fans up to full speed.

The machine commends itself to a wide range of usage, and the owner will frequently find new and unique methods of applying either the suction or the pressure connections

It is interesting to note that several machines have been installed in up-to-date garages for cleaning and renovating the automobiles as they come in from the road. For theatre renovating it has proven indispensable, and this fact is evidenced by the large number of machines installed in the various theatres throughout the East. The machine can also be used to good advantage for cleaning horses, and should appeal particularly to owners of large livery and boarding stables.

as it can be moved from one part of the stable to another, providing a flexible and convenient method of cleaning the horses.

cleaning and disinfecting in the home and office buildings, but this machine affords him a cheap, portable and efficient method of

Fig. 3. Renovator Removing Dust from Window Curtains

The average person does not fully appreciate the dangers arising from improper keeping carpets, rugs, chairs, etc., in a thoroughly sanitary condition.

A MOTOR DRIVEN LAUNDRY

By L. E. Smith
Small Motor Department General Electric Co.

In discussing the advantages of the electric drive with customers they frequently reply, " Yes, electric power is very convenient and has many advantages, but I cannot afford to pay for the increased charges entailed by its use. I require steam, anyway, so that the use of the steam engine for power adds little to my expenditures."

The numerous benefits which result to a customer from installing electric drive do not appeal to such persons, unless it can be shown, in addition, that the electric motor will reduce, at least slightly, the monthly cost of power. General statements regarding possible savings have little or no convincing effect. If the order of such a prospective purchaser is to be secured, he must be shown by actual figures that the purchase and use of electric motors means a saving of so many dollars and cents per month. A careful comparison of the customer's present power cost when using his steam engine, with a close estimate of the power cost when employing electric motors, will frequently astonish the prospective customer, and discredit his argument that electric power is more expensive, notwithstanding its added conveniences.

Fig. 1. General Electric Motor Driving Washing Machine

Possibly the proprietors of steam laundries are more difficult to convince than others that the use of electric motors and central station service will be less expensive than older means of power supply, because they actually require a steam boiler in their work all the year, and argue that the added cost of operating a steam engine under these conditions is almost neg'igible.

Therefore, in the following tabulation it may be of interest to note the relative costs of the two methods, based on actual figures taken from the records of an electrically operated laundry that has been in satisfactory operation for the last year.

WITH STEAM ENGINE

Item	Dollars per Month
Coal	$60.00
Labor	62.50
Water	16.00

WITH ELECTRIC MOTORS

Item	Dollars per Month
Coal	$25.00
Labor	12.50
Water	11.00
Electric current . .	45.00
Steam engine, Total	$138.50
Electric motors, Total.....	93.50

Saving over steam drive, $45.00 per month, or $540.00 per annum, which is equal to one year's interest at 36 per cent. on the investment required. In addition to covering interest on the investment at 6 per cent., the saving will return the entire cost of the change from steam to electric drive in three years and four months, no allowance being made for the old engine.

It will be noted in the above tabulation that no comparison has been drawn between the cost of maintenance of the two systems. As an actual fact, this amounts to practically nothing in the case of electric drive, while with the steam engine repairs are frequent

Fig. 2. General Electric Motor Driving Laundry Mangle

and expensive, due not only to their actual cost, but also to the value of the time lost during repairs, as the whole plant goes out of service when there is any trouble. In addition to all this, the cost of oil is greatly reduced, as well as the cost of belts and the maintenance expense of shafting.

Under the same conditions, a laundry in another part of the country might show a much greater saving, due to the fact that it was located in the heart of the coal district, where soft coal can be purchased at the rate of from $1.50 to $1.75 a ton; whereas in other parts of the country, the cost per ton runs up to two or three times this amount.

The rate of 5½ cents per kilowatt hour compares favorably with the rates of many other central stations, and a water rate of 9.3 cents per thousand gallons is a fair average.

The laundry herein referred to has in service a total of 16 General Electric CQ motors, which are distributed as follows:

One	5	h.p. motor	operating	carpet cleaner,
Two	5	h.p. motors	"	washing machines,
One	2½	h.p. motor	"	collar ironer,
One	2½	h.p. "	"	mangle,
Two	2	h.p. motors	"	extractors,
One	½	h.p. motor	"	exhaust fan,
One	½	h.p. "	"	bosom ironer,
One	½	h.p. "	"	starcher,
One	½	h.p. "	"	blower,
One	½	h.p. "	"	body ironer,
One	¼	h.p. "	"	collar shaper,
One	¼	h.p. "	"	collar starcher.

The two accompanying illustrations show the typical methods used in making the installation—suspending the motors from the ceiling and employing only light countershafting, and as little of that as possible. The chief advantages of an individual drive are obtained by doing away with long series of line shafting and belting, as in this way the machines are entirely independent, and may be so operated as to best meet daily conditions of business.

If a prospective customer can be shown as favorable a proposition as the above, based on his present power cost and an estimate of electric power, he can no longer say, "Does it pay?" but, "Can I afford to do without the electric motor?"

A MODEL SMALL ISOLATED PLANT

By Edw. E. Peasley

Dreamy, picturesque Vineyard Haven!—probably the last place one would naturally expect to find an installation of man's latest and greatest development in the steam engineering line—the Curtis steam turbine.

This town, tucked away on Martha's Vineyard, a half hour's sail from the southern

Powerhouse of Luxemoor Co., Vineyard Haven, Mass.

coast of Massachusetts, is the Mecca of pleasure seeking vacationists from June to October, and its quaint old houses and winding streets give no indication that enterprise would locate here, or if established, would install a plant which lends excuse to the caption of this article.

The plant mentioned is that of the Luxemoor Company, manufacturers of fancy leather, and consists of a 25 kw., 125 volt Curtis turbine-generator, furnishing current for power and lighting in the factory. The treatment of the entire installation has been in accord with the best modern engineering practice, and shows the result of careful planning intelligently carried out to the smallest details.

The power house is located about twenty-five feet from the factory and is a one-story building built of natural field stone laid in cement. Its appearance is pleasing to the eye, and its location, under the brow of a slight hill, is such that the discharge of the exhaust is not prominent from the main street, which contains many beautiful summer residences in the immediate vicinity. Unlike the exhaust from reciprocating engines, that from the Curtis turbine is noiseless, thus eliminating another objectionable feature.

Fig. 2. 25 Kw. Curtis Turbine-Generator Installed in Luxemoor Company's Power House

The power house (Fig. 1) consists of two rooms separated by a heavy fire wall, one room containing the 50 h.p. tubular boiler supplying steam at 125 lbs. pressure; the other room the turbine set and a two panel black slate switchboard, consisting of a generator panel and a four-circuit feeder panel (as shown in Figs. 2 and 3). The floor in both rooms is of cement, finished smooth. The generator room was made of size sufficient to accomodate another 25 kw. turbine unit, although hardly large enough to take in a reciprocating set of like capacity.

Power is delivered to a short line shaft in the factory by a 20 h.p. slow speed motor of the CLB type; and from this shaft are driven the five or six machines used in their processes.

The owners are loud in their praise of the small turbine, stating that since the apparatus was installed in 1906, it has never been out of commission, and that they have not expended a cent for repairs of any kind. They are further convinced that their fuel cost is much lower than would be the case if a reciprocating engine were used, due to the

Fig. 3. Switchboard of Power House

well maintained efficiency of the turbine. The cost of attendance is practically negligible, as their fireman acts as engineer and has considerable time for other duties outside the power house, the turbine requiring almost no attention.

NOTES

EASTERN NEW YORK SOCIETY OF CHEMISTS

The fact that interests other than electrical are being fostered and developed in Schenectady through social organization, is shown by the formation of an Eastern New York Society of Chemists, in the Laboratory at Union College, December 16th.

The meeting was addressed by Marston T. Bogart, Ph. D., of Columbia University, President of the American Chemical Society and of world-wide reputation for researches in the field of organic chemistry.

The subject of Dr. Bogart's remarks, "Stereo Chemistry," was handled in a masterly and most interesting manner, and each person present was enabled to follow the speaker closely by the aid of the diagrams and excellent models shown.

Following the address, organization was effected by the election of officers, as follows:

President, Dr. W. R. Whitney, of the General Electric Research Laboratory; Vice-President, Prof. Edward Ellery, of Union College; Secretary, F. C. Zapf, Research Laboratory of the General Electric Company; Treasurer, L. M. Willey, Research Laboratory of the General Electric Company.

The officers, with the three following gentlemen, were elected as an Executive Committee, to arrange for further meetings and programs for the Society: Dr. Wm. P. Mason, Rensselaer Polytechnic Institute, Troy; Mr. John Hurley, Little Falls; Dr. Edward J. Wheeler, State Department of Agriculture, Albany.

The Society embraces a territory lying within a radius of sixty miles of Schenectady, and many noted workers in the field of chemistry are included within this boundary. It is planned to hold meetings monthly during all but the summer months, and it is expected that some of the ablest authorities on chemical science in the country will be heard here under the auspices of this organization.

Application has been made to the American Chemical Society for a charter as a Local Section, and it is expected that action will be taken on this matter at the Chicago meeting, December 31st to January 4th.

PITTSFIELD SECTION A.I.E.E.
Season of 1907-1908

The Pittsfield Section of the American Institute of Electrical Engineers has started its season most auspiciously, and has an interesting series of meetings planned for the coming year. The Section has adopted the plan of admitting "local" and "student" members on payment of one dollar and fifty cents and one dollar, respectively. As a result of a careful canvass by an active committee, the membership has been increased by rapid strides from about twenty-six members on last year's roll to two hundred and two members, between the dates of November 2nd and December 6th.

In addition to the meetings of the Executive Committee, three regular meetings have been held.

The first meeting of the Section, which was held on November 2nd in the attractive parlors at the Wendell Hotel, was addressed by Mr. D. B. Rushmore, of the Power and Mining Dept. of the General Electric Co., Schenectady, who spoke in a very interesting manner on the organization and work of the Institute, and the work of the Schenectady Section. Mr. Rushmore's remarks were especially appropriate for the opening meeting, and greatly assisted the officers of the Pittsfield Section in stirring up an active interest in the work. The Secretary gave a list of the speakers who had consented to present papers before the Section. Forty-one new members were enrolled by the Membership Committee at the close of the meeting, and an informal reception and smoker added to the enjoyment of the occasion.

The second meeting of the Section was held on November 14th and, on account of the increase in membership, the meeting had to be held in the large dining room of the Wendell Hotel. One hundred and ten members were present, who listened attentively to a very interesting lecture by Mr. H. H. Barnes, Jr., on the "Curtis Steam Turbine." Mr. Barnes gave a very clear and comprehensive description of the construction and operation of the turbine, and brought out a large number of special features of the Curtis machine, especially in regard to matters of economy in floor space, steam comsumption, etc. The lecture was illustrated with lantern slides, and a feature of the evening was a number of humorous slides which provided amusement for both the speaker and the audience.

An audience of one hundred members greeted Mr. E. B. Merriam at the third meeting, held on the evening of December 6th. Mr. Merriam selected as his subject "Some Notes on High Power Testing," and described a large number of developments in the design of apparatus for controlling electrical equipments of large capacities. The talk was illustrated with a large number of lantern slides, showing the construction of the later styles of circuit breakers, oil switches, fuses, relays, etc., and the same devices under tests. Oscillograph records were also shown and a brief description was given of the construction and operation of the oscillograph.

Following the lecture, there was a brief discussion of the points brought out during the evening.

It is the aim of the Committee to have the majority of the meetings of a popular nature, and as informal as possible. Special features are to be introduced from time to time to provide some amusement, and to break away from the regular routine.

The Executive Committee for the Pittsfield Section for the year is: Mr. Joseph Insull, Chairman; Mr. Henry L. Smith, Secretary; and Mr. W. A. Whittlesey.

* * * *

The new gas-electric car, described on page 101 of this issue of the REVIEW, received official test on January 15th, the run being made from Schenectady to Delanson, thence to Albany, Troy and back to Schenectady. This route was eminently suited for testing the car on curves and grades; and its performance was even more satisfactory than had been anticipated. A party of officials and engineers from the Delaware & Hudson Railroad, the American Locomotive Company and the General Electric Company, attended the trial trip.

* * * *

The following Bulletins have been issued by the Publication Bureau of the General Electric Company, since publishing the previous list, to be found in the November number of the REVIEW.

4540 Parts of GE-90-A and B Railway Motors.
4541 Parts of Edgewise Parallel Rod 220 volt, D.C. Multiple Enclosed Arc Lamps, Forms 7 and 6.
4542 Concentric and Inverted Diffusers.
4543 Parts of R-53-A Controllers.
4544 Continuous Current Railway Switchboards.
4545 Single-phase KG Motors.
4546 Electrification of the West Shore Railroad.
4547 Parts of CO-2002-E Crane Motors, 250 and 500 Volts.
4549 Thomson High Torque Induction Test Meter, Type IB-2.
4550 Form G, P and K Circuit Breakers.
4551 Thomson Horizontal Edgewise Instruments, Type H, for Switchboard Service.
4553 Parts of BJ Connection Boxes.
4554 Portable Instruments, Type P-3.
4555 The Electric Drive in Cement Plants.
4556 Series Luminous Arc Rectifier System.
4557 K-34, K-35, and K-36 Controllers.

TWO DOLLARS A YEAR TWENTY CENTS A COPY

GENERAL ELECTRIC REVIEW

VOL. X, No. 4
PUBLISHED MONTHLY BY
GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU
SCHENECTADY, NEW YORK
MARCH, 1908

60 KW. INDUCTION FURNACE

(Copyrighted by American Electric Furnace Co.; reproduced by permission.)

GENERAL ELECTRIC REVIEW

VOL. X, No. 4 | MARCH, 1908

CONTENTS

TYPE CY 19 1/4 H.P. PORTABLE VENTILATING SET FOR UNITED STATES NAVY

(See page 194)

VOL. X, No. 4 SCHENECTADY MARCH, 1908

GENERAL ELECTRIC REVIEW

CENTRAL STATION REDEVELOPMENT OF WATER POWER*

By ROBERT E. HORTON,
HYDRAULIC ENGINEER

The object of this paper is to present a resumé of the advantages that may result from the substitution of central hydro-electric power stations with short transmission lines to the mills, in place of the present systems of power development and distribution at many existing water power centers.

Advantages of Redevelopment

As compared with an entirely new power undertaking, the redevelopment of existing water powers presents certain advantages.

(1) In original development a market must, as a rule, be created either by displacing existing motive power—usually costly steam plants—or else by creating or attracting new industries. Furthermore, the power must usually be transmitted several miles, and right of way and franchises obtained, often under conditions of competition.

(2) In redevelopment, the power is at the site where it is to be used; a part will be taken by established and operating concerns that have hitherto used the same power, and these will be the best customers for the additional power created. Their existing water wheel plants will be displaced, it is true, but where these are old, leaky and inefficient, as is very commonly the case, the riparian owner will be relieved of the cost of replacement and repairs, and will often gain valuable land and room, formerly occupied by canals, flumes and penstocks.

In order to induce a riparian owner to join in a scheme for redevelopment, he must be approached with arguments showing the advantages of the scheme, compared with a continuation of the existing system of development. This may be done in part by outlining the disadvantages of the methods in use.

(3) In general, redevelopment will result in a large gain in the power available. This will be accomplished through an increase in the average head, efficiency of turbines, reduction of waste and leakage, and better utilization of pondage. These matters will be discussed in detail as we proceed.

(4) With redevelopment, the necessity of crowding the mills into a narrow compass accessible to the hydraulic canals will be removed, and manufacturing districts will be afforded a chance to expand.

Early Methods of Utilizing Water Power

The system of power distribution in use in many of the older water power cities consists of a series of head races, or hydraulic canals as they are called, carrying the water to the mills where it is to be used. At the time the earlier developments were made, overshot and breast wheels were in vogue, and to accommodate these, the fall, if it exceeded twenty or thirty feet, was divided into two or more levels. A large water power in Northern New York wasted, until recently, two-thirds of the available fall, and gave as a reason, that it was impracticable to operate a saw mill on a head of more than 16 feet.

The sub-division of the head into several levels also increased the opportunities for dividing the power into small units, and enabled the area supplied with power to be extended. As a rule, the tail races of mills taking water from one level discharge into the next level below.

The distribution and return systems of canals often become very complex, as head canals occupy valuable space, and tail races sometimes have to be excavated or tunnelled

* Lecture delivered before the Schenectady Section A. I. E. E.

TABLE NO. 1

Examples of the Hydraulic Canal System of Water Power Development

Compiled by Robert E. Horton, Hydraulic Engineer

River	Location	Drainage Area Sq. M.	Total Fall Ordinarily Available: Feet	Total Fall Ordinarily Available: Air Line Distance	Estimated Permanent h.p. available	Present Development: Hydraulic Canals: No.	Present Development: Hydraulic Canals: Total Length Feet	No of Levels	Number of Mills	Heads under which Water is used	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	
Merrimac	Lawrence, Mass.	4625	28	5700	11000	2	7700	1	About 22	20 to 28	
Merrimac	Lowell, Mass.	4083	33	7000	11845	10	26200	2	" 10	14, 19	
Merrimac	Manchester, N. H.	2839	51	——	12000	3	12600	2	" 13	21, 30	
Connecticut	Holyoke, Mass.	8000	61	3250	14000	3	18500	3	" 50	36+12, 20+26	
Mohawk	Cohoes, N. Y.	3150	104	3600	9450	9	17500	5	" 30	18+25+22.5+19 +19	
Mohawk	Little Falls, N. Y.	1306	30	1000	1500	4	2400	2–3	"	8+18	State dam and Middle dam
Raquette	Potsdam, N. Y.	1000	10	Small	500	4	Small	1	" 9	10	
Saranac	Plattsburg, N. Y.	630	15	at dam	300	2	Small	1	" 6	4, 11, 10	
Oswegatchie	Ogdensburg, N. Y.	1609	8-12	Small	600	1	About 2500	1	" 16	8 to 12	
Black	Watertown, N. Y.	1900	70	4500	5600	4	——	1	" 7	10 to 17	Upper Fall Sewall Island
						3	——	1	" 8	11 to 18	Lower Falls Sewall Island
						4	——	1	" 10	8 to 20, 25	Upper level Beebe Island
						4	——	1	" 6	10 to 12, 15, 18	Lower level Beebe Island
Black	Black River, N. Y.	1880	16	500	1200	4	Small	1	" 9	8, 10, 11, 13 to 15	
Black	Carthage, N. Y.	1850	55	4750	3800	3	Small	1	" 3	11 to 13	Tannery dam
						2	600	1	" 14	6 1/2 to 9 1/2, 17	State dam
						1	Small	1	" 2	9, 18	Lower dam
Seneca	Baldwinsville, N. Y.	3120	11	2000±	500	3	3000	1	" 10	8 to 10	
Oswego	Oswego, N. Y.	5000	20	Short	2500	2	7000	1	" 15	16 to 20	Oswego and Varick Canals
Grand	Grand Rapids, Mich.	4900	14	2000±	2100	2	6300	1	" 12	8 to 14	
Hudson	Troy, N. Y.	8000	7-10	Small	1200	2	1200	1	" 8	7	

TABLE NO. 2

Examples of Cascade Development of Water Power

Stream	Location	Fall in Feet	Air Line Distance Miles	Drainage Area Sq. Miles	Storage Millions of Cu. Ft.	Estimated Permanent H. P. Available	Present Development: Number of Dams	Present Development: Number of Mills	Present Development: Fall now Utilized, Feet
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rondout Creek	Napanoch, N. Y.	About 150	1.0	95	Honk Lake	300	7	9	125±
N. Chuctenunda Creek	Amsterdam, N. Y.	About 300	2.1	33	Ponds	100	Several	Many	——
Poestenkill	Troy, N. Y.	200	0.4	95	Ida Lake	300	4	12	120±
Lake George Outlet	Ticonderoga, N. Y.	About 225	1.25	234	45 Sq. M.	3000	3 or 4	10 or 15	140-160
Moodus Creek	E. Haddam, Conn.	350	2.0	Few	196	800	13	13	346
Pine Brook	Pokatapaugh, Conn.	460	7.0	Few	259	800	19	19	339
Hockanum River	Rockville, Conn.	Over 250	Short	79	680	1500	11	13	254
Hoosic River	Schaghticoke, N. Y.	100	1.0	635	Small	2210	4	5	70
Battenkill	Middle Falls, N. Y.	140	1.6	454	600 Acres	2170	2 or 3	5 to 8	——
Seneca River	Seneca Falls, N. Y. *	49	0.8	770	Large	1529	3 or 4	10 or 15	26-39
Keuka Lake Outlet	Penn Yan, N. Y.	277	6-8	187-213	17.5 Sq. M.	5980	——	6	63.5
Genesee River	Rochester, N. Y. *	255	2.0	2475	Lakes	8970	3	About 50	200±
Fish Creek	Schuylerville, N. Y.	100	1.0	258	6.8 Sq. M.	2200	2 or 3	4 or 5	60-90

* May also be considered as belonging to the hydraulic canal system of development.

under buildings or superior canals. The above described method may be called the *canal system of development.*

Throughout the New England States there are numerous small streams entering the larger stream valleys through narrow precipitous channels, and in many cases natural or artificial lakes exist on the highlands. At many such places a small steady volume of flow, under a great head, may be obtained at points bordering on the large valleys, which are the main highways of commerce. The pioneers selected these small steady streams and built mills on their banks to grind grain and saw lumber. Large water powers were left untouched because of the great cost of development and the impossibility of utilizing large volumes of water with the old-fashioned water wheels. Thus the sites of future cities were often determined by small streams, and industries were founded that have since vastly outgrown the water power on which they were at first dependent.

In the early days, as the industries increased in number, one dam after another was built along the stream. Often these dams are but a few hundred feet apart and there may be ten or twenty of them in a single village. As a rule, the crest of each dam is placed lower than the level of the tail race of the mill above by an amount sufficient to prevent backwater.

There is usually a loss of head, varying from a few inches to many feet, between every two dams. Usually the most desirable sites are first developed, and a considerable portion of the total fall is often left unused, or, if used, is afterward abandoned. The great cost of constructing and maintaining so many small dams is evident, and in view of the desirable location of the power, it appears that in many cases redevelopment under a single fall would pay a liberal return. This system of utilizing water power may be called *cascade* development.

Examples of the Canal System of Development

The examples given in Tables 1 and 2 have been chosen mostly because of historical or local interest. It is quite certain, however, that central station redevelopment would be a very profitable undertaking at a number of these places, as well as at many others not included in the list. In the tables it has only been possible to give a very meagre resumé of the conditions at each place. The permanent horse-power estimated is not to be considered as a close figure, but is given to convey an idea of the magnitude of power available. Of course the economical basis of development would in most cases be much greater. A comparison of columns 4 to 11 of Table 1 shows the wasteful method

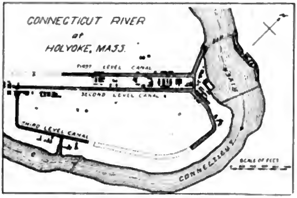


Fig. 1. Map Showing Development of Water Power on Connecticut River at Holyoke, Mass.

of development made necessary by the canal system where the water has to be taken to the mills, only a few of which can be so placed as to utilize the full available head. In fact, very many mills at these older developments only utilize from one-half to three-quarters of the fall. A few of these water powers will be described with a little more detail.

Fig. 1 shows the general scheme of development on the Connecticut River at Holyoke. A total fall of 61 feet is available in a distance of about 3250 feet below the dam. The raceways have a total length of 18500 feet, and occupy an area of nearly twenty acres. Most of the water is used on two levels, the total fall utilized being from 46 to 48 feet. The natural conditions are favorable for central station redevelopment, and by such a change the greater part of the canals could be abandoned and valuable land reclaimed where factories are now closely crowded. The permanent power could probably be increased one-fourth to one-third, the measurement and sale of power greatly simplified, and the use of surplus power facilitated and increased. Something like 150 turbines, many of them of old patterns, could be dispensed with, together with their attendant paraphernalia of screen racks, flumes, penstocks, wheel pits, draft tubes and harness. There are about sixty mills using approximately 30,000 h.p. during the day time and about one-half as much at night. Complete redevelopment is probably impracticable, as most of the power was originally sold on long term leases, carrying title to land for factory sites with water power.

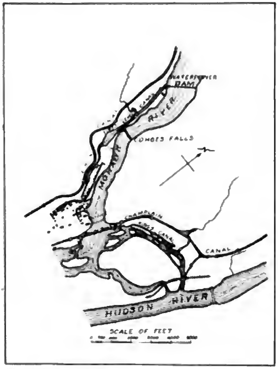


Fig. 2. Map Showing Water Power Development on the Mohawk River at Cohoes and Waterford, N. Y.

Fig. 2 shows the power development on the Mohawk river at Cohoes and Waterford. There is a total fall at Cohoes of 120 feet, of which 103 or 104 feet is developed. Nine canals are in service, having an aggregate length of 17,500 feet, and an area of about 22 acres. There are five levels, but the water is used under various heads, the principal combination of falls being 18, 25, 22.5, 19 and 19 feet, making a total of 103.5 feet. The horse-power of the wheels in use a few years ago was 6556. There are some thirty or forty mills, and the map fails to give an adequate idea of the complexity and number of raceways, wheel pits and turbines necessary to the use of the water on so many levels. The dam of masonry is a permanent structure, which cost $180,000, and the main or first level canal is admirably located for incorporation in a central redevelopment scheme. In fact, the cost of the power station and a short conduit would constitute nearly the entire expenditure necessary. Here, as at Holyoke, outstanding leases are a hindrance.

Fig. 2 also shows King's Canal on the fourth branch or "sprout" of the Mohawk as it debouches into Hudson River. Here are eight or ten mills operating under a low head, cramped for building room, and liable to inundation during freshets. The water rights appear rather uncertain, and the water level is sometimes drawn down in summer to the detriment of all. The Mohawk has four or five outlets, but only one of these is dammed, so that at best the water supply is limited. There are evident opportunities for improvement by redevelopment, but as is often the case on power canals, everybody's business is made the business of nobody, and matters stand as they were sixty years ago, although in the midst of a thriving and populous manufacturing district with admirable shipping facilities.

Fig. 3 shows the water power on Seneca River at Baldwinsville,, N. Y. Here a low head of 11 feet is combined with the flow of a large and remarkably uniform river. A navigation canal on the left bank is also used as one of the raceways, and there are in all about ten mills, and forty or fifty turbines. Many of the turbines are very old scroll pattern wheels which have the reputation of disposing of all the water that can get to them, and are sometimes termed "water

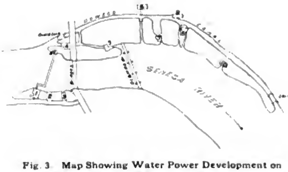


Fig. 3 Map Showing Water Power Development on Seneca River at Baldwinsville, N. Y.

sows." There is no systematic control of the usage and draught of water—some mills have burned down, and the water flows unhindered through the abandoned flumes. The various leakage losses that I have repeatedly measured often aggregate 500 cubic feet per second, or more. I visited this place last summer at a time when the water was drawn two and one-half feet below the flashboard crest, nearly one-fourth of the head thus being directly lost. The power could easily be redeveloped by using the existing masonry dam and one short canal.

The conditions at Black River, N. Y., shown in Fig. 4, are chosen as a single example of many apparently good opportunities for redevelopment in this important wood pulp and paper mill region. Here, as is often done elsewhere, a mill not reached by the flume or canal is supplied with power by wire rope transmission. A fall of 16 feet is available, yet some of the mills operate under heads as low as eight to ten feet. In this connection it may be noted that in the city of Watertown there is a total fall in Black river of 122 feet, seventy feet of which occurs within a distance of 4500 feet. This latter fall is at present developed by means of three dams, having fifteen hydraulic canals on four levels. There are twenty-five or thirty mills, and the total fall utilized in some cases is as small as forty feet, or four-sevenths of the available drop.

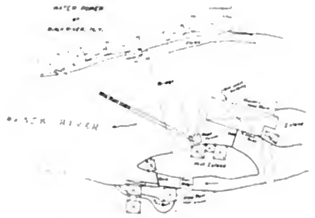


Fig. 4 Map Showing Water Power Development at Black River, N. Y.

Examples of Cascade Development

The data given in Table 2, like that given in Table 1, is chosen largely from the results of personal visits and investigations.

Fig. 5 shows the Battenkill between Middle Falls and Greenwich, N. Y. Here a fall of 140 feet could be obtained in a distance 1.6 miles. Redevelopment might be made by means of a power canal following the hill brow contour 350 feet from the dam to a point A, and thence a pressure conduit crossing the stream and leading to a power house at B. There are at present two or three dams where part of this power is used by several mills.

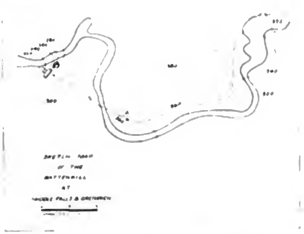


Fig. 5 Battenkill Between Middle Falls and Greenwich, N. Y.

Fig. 6 is a sketch map of the Hoosic river in the vicinity of Schaghticoke, N. Y., where a total fall of 100 feet occurs within an air-line distance of about one mile. Approximately 70 feet is at present developed by means of several dams. The dotted line AB shows a suggested course for a cross-country power canal, the water being led from B down the steep hill slope to a central power station at C, and thence discharging through an excavated channel into the river at D.

Fig. 7 is a sketch map of the outlet of Saratoga Lake at Schuylerville. Here again is a fall of 100 feet, now partly developed and used by several mills. The plan of redevelopment would be much the same as described for Schaghticoke.

Fig. 8 shows Lake George outlet at Ticonderoga, N. Y., where there is apparently an unusually good opportunity for redevelopment. The yield of a drainage area of 234 square miles is regulated by Lake George, which has an area of forty-five square miles. There is a total fall of about 225 feet, of which perhaps 150 feet is at present fully utilized at several dams. It appears that a power canal, about one mile long, could be constructed from A to B without difficulty, and the water conducted from the latter place by pressure conduits to a power house at C.

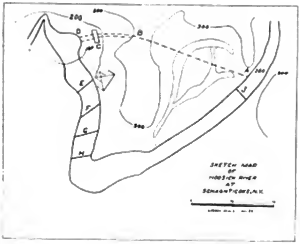


Fig. 6. Hoosic River in the Vicinity of Schaghticoke, N. Y.

Mutual Interference of Mills and Waste of Pondage

Where power is developed at successive dams under the cascade system, or where the same water is used on two or more levels in the canal system, the lower riparian owners are, in times of deficient water supply, largely at the mercy of those above.

I will illustrate some of the aggravating conditions that arise, such as have been the source of numerous and interminable law suits.

An upper owner A has a large pondage and runs his mill ten hours per day, utilizing a large part of the night inflow by means of pond storage. At a dam farther down stream B wishes to run his mill twenty-four hours per day, but requires less power than A. Under the conditions assumed he gets little or no power at night until A's pond has refilled, while he may be obliged to waste a large part of the day time flow past his mill. If A and B change positions the condition will be no better. Again, suppose there are on the same stream an electric plant running nights and a mill running daytimes, and that the uppermost has pondage sufficient to hold back the inflow when it is idle; it is evident that the lower plant may at times be deprived of almost all useful power. Consider a dozen successive dams, each with a pondage just large enough to control the low water flow for an hour or two, but with a total capacity sufficient to hold back a full day's flow. This is a case of quite common occurrence. Now consider these mills as operating through various hours, one requiring much power when another needs but little. It will be seen that the distribution of the power to the mills, especially those lower down, is a merry game of chance.

In general, the greater the diversity of conditions of use, the greater the waste by mutual interference under the cascade system of development.

In some cases of cascade development on streams fed by lakes, agreements or court decrees exist regulating the rate and time of draught from storage. This is at best a partial remedy, and virtually amounts to

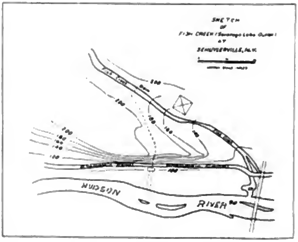


Fig. 7. Saratoga Lake at Schuylerville, N. Y.

operating the mills to suit the power, rather than the power to suit the mills, as can be done with redevelopment under a single head.

The Theory of Pondage

Where mills operate only part of each twenty-four hours, say ten hours for example, it is a common practice to draw down the pond level during the running hours, and so utilize such a part of the night inflow as is required to refill the pond. Where there are several mills drawing water from the same dam, the water is often drawn down below the crest level to such an extent as to greatly reduce the head and effective power available.

With any given inflow rate Q in cubic-feet-seconds, initial head H in feet, hours run N, and pond area A in square feet, there is some depth D′ of pond depletion that will yield the maximum amount of power. By an application of the calculus the following expression for the depletion can be derived:

$$D' = \frac{AH - 1800\ NQ}{A}$$

For example, with A = 5 acres = 217800 square feet, N = 10 hours, H = 20 feet, and Q = 200 cubic feet per second, we find D′ = 3.47 feet.

In other words, more power could be obtained during ten hours if the pond was drawn down a certain number of feet each day and allowed to refill at night, than if the drawing down of the head was either

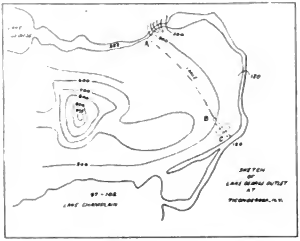


Fig. 8. Lake George Outlet at Ticonderoga, N. Y.

greater or less. In many cases the variation in the amount of power obtainable as a result of the varying utilization of pondage is very large.

In canal and cascade developments the utilization of pondage is usually a matter of chance and guess work. With central station redevelopment, the power being under a definite control, economical use of pondage becomes practicable.

Measurement and Division of Power

To prevent the reduction of the head by drawing down the pond level, and to regulate other abuses sometimes incident to divided water powers, the regulation of the water supply to the mills is often placed in the hands of a commission or water-master. Under the most favorable conditions the division of a variable stream among several mills, running at different hours and with varying needs for water, it is a difficult matter. The water used cannot ordinarily be measured by weirs placed in the head and tail races without too great a loss of head. Submerged weirs are sometimes used, which cause a smaller loss of head, but these are usually less accurate and reliable than weirs with free fall. In other places the water used is estimated from a record of the head and run of water wheels at the mills. Daily measurements of the flow in the hydraulic canals by means of rod floats is the accepted method in several of the older water power centers. All these methods are costly and difficult to carry out, and the results are often unsatisfactory. With a central hydro-electric station both the total power delivered and the rate of use of power by each mill may be constantly open to inspection, and abuses can be regulated without awaiting the results of elaborate measurements and calculations.

Increased Efficiency from Redevelopment

Minor losses of head, such as are met with in power canals, screen racks and penstocks can be little reduced. Obviously there is little real difference whether six inches of head is lost on one-tenth the flow of a stream in each of ten canals, or on the entire flow in one canal, although there will be some gain in head by a reduction in the length of the canals, and by the use of clean racks, and canal gates and waterways of adequate size. A large gain in efficiency may often result from discarding antiquated, worn-out, poorly set and inefficient water wheels, many of which utilize only part of the head; and by the use of a smaller number of large wheels, mostly operating at full gate, to replace a greater number of wheels of promiscuous types and sizes, with their attendant losses by step friction and mill work. With individual power plants nearly every mill will have one or more wheels operating at part gate and low efficiency, while with a central power plant all the water wheels, excepting one or two, as a rule, can be operated at an average load and gate near to the point of maximum efficiency. Out of a total of 371 turbines in use in the Black river region in 1898, I found 101 which were ordinarily operated at part gate, while a much larger number were so operated at times. Of these wheels, 195 were not over 36 inches in diameter, and were largely used in wood pulp grinding where wheels of large capacity, operating at full gate, can be used to advantage. In one mill 36 old small register gate turbines were in use, doing work that might have been done by about one-fourth as many large modern wheels.

The better class of American stock pattern turbine water wheels have been developed from tests made at Holyoke, under a head of about 16 feet. For heads much greater than this it is probable that better results can be obtained by the use of wheels of special design. Redevelopment under a single head offers excellent chances for the development of hydraulic turbo-generator units, specially suited to the conditions, as is done with steam turbo-generator units.

Unused Water Privileges

At very many of the older power developments a portion—often one-fourth to one-half—of the water privileges have never been developed, or have been abandoned. Taken singly these unused privileges may be of little value, but collectively they often represent an important source of power in an ideal location.

Under the canal system of development, power belonging to unused privileges is often utilized rent free by operating concerns. Apparently such surplus power should be distributed among the various users. With the canal system the surplus usually goes to the plant that has the largest excess wheel capacity, and not infrequently, I regret to say, it goes to the biggest hog on the power canal.

In the cascade system of development by successive dams, the power at unused privileges is usually wasted. With redevelopment the unused privileges can be made productive, and the resulting power sold or equally distributed. The owners of unused privileges will usually co-operate in redevelopment, because it means to them a return on an otherwise idle investment.

Electric Power Distribution

The change in factory power distribution resulting from redevelopment may be little or great as desired. For example, the motor may be simply harnessed to the line shaft in place of the water wheels, or the main line shaft may be dispensed with and motors placed in each room or on each machine. If, however, an auxiliary steam plant is used the line shafting will usually be retained, though I apprehend that in most cases individual steam plants will gradually be discarded, and the auxiliary steam plant, if any is needed, placed at the central power station.

All the arguments in favor of electric power distribution versus mill work in factories are as applicable to mills supplied from a central power station as to those generating their own power. This is a field somewhat outside the limits of my subject, and I shall not enter it in detail. The following brief summary covers the main points:

The removal of lines of shafting, hangers, pulleys, etc., will result in decreased floor loads; increased room for and accessibility of machinery; avoidance of the large friction losses from mill work; reduction in repair and operation charges; and diminished fire and accident hazards.

Power need only be used when work is done, thus increasing the economy. Easier regulation will also result, as the throwing on or off of one machine will not affect adjacent machines. Reduced vibration, greater flexibility, and opportunity for use of yard and portable machines may also be noted.

Uncertain and Conflicting Water Rights

Having noted the advantages of redevelopment, it seems at first surprising that so little has been done in this field of hydro-electrical work. One obstacle to redevelopment may be found in the existence of uncertain and conflicting water rights, which gives rise to distrust, jealousy and an over estimation of their rights by individuals. With the water rights subdivided on a definite, fair and open basis, chances for selfishness would be reduced, and the matter of dealing with the water right owners would be greatly facilitated.

In the older power developments one of two plans was usually followed:

(1) Leases were granted to lands, carrying with them water under a head, as at Holyoke, Lowell and Lawrence in Massachusetts, and at Cohoes and on the Oswego Canal in New York.

(2) The original owner sold outright to

each purchaser the right to a certain power. These sales were made on different bases. In some cases the right was given to use a specified number of square inches of water under the available head where a square inch usually meant the theoretical flow through an orifice one inch square. In other cases the right was sold to use water enough to drive a mill, or to drive machinery or water wheels of some specified kind. Examples which have come to my notice illustrating the uncertainty of such deeds are, "water enough for the run of mill stone," "water enough for a blacksmith shop and a fulling mill," "water enough for a Johnston reacting water wheel as made in 1848."

In other cases the fractional method of partition is used, each riparian owner being entitled to so many fourths, seventeenths, sixty-fourths, or other subdivision of the total flow of the stream. The words "total flow" are intended to mean the minimum available flow in some cases, the average flow in other cases, and an arbitrary or assumed quantity in still other cases. As a rule the actual amount of power available was unknown when the deeds were granted. Such indefinite deeds pass from hand to hand and from generation to generation, using the original wording. The riparian owner draws as much water as he wants, as much as he can get, or as much as is allotted him, according to his influence and the disposition of his neighbors. Further complications arise from the once prevalent custom of granting first, second and third rights. Recently in visiting the mills on a power canal, every proprietor represented to me, and apparently honestly believed, that his was the "first right."

Organization of Redevelopment

The preliminary stage of redevelopment comprises the formation of a working agreement or consolidation among the water right owners affected. There are several ways of proceeding:

(1) By buying in the existing water rights.

(2) By the formation of a trust or holding company in which each riparian owner shall receive stock in proportion to his water rights.

(3) By a combination of the above methods.

In general, undeveloped or disused water rights should be acquired outright. Operating concerns are likely to object to yielding the control in their water rights unless an agreement is made to supply them with power. There is no reason why participating concerns should not be given first chance to lease the redeveloped power, but agreements to supply power in perpetuity or to supply any indefinite or unmeasured amount of power should be avoided. In these days of water power booms and promotion schemes, riparian owners get erroneous impressions of the value of their holdings and ask exhorbitant prices. Such inflation of values should be discouraged, as it leads to non-paying investments which are likely to reflect improperly on engineers. If redevelopment is undertaken by an association of the riparian owners, the difficulty at once arises of determining not only the actual, but also the relative rights of each. In the allotment of stock and the adjustment of a basis of profit sharing, jealousies and quarrels are apt to arise that will block the proceedings.

A case recently came to my notice where the riparian owners tried to come to an agreement as to their respective rights in order to join in the erection of a new dam. One man claimed 3200 square inches, although search failed to show that more than 2500 square inches had ever been deeded to him. The assembled owners finally agreed, however, as a last resort, to allow him 3200 square inches. Thereupon he talked the matter over with his wife and soon realized that the greater his water rights the larger share he would have to pay toward the dam, and then stubbornly refused to accept what he had asked for. I lament to record that his easy natured neighbors finally built the dam without his aid.

After the unification of water rights has been accomplished, redevelopment becomes a matter of engineering of an interesting nature. In general, the existing dam, lands and canals will be incorporated in the plans as far as they are of use. It will generally be necessary to so plan the work as to avoid interference with existing mills during the construction period. Most details of the construction are common also to other water power developments, and need not be specially treated here. I will, however, emphasize the value of a continuous gauging record of the stream flow, and the necessity for a more honest, thorough and logical determination of the economical size of development therefrom, than has commonly been made in power development schemes in the past

PORCELAIN FOR ELECTRICAL PURPOSES

By E. L. Barringer

Within the past ten years the manufacture of porcelain for electrical purposes has become an important branch of the pottery industry, and a number of plants throughout the United States are engaged exclusively in its production. Porcelain as an insulating material occupies a field by itself, and probably more is made yearly than of all other insulating compounds combined, with the exception of rubber.

The characteristics which give porcelain its value to the electrical industry may be stated as follows: High insulating value; a vitrified structure which resists the entrance of water or moisture; refractoriness; resistance to oils, vapors, etc.; freedom from any tendency to warp, weaken or deteriorate in any way with age or severe service conditions; attractive appearance; ease of forming into various intricate shapes which are made permanent by firing; mechanical strength, with the exception of resistance to impact; and comparative cheapness. Other insulating materials may be superior to porcelain in this or that respect for certain purposes, but none combine to the same degree the qualities enumerated above.

Porcelain is differentiated from other ceramic products by its white color, impermeability, refractory qualities, and translucency in thin sections. Porcelain for electrical purposes is practically the same in composition as that used for high grade utilitarian and ornamental wares, and differs only in the form of the ware and the processes employed in molding it to shape.

Chemically, porcelain is a double silicate of potassium, or sodium, and aluminum. In some porcelains, lime is used as an additional base, and more rarely, magnesia. Feldspar introduces the potash, or soda, and alumina and silica; china clay and ball clay supply alumina and silica; and lastly, the additional silica needed is supplied by ground quartz or potters' flint. Thus the raw materials for porcelain consist usually of feldspar, china clay, ball clay and flint, used in the proper proportions to give the desired silicate when fired to a high temperature. The clays used are: kaolin or china clay, (a soft, white, refractory substance), and ball clay, (a buff-colored, very plastic material). China clay is very short, and cannot for this reason be used alone, which fact necessitates the use of enough ball clay to give the desired plasticity to the composition. On the other hand, ball clay cannot be used alone satisfactorily, owing to its yellowish color and its tendency to cause sticking in the molds and cracking of the ware during drying and firing.

Considered from the manufacturing standpoint, there are two classes of electrical porcelain—dry-process porcelain and wet-process porcelain—the difference being that in dry-process porcelain the mixture of raw materials is made to the form of a damp powder and pressed into shape in steel dies in screw presses; whereas in wet-process porcelain the raw material is mixed to a stiff mud or dough, made into a blank form, partially dried, and turned on a lathe to the final shape.

Dry-process porcelain is used for wiring fixtures, knobs, cleats, receptacles, attaching plugs, switch bases, etc. The parts shown in Fig. 1 indicate the field in which this quality of porcelain is used.

Wet-process porcelain is used for high tension insulation, such as is necessary for oil switches, transmission lines and transformers. This porcelain is more dense, and possesses a higher insulating value than the dry-process porcelain. As an instance of this, in one experiment the same composition, made up by both dry-process and wet-process, showed 1.7 per cent. absorption for the former method and 0.5 per cent. for the latter. Chemically, there is little or no difference between the two porcelains, but usually in the wet process a larger proportion of plastic clay (ball clay) is used than in the dry. This is to facilitate molding into the desired shape, wet-process methods usually requiring more "flow" to the body than dry-process because of difference of pressure in molding. Fig. 2 shows a group of wet-process porcelains.

With the exception of molding, the manufacture of the two classes of porcelain is practically the same, and the following description of the process applies to both, except where otherwise noted.

The raw materials—feldspar, china clay, ball clay and flint—are weighed out and conveyed to the blungers, which are cylindrical tanks containing horizontal arms revolving on a central shaft. Water is added to the mixture of raw materials in the blunger, and the mass is stirred or "blunged" until of the consistency of cream. The porcelain body in this liquid, creamy state is termed "slip." After blunging, the slip is run through a coarse sieve (which removes woody particles and other coarse matter), into an underground tank or agitator, in which revolving arms prevent any settling out of the porcelain materials. From this underground agitator the slip is pumped up and onto a fine sieve or lawn, which separates any particles coarser than 150 mesh. The sieved material falls into a second agitator, from which it is pumped to filter presses. In the filter press the water is removed from the slip by pressure, the porcelain mixture remaining in the press in the form of solid, damp cakes.

A view of the slip room in the porcelain shop of the General Electric Company is shown in Fig. 3. Individual electric drive is used, insuring cleanliness and order in the slip room, where it is highly desirable, and also permitting of the independent operation of machines which run intermittently, such as the disintegrators, pump and sieve. Any disturbance in any of the machines cannot affect the remainder of the system.

Up to this point the treatment is the same, whether the porcelain is to be wet-process or dry-process. The further preparation of the "body" or porcelain mixture now differs, according to the process for which the stock is intended.

For dry-process porcelains the damp cakes from the filter press are dried over steam coils until just the necessary moisture remains for pressing about 20 per cent by weight. The mixture, still in cake form, but not as damp as on coming from the filter press, is fed into a four-vaned disintegrator which revolves at a speed of about 1400 r.p.m., and which beats the mixture to a fine, loose, damp powder, in which form it is ready for pressing into shape. The pressing is accomplished in hardened steel dies, pressure being produced by a hand-operated vertical screw. Fig. 4 shows several of these presses of the larger size, requiring two operators. For the smaller presses one operator is sufficient.

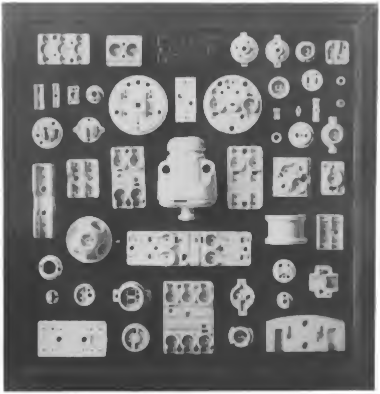


Fig. 1. Dry Process Porcelains

There are about 70 of these machines used in the porcelain shop of the General Electric Company, mostly of the Company's own manufacture, and about 1200 stock shapes are made, some of which require very complicated and ingeniously constructed molds. This equipment keeps a force of tool makers busy repairing old molds and making new ones as new designs require them. The damp clay powder "flows" well under pressure, and pieces of intricate shape, with thin walls and irregular recesses, can be molded without difficulty. In this respect porcelain has an advantage over other molded compounds which lack the plasticity of clays and will not flow so readily and uniformly under pressure.

The molded pieces are placed on pallet boards, which are stored on drying shelves, or "stillages." Beneath these shelves steam pipes are located, which supply the necessary heat for rapid drying. The drying period occupies from a few hours to several days. After the "burrs" or "fins" occasioned by the joints between the mold parts have been removed from the thoroughly dried pieces by hand brushing, the glaze is applied to the surfaces requiring it. The glaze material is used in the form of a thick liquid, or "slip," which is either sprayed on the porcelain pieces, or into which the porcelain is dipped and quickly removed, either method leaving on the ware a thin coating of the green or "raw" glaze. The glaze consists of the same materials as the porcelain body; *viz.*, clay, feldspar and flint; with the addition of calcium carbonate or whiting, which lowers the melting point sufficiently to cause the glaze to run to a smooth, glassy layer at the same temperature at which the porcelain vitrifies. The porcelains are now ready for the kiln, but as both dry-process and wet-process are fired in the same way, the wet-process ware will be first followed to this point.

Fig. 2. Wet Process Porcelains

The porcelain mixture for wet-process ware is not dried on coming from the filter press, but the damp cakes are piled up in a large mass and smashed together with wooden mallets. From this pile the material is fed in chunks by hand into a vertical pug-mill, which "pugs" and kneads the clay to form a homogeneous mass and remove enclosed air. The mixture is forced from the bottom of the machine in a horizontal stream by an auger, and from this slowly-issuing stream, or column, of clay—which is about 8 inches in diameter—sections are cut off to be molded. The clay is now a soft, plastic mass, and the sections cut off from the pug mill are placed in plaster of paris molds, which are in turn placed in a "jigger." In this machine the soft porcelain body is forced to the walls of the plaster molds by a descending coring pin, operated by a "pull-down," and the blank cylinder is thus formed. After drying over night, the blank clay piece is removed from the plaster mold and is then allowed to dry on shelves over steam coils until in a "leather hard" condition. In this state it can be cut very easily (about the same as cheese), and at the same time is sufficiently strong to retain its shape under pressure of the tools. The final contour desired, including grooves, etc., is worked on the blank piece either in a lathe or on a vertical jigger. The cutting tools are peculiar to the clay industry, and consist of triangular, oval, and irregular-shaped scrapers or cutters, knives, sticks, etc. After cutting to the desired shape, the piece is sponged off to remove tool marks, and then placed on shelves to dry.

Fig. 5 shows a porcelain "blank" from the plaster mold, and one of the same blanks machined to the final form. The same piece is also shown after being fired. The material taken off in cutting to shape removes the fine surface drying cracks, or "folds" in the materials where jammed against the plaster mold.

Drying must be carried on with care to avoid cracking or checking. Though the ware may look white and dry, yet it is often not thoroughly dry inside and will crack when fired in the kilns.

With wet-process porcelains the drying occupies from one to six weeks. The dried ware is glazed in the same manner as the dry-process porcelain. A deep brown glaze is used on a large part of wet-process porcelain, this glaze being similar in constitution to the clear or colorless glazes, but containing coloring oxides which unite with the other ingredients of the glaze to form colored glasses.

The dried porcelains, both dry-process and wet-process, are placed in "saggers," (cylindrical, fire-clay boxes), and set in the kilns. The saggers are necessary to build up the ware in the kiln, and also to protect it from the fuel, gases, flying ash, etc., preserving the clean white body and smooth, glazed surface. They are made of a mixture of fire clays and have a coarse, open structure, similar to that of fire-brick. From 900 to 3500 saggers can be placed in each kiln, depending on their height, which varies from 2 to 10 inches. In addition to round saggers, a small proportion of oblong ones are used.

The kilns are of the old potters' type, bottle shaped, with outlet stack in the middle, and six or eight fire boxes around the base. Soft coal is used for fuel. Flues from the fire boxes lead radially to the center

Fig. 3. Slip Room in the Porcelain Shop of the General Electric Company

of the kiln, and each fire box is also an outlet to the interior of the kiln over "bag walls."

The temperature is raised as rapidly as possible to between 1200° and 1400° C., and held at this point for some hours. The finishing temperature is determined either by glaze-color trials, shrinkage trials or pyrometer cones. The last named method is the one mostly used in the porcelain shop of the General Electric Company. The pyrometer cones are small, triangular cones, about 2½ inches high, composed of the same materials which enter into the porcelain composition, but

Fig. 4. Presses for Dry-Process Porcelains

varied in such a way that a series of cones is secured with softening-points ranged about 20° C. apart. A set of three cones is put in the kiln within the range of a "peep-hole," the melting-point of one of these cones corresponding to the desired temperature, while the other two cones soften or melt at 20° C. above and below this point. When the first, or most fusible of the cones has melted, indicating an approach to the proper temperature, the firing is carefully manipulated until the middle, or critical cone has softened and bent over, when the kiln is "shut off." The last cone of the series, or the most infusible, must not be melted down. A shrinkage of about 14 per cent. occurs in the porcelain mass during firing. On this account dies must be made proportionally larger than the sizes required in the finished pieces. The firing operation vitrifies the porcelain mass, or body, and fuses the glaze to a smooth, transparent coating. The firing period occupies from 25 to 45 hours, depending on size of kiln, quality of fuel, weather conditions, etc. A reducing fire gives the whitest porcelain, and the firing is usually of this character.

If the proper temperature in the kiln is exceeded, the porcelains undergo too much shrinkage, and also become rough on unglazed surfaces and bubbled on glazed surfaces. Over-firing will also cause warping, distortion, and a bluish color. Underfiring results in imperfect vitrification, insufficient shrinkage, and a yellowish tinge to the color. The glaze on underfired pieces is dull and cloudy, instead of bright and transparent. It will be seen, therefore, that correct firing is extremely important, and determines whether the porcelain is to be good or bad, no matter how carefully the work may be done up to this point

After the ware has been properly fired, the kiln is cooled rapidly and the porcelains removed and sorted.

Dry-process porcelains are removed to the shipping room, boxed and delivered to the department where they are to be assembled to form the various wiring fixtures. The burning is usually carried out with such regularity that the size of the porcelain can be depended upon within a certain small variation, and there is no difficulty in fitting together the porcelain and metal parts. A small percentage of the dry-process ware which must be unusually close to a certain size is gauged and sorted. No insulation test is required on dry-process porcelains. The vitrification and consequent non-absorption can also be depended upon regularly. The requirements specified by the General Electric Company for satisfactory dry-process porcelain may be stated as follows:

The variation in size above or below the dimensions called for must not exceed $\frac{1}{64}$ in. to the inch, except that knobs and cleats may vary in height $\frac{1}{32}$ in. to the inch. The porcelain must be well vitrified, and the absorption in an unglazed piece immersed in water must not exceed one per cent. by weight in 48 hours.

The porcelain body must be uniform and free from cracks or holes. The glaze must be bright and smooth, with no checks or pinholes, or thickening at the edges which would interfere with assembling. Glazes free from lead and such as use no lead salts for fluxes are required, as arcing tends to reduce the lead present to the metallic state.

The wet-process porcelains, on coming from the kiln, are first sent to be tested, and then to the various departments where they are assembled. Practically all of these porcelains are tested to insure their having the proper disruptive strength. The test voltage varies from 2000 to 125,000 volts, according to the purpose for which the insulators are to be used. It is a fallacy to suppose that increased thickness gives added disruptive strength. This is perhaps true within narrow limits; but, in general, increased thickness makes proper vitrification more difficult to accomplish, and the ware will contain small cracks and hollow spaces, which will break ing the insulation, the average factor of safety being 2½ to 1. A large proportion of insulators for this work are tested only in assembled apparatus, and no preliminary test of the porcelain alone is considered necessary.

In testing insulators used in high-tension transmission lines, both dry and wet tests are used, the former to insure the proper resistance to puncturing, and the latter to determine the correctness of the design for avoiding arcing under given conditions. One carefully conducted wet test is ordinarily sufficient for insulators of any one design, but every insulator manufactured must be tested as to its disruptive strength. The insulators are usually designed so as not to puncture or arc over dry, at a voltage from 2 to 2½ times that which will be carried in service.

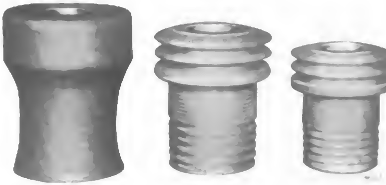


Fig. 5. Green Porcelain Blank; Same Cut to Shape; Machined Porcelain after Firing

up the continuity of the mass and reduce its resistance to puncturing voltage.

The requirements for wet-process porcelains are: a thoroughly vitrified body which will not show over 0.25 per cent. absorption when immersed in water for 48 hours; a permissible variation in dimensions of $\frac{1}{32}$ in. to the inch, above or below the given size. The requirements for the appearance and character of the glaze are the same as for dry-process ware.

In testing wet-process porcelains a great many variations are employed by different manufacturers and users. For insulators used in high-tension oil switch apparatus, or porcelain bushings used in large transformers, the test is usually only a "dry" test, as these insulations are, of course, not subjected to rain or fog or other weather conditions affect-

There are various methods of applying the test potential, the average practice with insulators of the common petticoat type being to immerse the head of the insulator in water, and, after filling the pin-hole with water, to raise the potential between top and bottom until the test voltage has been reached. Salt water is sometimes preferred, owing to the better conductivity it provides from the metal terminals to the porcelain. In one factory making a specialty of high-voltage insulators, as many as 1800 insulators can be set up and tested at one time. Here a small chain is suspended into the water in the pin-hole, while the pan containing the water in which the head of the insulator is immersed forms the other connection.

Wet tests are made by applying a spray of water to the insulator, which is mounted on a pin, while the potential is raised. Arcing between the line wire and pin should not take place at less than the service potential, nor at less than any higher voltage which may be set by the engineer. The force of the water stream and angle at which it plays on the insulator are details subject to variation. To represent conditions of a rain and wind

Fig 6. Cross Section of Link Strain Insulator

storm, the spray is sometimes applied at an angle of 30 to 45 degrees from the horizontal, or a fan is used to deflect a vertically falling spray, to cause it to strike the insulator at an angle.

In testing the disruptive strength of multipart insulators, it is the practice to give each section a preliminary test before assembling, in the same manner as the complete insulator is tested, but at a proportional potential. In determining the potential applied in testing, both voltmeter and air-gap are used, some preferring one and some the other. While the voltmeter reading may not represent the maximum instantaneous potential, the air-gap potential, on the other hand, may be influenced considerably by atmospheric conditions.

Defective porcelain punctures with a violent cracking, the path of the puncture is heated, and a small globule of fused porcelain or glaze appears on the surface. Imperfect vitrification and the presence of checks or cracks, due usually to faulty drying or burning, are the principal defects causing the failure of porcelain in test.

Of the wet-process porcelains used for high tension transmission, the commonly used petticoat type of pin insulator is well known, and its merits and limitations well understood. Within the past year the insulators of the "suspension" type have been introduced, which are intended to overcome some of the defects of the pin insulator. Fig. 6 shows the General Electric Company's link suspension insulator in sectional view and in service assembly.

The advantages of an insulator of this type may be enumerated as follows: Higher electrical and mechanical factors of safety than heretofore obtained, resulting in the transmission of energy at higher voltages; flexibility of the system, avoiding torsional strains on the cross arm or insulators exerted by a cable swayed by wind; longer spans; simplicity of construction, and security in case of accident.

Porcelain used in high tension transmission must be of the highest grade, thoroughly vitrified, free from flaws of any kind, and strong mechanically. As stated before, porcelain is mechanically strong, except in the quality of toughness. It has very high resistance to crushing, and fairly high transverse and tensile strength. The resistance to sudden blow or shock is not so important in line insulators, which are well out of reach, as is the other quality of withstanding steady strains in any direction.

The respects in which porcelain fails to equal other insulating compounds, and which prevent its being a practically perfect insulating material, are its inability to withstand local over-heating without cracking; its lack of toughness and non-flexibility; the impossibility of imbedding metal parts within it; and, in some measure, its hardness. In arc deflectors or arc chutes porcelain would fail at once, through cracking and bursting, and finally through being fluxed by the arc. For such purposes a tough refractory compound, such as asbestos compounds, is much better suited, as this will neither crack when heated in spots nor flux readily with repeated arcing across the surface. The inability of porcelain to withstand impact or vibration under load renders it necessary to employ other materials for such conditions, such as hard rubber, asbestos compositions, and various molded compounds. As to imbedding metal parts in proclain in the same manner as in some materials, the high fire necessary to properly vitrify the porcelain prohibits this, because of the fluxing of the metal with the porcelain mixture which will take place at this temperature. The lack of flexibility in porcelain, and its hardness, prevent its being worked to any desired form after once being baked, and no alterations are possible.

However, with its shortcomings considered, porcelain is, as before stated, in a class by itself, and far ahead of all molded compounds in general value to the electrical industry.

HIGH VOLTAGE FUSES

By E. B. Merriam

Recent development on high voltage fuses and tests on 60,000 volt transmission lines indicate that many desirable combinations of a non-automatic switch and fuses are possible, the switch serving to open or close the normal load of the line and the fuses taking care of heavy overloads and short circuits. This provides a very economical arrangement where there is a moderate amount of power to be tapped from a transmission line, and where the expense of an automatic oil switch installation might be considered prohibitive. A fuse has not been considered as an effective protective device on high voltage circuits until recently. To be satisfactory for this class of work the fuse must be quick acting, so that synchronous apparatus will not be thrown out of step in case of short circuit on the transmission line, and it must open the circuit with no line disturbances. Past practice has demonstrated that open air fuses are unsatisfactory on account of the vicious arcs set up when a high voltage circuit is opened and the hot gases are unconfined. Air arcs at high voltages and hot gases which are of low resistance will involve adjacent conductors unless measures are taken to confine the disturbance. Such an arrangement complicates the station layout, and is only one of many of the objections to open-air arcs, These arcs are the origin of line disturbances, with the consequent break-down of insulation.

Fig. 1. Expulsion Fuse, Type T, Form D 60 000 Volts, 100 Amperes

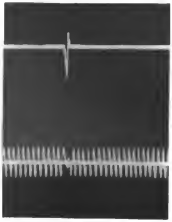


Fig. 2. Oscillogram Showing the Performance when Fuse Opens a Line Under Short Circuit

A fuse blown in a confined space, such as a non-conducting tube of suitable dimensions, proper consideration being given to the voltage, has the property of opening the circuit quickly, the arc being projected from both ends of the tube. This action can be improved if the tube is closed at one end and provided with a proper expansion chamber. Some designs introduce a moving element, such as a switch arm, which will elongate the path of the arc and thereby shorten the length of tube required, but this is undesirable as it introduces a long whipping air arc in series with the expulsion tube, and defeats the very purpose which was to be accomplished: namely, avoiding an open-air arc when the fuse blows.

Fig. 3 Fuses Opening Short Circuit on 60,000 Volt System

To meet the demand for a fuse that will avoid all these objections and open the circuit with the least disturbance, the General Electric Company has developed the Type "T" Form "D" expulsion fuse and disconnecting switch. The fuse holder (Fig. 1) consists of a long re-enforced fiber tube, one end of which is inserted in and closed by a large hollow receptacle termed the "expansion chamber." The fuse wire or ribbon is fastened to a plug in the bottom of the expansion chamber, and from this is passed through the expansion chamber and tube and connected to a top clip provided for the purpose. The fuse has a reduced section in the expansion chamber to insure blowing at this point. The entire device is insulated from ground by standard line insulators, thus avoiding any complication in installation. The cradle and fuse holder are so designed that the combination can be used as a disconnecting switch, and magnetizing currents of transformers can be broken, and if necessary, immediately switched on without re-fusing or any operation other than simply throwing the switch. Of course there is a considerable arc projected from the open end of the tube when the fuse blows, but this is not objectionable, as it consists of the fuse metal and is not a power arc. Tests on this type of fuse indicate that the circuit is opened in from one-half a cycle to three cycles, and that with the momentary reduction of voltage due to the short circuit, synchronous apparatus will not drop out of step.

Referring to the oscillogram (Fig. 2), it will be observed that the circuit was opened near the zero of the current wave, the entire operation occupying only .02 of a second. Fuses of this type have been tested on 30,000 and 60,000 volt circuits under varying conditions, and have given great satisfaction. Some of the larger fuses will take a longer time to blow, but if the conditions are known beforehand the results can be controlled.

Fig. 3 shows the action of these fuses opening a short circuit on a 60,000 volt system.

Fig. 4 illustrates the action of an expulsion fuse on a 30,000 volt circuit.

Fig. 4 Expulsion Fuses Opening Short Circuit on 30,000 Volt System

Tests have been made on sub-station feeders protected by 3 ampere fuses of this type, and the defective feeder was cut off without shutting down the main system. The voltage at this time dropped very low momentarily, but did not at any time rise above the normal value.

ELECTRO METALLURGY OF IRON AND STEEL

PART II

By SAMUEL A. TUCKER
ADJUNCT PROFESSOR OF ELECTRO-CHEMISTRY, COLUMBIA UNIVERSITY

KJELLIN PROCESS

This process for the production of high grade steel was first introduced at Gysinge in Sweden, and has the great advantage over other electric processes of working without electrodes, thus preventing the introduction of any impurities that they might contain, as well as increasing the carbon content of the resulting steel. Indeed, it may be said that steel made by this process is of the very highest quality.

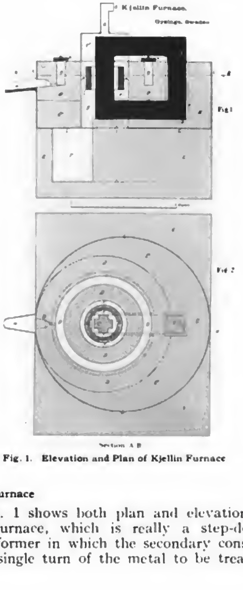


Fig. 1. Elevation and Plan of Kjellin Furnace

The Furnace

]Fig. 1 shows both plan and elevation of the furnace, which is really a step-down transformer in which the secondary consists of a single turn of the metal to be treated. The figure gives a drawing of a 225 h.p. furnace, and shows the circular brick-work D, supported by the iron casing L, to be about 10 ft. in diameter. The annular space F retains the one leg of the core and the primary winding A. The secondary is formed by the channel B, which is on a level with the working floor and is provided with the detachable covers K, the charging being done by removing these covers.

Such a furnace will give an average output of steel of 4100 kgs. per 24 hours, with a power consumption of 165 kw., although the loss of heat by radiation is considerable, amounting to about 50 per cent. The temperature of the metal at tapping is from 1600 to 1700 degrees C, but the heating is under very perfect control.

The primary winding of this furnace is built for 3000 volts, the insulation consisting largely of mica, while ventilating spaces and water cooling devices are provided to prevent overheating.

Later furnaces, such as the Colby furnace in use at Philadelphia, operate at low voltage on the primary, the winding consisting of copper tubing through which water is circulated.

The method of working for the production of a high carbon steel for the Canadian Commission was as follows:

Composition of the Charge:

	Kgs
Pig Iron	300
Steel scrap	125
Bar scrap	600
Metal in the furnace, estimated	700
12% Silicon pig	30
80% Ferro-manganese	1
	1756

Composition of Pig Iron:

Carbon	4.400%
Silicon	0.080
Sulphur	0.015
Phosphorous	0.018
Manganese	1.000
Copper	0.015
Arsenic	0.035

Composition of Bar Scrap:

Carbon	0.200%
Silicon	0.030
Sulphur	0.003
Phosphorous	0.009
Manganese	0.120
Copper	0.008
Arsenic	0.035

The charge was added gradually, some slag being removed as the process progressed. At the end of six hours the metal was ready for tapping, for which purpose the heat was raised towards the last.

The cast ingot weighed 1030 kgs., some of the metal being held in the furnace for the next run, as a metallic circuit has to be maintained in the secondary at all times.

One ton of product takes 2053 lbs. of material, and the energy required for working this particular charge was 857 kw. hours, equal to 0.116 h.p. years per ton of steel produced.

Composition of the Product:

Carbon	1.082%
Silicon	0.194
Sulphur	0.008
Phosphorous	0.010
Manganese	0.240
Arsenic	0.012
Copper	0.031
Aluminum	Trace

The quality of the steel produced by this process is the very best, and ranks with the highest grades of crucible steel; indeed, the process is nearly identical with the best crucible practice, and is conducted with much greater economy. Moreover, the control of the whole operation is very perfect.

From recent experiments carried on in Germany with induction furnaces now in operation, it is found that the removal of the sulphur is a simple matter, and that it is best to have the charge low in phosphorous if a low carbon steel is desired. If the removal of carbon is not an object, the sulphur and phosphorous can be reduced to traces. The furnaces are preferably made tilting, so that the contents may be poured, which is a better arrangement than that of the original Kjellin furnace using a fixed position with a pouring channel. In the German plant these furnaces have a capacity as high as 24 tons per day. Economically, it is only possible to use a fluid charge, which is first melted in a separate furnace and then delivered molten to the induction furnace. It seems, therefore, that this process has a distinct future in being able to handle open hearth product in the molten condition which is to be converted to the higher grades of steel.

A small induction furnace manufactured under the Colby patents, with a capacity

Fig. 2. 736 Kw. Induction Furnace, Showing Tilting Mechanism
(Copyrighted by American Electric Furnace Co., reproduced by permission)

of 190 lbs. of steel, was put in operation at the Disston Saw Works at Philadelphia, and was so far successful as to manufacture steel of such quality as to meet the exacting demands of the company.

It is found best to use currents of low frequency on the primary of the induction furnace, in order to compensate for the low power factor. This means more expensive machinery for the generating plant, but notwithstanding this drawback, there is very great economy over the crucible process. With the induction furnace the casting of large ingots is a matter of great ease, which is a very obvious advantage, as uniformity is attained with a minimum amount of labor.

Figs. 2, 3 and 4 show views of 736 kw. furnaces recently installed at the Roechling Iron and Steel Works in Voelklingen, Germany. Figs. 5 and 6 are two views of a 450 kw. induction furnace; while the illustration on the cover of this issue of the REVIEW shows the 60 kw. furnace in operation at the Disston Works at Philadelphia.

KELLER PROCESS

This process is applied primarily to the reduction of iron ores for the production of pig iron, and has been in operation at the works of Keller, Leleux & Company at Livet, France, for some time. Steel making is also carried on by this company, but their electric steel furnace is so similar to the Heroult steel furnace that a description is unnecessary. The Keller furnace for the reduction of iron ores presents considerable originality, the heating being accomplished both by the arc and resistance principle. Fig. 7 is a diagram of the two hearth furnaces, and Fig. 8 shows a general view of the same furnaces, which consist of an iron casing of square cross section with refractory lining. The two square shafts of the furnace are connected by a channel which is filled with molten metal when in operation. The electrodes are arranged vertically, and have a cross section of 28 in. On the bottom of the furnace is placed a slab of carbon for use in starting the furnace, the path of the current being from one electrode, through the charge to the carbon slab of one shaft, then by outside metallic connection to the carbon slab in the second shaft, thence through the second charge and electrode.

After the furnace is in operation the molten metal collects in the hearth immediately above the carbon slabs, and also circulates in the channel connecting the two, so that the bulk of the current is carred directly through the channel. This arrangement facilitates the removal of the molten metal and slag, and at the same time does not hinder the working of the furnace during this dis-

Fig. 3. 736 Kw. Tilting Type Induction Furnace
(Copyrighted by American Electric Furnace Co.; reproduced by permission)

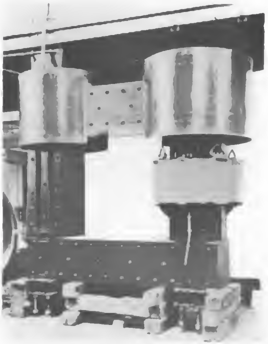


Fig. 4. Transformer of 736 Kw. Induction Furnace
(Copyrighted by American Electric Furnace Co.; reproduced by permission)

charging, as the current during this time is again carried by the outside shunt circuit.

The heating is accomplished largely through resistance, for as the charge is introduced the electrodes are raised, and the reduction of the ore proceeds very regularly and is facilitated by the passage of the hot gases ascending from the hotter zones of the shafts. In the later type of furnace (Fig. 9), this effect is particularly sought, the shaft being built longer, thus economizing the thermal energy. The figure shows a furnace with four hearths and one central well, the electrical connections being on the same plan as for a furnace having two hearths.

It has been found that the use of resistance heating of the charge itself makes it easy to obtain control of the temperature, so that the process is carried on quietly and with ease. Regulation of the electric energy is effected by changing the elevation of the electrodes, thereby increasing or decreasing the resistance.

The furnaces are of considerable size and are designed to absorb about 400 to 600 kw., the current being from 6000 to 11000 amperes.

Although the smelting of iron ore was the chief object in the design of the Keller furnace, it has been used successfully for the production of ferro-alloys, such as ferro-chromo, ferro-silicon, and the like. Several runs were made at Livet to demonstrate the smelting of iron ores for the Canadian Commission, and very careful data was secured, with special attention to the following points:

1. The output of pig iron for a given consumption of electric energy.

2. The yield of metal per ton of ore charged.

3. The quantity of coke required as a reducing agent.

Fig. 5. 450 Kw. Induction Furnace, Front View
(Copyrighted by American Electric Furnace Co.; reproduced by permission)

4. The quality of pig iron obtained, with reference to its suitability for the various metallurgical processes for which it was subsequently destined. The ore contained:

Metallic iron	48.690 per cent.
Phosphorous	0.011 " "
Sulphur	0.020 " "
Silica	2.700 " "

This was mixed with coke, lime and quartz to form a suitable mixture, and was charged down the shafts around the electrodes. The operation was carried on for 55 consecutive hours, a total of 23466 kgs. of mixture being treated in this time.

Subsequent runs were made to ascertain if it was possible to obtain other grades of iron by varying the proportion of the charge, and this was found to be the case. The results of the experiments were also found to agree very closely with the workings of an ordinary blast furnace, and about the same changes in the product could be brought about by the means usually employed in ordinary metallurgical practice. An estimate of the cost of the process per ton of pig iron produced, was made by Mr. Harbord, who compares it to modern blast furnace treatment, as follows:

Fig. 6. 450 Kw. Induction Furnace, Top View
(Copyrighted by American Electric Furnace Co.; reproduced by permission)

From this charge 9868 kgs. of metal were obtained, with a production of 2025 kgs. of slag. The metal had the following average composition:

Total carbon	4.200
Combined carbon	0.800
Graphite	3.420
Silicon	1.910
Sulphur	0.007
Phosphorous	0.027
Manganese	4.300
Arsenic	Trace

The electric energy consumed per ton of pig was 0.475 e.h.p. year, which at $10.00 per e.h.p. year amounts to $4.75 per ton of metal produced.

ELECTRIC SMELTING		BLAST FURNACE	
Ore	$2.76		$2.72
Coke, 0.34 ton	2.38	0.925 ton	6.40
Electrodes	.77		
Lime, 400 lbs.	.40	400 lbs.	.40
Labor	.94	American practice	.42
Electric energy at $10 e.h.p. year	3.50		
Steam raising for blowing engine			.10
Miscellaneous materials			1.30
Repairs and maintenance	1.30		
	$12.05		$11.34

THE GEROD PROCESS

This process is one for the production of steel, and is in operation at the Société Anonyme Électro-Métallurgique at Ugine in France.

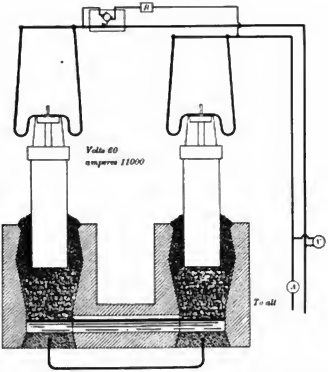


Fig. 7. Diagram Showing Electrical Connections of Keller Furnace with Two Hearths

While the chief object of this process is to manufacture ferro alloys, the furnace is well adapted for, and has been successfully operated as an electric steel furnace.

The furnace (Fig. 22), is of the arc type, having a single vertical electrode for one pole so far as electrical connection is concerned, but which actually is split up into four units all connected with the same lead. The body of the furnace is cylindrical and consists of an iron casing lined with magnesia brick, the bottom of which is provided with several hollow masses of iron, cooled by water. These iron masses serve as the other pole, and the arc takes place between the upper electrode and the slag floating on top of the reduced metal.

It will be seen that the furnace is very similar to the Heroult steel furnace, and the operation of refining is much the same as that called for by the Heroult process, in so far as the changing of the slags and their removal is concerned. The furnace is arranged upon trunnions for the purpose of discharging, and it is said that the use of one electrode makes the operation exceedingly simple. The exact details of the working of the Gerod process have not been published, but it is claimed that with a 250 kw. furnace one ton of steel has been produced in 4 ½ hours, using 1⅓ tons of charge with an expenditure of 1060 kw. hours of electric energy.

Fig. 8. General View of Keller Furnace with two Hearths

The processes which have been described are the most important, because in most cases authentic figures have been published of the actual working, and they are all on a commercial basis. This cannot be said of several other processes of which much has been written, but of which only little is actually known. For this reason we have not described the Gin, Stassano, Conley, Harmet processes, etc., as it would be only confusing to the subject, giving no information based on actual commercial working.

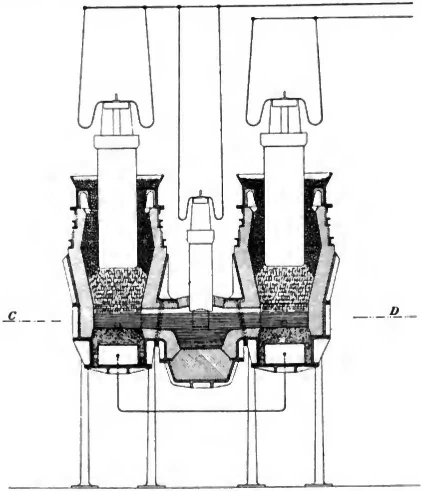


Fig. 9. Keller Electric High Furnace with a Plurality of Hearths

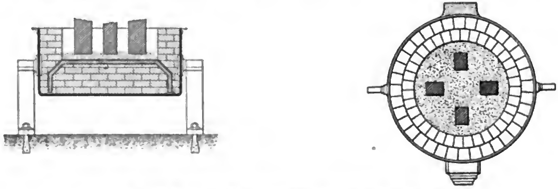


Fig. 10. Sectional Elevation and Plan of Gerod's Furnace

A comparison of the energy consumed in the important processes would rank about as in the following table:

HEROULT STEEL PROCESS*

Energy Consumed

Charged Cold

No. 1.	653 kw. hours per 2000 lbs.	(Canadian Commission)
No. 2	882 kw. hours per metric ton (2204 lbs.)	(Goldschmidt)
No. 3.	1000 kw. hours per 2000 lbs.	(Canadian Commission)
No. 4.	1000 kw. hours per 2000 lbs.	(Canadian Commission)

Charged Hot

No. 5	360 kw. hours per metric ton	(Eichoff)

HEROULT REDUCTION PROCESS

No. 1.	3080 kw. hours per 2000 lbs.	(Canadian Commission)
No. 2.	2306 kw. hours per 2000 lbs.	(Haanel)
No. 3.	2342 kw. hours per 2000 lbs.	(Haanel)

KJELLIN STEEL PROCESS

No. 1.	970 kw. hours per metric ton	(Goldschmidt)
No. 2.	966 kw. hours per metric ton	(Neumann)
No. 3.	757 kw. hours per 2000 lbs.	(Canadian Commission)
No. 4.	947 kw. hours per 2000 lbs.	(Canadian Commission)

KELLER STEEL PROCESS

Charged Cold, Using Ore

No. 1.	2800 kw. hours per metric ton	(Goldschmidt)

Charged Cold, Using Pig Iron

No. 1.	730 kw. hours per 2000 lbs.	(Canadian Commission)

KELLER REDUCTION PROCESS

No. 1.	3110 kw. hours per 2000 lbs.	(Canadian Commission)
No. 2.	1475 kw. hours per 2000 lbs.	(Canadian Commission)

GEROD STEEL PROCESS

No. 1.	1060 kw. hours per metric ton
No. 2.	1440 kw. hours per metric ton

The actual cost of the operation as conducted by the above processes varies anywhere from $6.00 to $35.00 per ton of product; and although at first sight this is hardly a satisfactory showing, it must be remembered that several conditions enter into the question. The factors which influence the cost of the operation are: size of plant, quality and cost of raw material, and power costs; and these vary considerably. Added to this, we have the results based on a small number of actual experiments.

There is little doubt that when any of these processes come to be conducted on a more extended scale, we may expect more encouraging figures, which will tend to extend this new industry very materially.

* The Electric Furnace in Iron and Steel Production by J. B. Kershaw.

CURRENCY AND FINANCE*

PART I

BY HENRY W. DARLING
TREASURER OF THE GENERAL ELECTRIC COMPANY

This is a subject that is engrossing a great deal of public attention at present, and one that is somewhat mystifying to the average reader of the newspapers because of the technical terms used. I am fortunate in having had my subject mapped out for me by interrogations that have been made to me and which I find, after a little examination, fairly illustrate the difficulties of the average reader.

I will give some of the questions as an introduction:

How are National banks organized?

How do they issue currency?

How can a National bank increase its currency issue?

What relation exists between National bank currency and government and other bonds; and also government currency?

How is currency increased by importation of gold?

What are the means employed in distributing gold among National banks, and how is it converted into currency?

What is the practical operation of the National bank clearing house?

What are the actual practical operations of the National banks in face of a currency stringency, and what are the problems they face?

What is the process from special government action to relieve stringency to the point of actual currency relief?

How does our National bank system compare with those of England, Germany and France?

How would our system be affected by establishing a Government bank?

We will first consider the question, "What is money?"

One definition of money is, that it is a trustworthy, easily circulated and promptly redeemable token, used in exchange for commodities or service.

The function of money is to facilitate exchanges; it is the common medium by which these are rendered feasible. There has been, since the beginning of days, a division of employment and labor. Each one must live by exchanging his products for those of others. No one man could manufacture all the products or things that he needed for his own use or for the use of his family; therefore it was necessary to have a medium of exchange.

There must be a standard of comparison of the worth and value of articles or labor exchanged; and the adoption of some one commodity as a standard renders this comparison of values easy. The chosen commodity then becomes the common denominator in terms of which we measure the value of other goods or commodities. Money makes exchanges easier by making them definite, and has resulted in an increasing tendency of people to trust each other. It offers an approximate means of estimating the present value of a future act—a standard of value of deferred payments—and so it comes about that money is called a "legal tender"—the standard by which future obligations are determined. The sum and substance of all modern commerce and business is the exchange of commodities and circulation of tokens, and these tokens are called money; they may have intrinsic value or they may not.

The worth of money depends on its ability to carry out its face value. Gold and other metals are used for the purpose because they have in themselves an intrinsic or commodity value in the arts; they are less destructible than paper, silk, wood and glass, and their use commended itself to the people. These tokens we call money must be stable in value, must be trustworthy, and must be instantly redeemable in commodities and labor. Their volume must expand and contract as trading increases or diminishes.

It is not necessary to trace the evolution to gold and silver as tokens superior to all others. They are divisible without loss; they are divisible into all the different values; they are beautiful and brilliant, and durable almost to eternity.

Next as to coinage: The tokens became a standard article and had to be distinctive. In Greece each city claimed the exclusive right to issue these; in the Roman Empire, the privilege belonged to the Emperor; while in France certain nobles said it was their right, and, as with many other things, they seized the right and held it, compelling the people to submit. In England the king alone coined silver and gold, and latterly it has been recognized as the exclusive privilege of the National government.

Every country has a history of the depreciation of its national currency due to various

* Lecture delivered before the Schenectady Section, A. I. E. E. January 16.

reasons, such as wars, famines, etc. Every currency system must be based on a standard unit of value fixed on some concrete substance. In England the unit of value is the pound, while in France it is the franc, and in America, the dollar. The currency must be suited to the wants of the people using it, or it fails of its intended purpose. The inhabitants of California refused to accept our greenbacks during the Civil War, insisting upon the use of gold; and gold is much more largely used out there now than paper money. Every currency system requires the use of subsidiary coins, which are sometimes made of copper or nickel. Our modern currency has been largely supplemented by the use of credits, checks, drafts and bills of exchange.

The Government furnishes various kinds of money with which to carry on business. Some kinds are good enough to use between the business people of the country, but not good enough to suit the Government. It requires a special kind of money when it has a debt against you. If you have duties on imports or interest on the public debt to pay, there are only certain kinds of money the Government will accept; that is, gold coin and silver dollars, or gold certificates and silver certificates, and United States Treasury Notes. The Government is bound, and the Secretary of the Treasury is likewise bound to maintain the parity of gold and silver, no matter what it costs.

United States notes or greenbacks have been redeemable in gold since 1900, and are now in circulation to the amount of $346,681,016. They are legal tender except for duties on imports and interest on the public debt. The Government does not accept any paper in payment of debts, with one exception; namely, the U. S. Treasury notes of 1890, originally amounting to $155,931,000, being the amount paid by the United States for silver bullion. They are legal tender, unless otherwise specified in contracts.

Gold certificates are issued by the Secretary of the Treasury upon deposits of gold coin, the certificates therefor being in denominations of not less than $10.00. These certificates are not legal tender, but are receivable for customs, taxes and all public dues.

Silver certificates are issued for silver dollars deposited with the Treasurer of the United States. These certificates have largely taken the place, in circulation, of the standard silver dollars which they represent. They are not legal tender except for public dues. Then we have the bank notes issued optionally by National banks, which are limited to the face value of bonds deposited in the National treasury, and are redeemable at a central redemption agency in the treasury at Washington. These are legal tender except for duties on imports and for interest on the public debt.

Money Institutions of New York State

I have mentioned the kinds of money the Government furnishes to the people, and this has brought me down to the issue of National bank notes. Before further describing these National banks and the notes issued by them, I would say that moneyed corporations chartered under the laws of the State of New York to do business therein are known as Trust Companies, Saving Banks, Mortgage, Loan and Investment Companies, and Building and Loan Associations. I was accused once of making a financial statement without a figure in it. I was not guilty of quite this, but I want to be as nearly so tonight as possible. The total resources of these institutions amount to $3,398,000,000, with a capital stock of $263,000,000. You can see, therefore, the vast importance of these State corporations. The *State Bank Act* is called in this state "The Banking Law," and seems to have been passed in 1882. It was re-passed in amended form in 1892, and is very much like the so-called National Banking Act.

Each director of a State bank must be a citizen of the United States—not an alien. The liability of a stockholder in the event of impairment of capital is to double the amount of his stock. Every State bank must render a report of its financial condition on approved forms, and at required intervals.

A State bank may be changed to a National bank, and likewise a National bank may be changed to a State bank. Circulating notes are issued on the security of stocks or bonds of the State or United States, which are deposited with the superintendent of banking; and on application the notes, engraved in the proper form, and issued by the banking superintendent, are given to the local bank, and have printed across the face of them, "secured by public stocks." These notes are issued to 90 per cent. of the commercial market value of the securities pledged, and redemption agencies are established in New

York, Albany and Troy. It is not absolutely necessary that a bank should take out any circulation; if it is found convenient, it may be done, or the bank may return the notes to the superintendent, and after a certain interval can require their securities to be reconveyed to them. It will be observed that the primary object of this law was to establish and maintain a system of banking. The act provides for a State banking department, and a bank superintendent with provisions for regular and rigid inspection. There are restrictions as to the amount that can be loaned to any one borrower. They may invest their deposits in municipal bonds, stocks etc.; also in railroad bonds, some of which are specified. The capital stock which must be paid up must be $500,000 in large cities of 500,000 population or more, and as little as $20,000 in small places. A deposit of $1,000 in some municipal stock must be made before a certificate can be issued and business begun. Directors must subscribe to an oath. Reserves of 15 per cent. of deposits must be maintained in large cities, and 10 per cent. in smaller ones, but of this, one-half may be on deposit in another bank on call.

As to trust companies: The difference between a trust company and a bank lies chiefly in the fact that originally trust companies were instituted to execute trusts, to administer the estates of insane persons, to be executors of wills, etc., and to do various other business of a trust character; and incidentally they were allowed, by the peculiar phraseology of the act itself, to receive public deposits. It was never intended that they should enter into the banking field generally and compete with chartered banks for deposits by the people, but by a construction of the statute itself it was found possible to do so, and the intrusion of trust companies as competitors for the business of banking is a comparatively modern development. The capital of a trust company must be $500,000 in cities of 200,000 population.

Trust companies also deal in securities, and receive money on deposit upon which interest is allowed, much the same as in the case of savings banks. They have, however, no right to issue bank bills, as do National banks, and they are not permitted to have branches, except in large cities. They have power to act as safe deposit companies. It was supposed that when they were compelled to invest their capital in bonds and mortgages that it would be an assurance of security to their patrons, but it has turned out that this system was not particularly advantageous. The principal difference between banks and trust companies, as originally intended, was that the trust companies were not required to keep any fixed ratio of reserves against their deposits. Last year, however, this law was changed and in cities of 800,000 population and over, they are now required to keep reserves of 15 per cent. of which one third may be in bonds, and not more than two-thirds may be on deposit in approved banks or trust companies. In smaller cities the reserve must be 10 per cent., of which at least three-tenths must be in money; not more than three-tenths may be in bonds; and not more than four-tenths in approved depositories.

The business or function of a bank, broadly speaking, is to gather up the savings of the people, and to make them useful for the promotion of the business and industries of the country under well-defined banking principles and safe and proper restrictions.

National Banks

We next come to the National banking statute passed in 1864. This National banking act was devised "to provide a National currency secured by pledge of United States bonds, and to provide for the circulation and redemption thereof," and National banks are agencies or institutions of the Government for this purpose. You know something of the circumstances in 1864, when the country's resources were depleted by the War of the Rebellion. The credit of the country had fallen low from the enormous slaughter of the population and the withdrawal of so many men from the industries, etc. The National securities were quoted at extremely low prices, and the country was flooded with irredeemable currency, of which it was said one needed about an equal number of cords to buy as many cords of wood.

The needs of the National treasury were exigent; the expenditure was enormous. There was a great struggle between those who favored the system of a monopoly, and the advocates of absolutely unrestricted freedom for banking; and from time to time the balance had swung from one side to the other. Loan after loan was made; the country was getting more and more deeply into debt. It was Alexander Hamilton who originally suggested the germ or basic principle; to "Bank upon the National debt as the best available capital." The draft of the proposed act was taken bodily from the laws of those states which appeared to have attained the greatest success under the free banking system, and sections covering the features of the securities to be pledged and the methods of supervision were added. Primarily, the aim was to procure the necessary funds for the purposes of the country, and incidentally to put into circulation bills furnished by the government, their redemption to be guaranteed and regulated by the United States. Added thereto was the skillful preparation of the law establishing banks, and the honest enforcement of appropriate banking laws. The following are the principal features of this act establishing these National banking associations — the instruments through which forced loans were to be obtained from the people, the value of the United States Bonds was to be enhanced, and a National currency system put into operation.

Congress has the sole right to regulate and control the operations of the National banks; the State legislatures cannot interfere. The usual powers incident to a banking business are conferred, but loans on the security of real estate are prohibited. In cities of large size (50,000), the capital must be $200,000; in smaller communities, as low as $25,000 is allowed. Of this 50% must be paid up, and the balance in monthly installments of 10%.

Directors must subscribe to an oath and must be citizens of the United States; furthermore three-fourths must have resided in the state at least one year, must be residents therein during continuance of office, and must qualify with 10 shares of stock. Shareholders are liable to double the amount of their stock in case of impairment of capital, except where the capital is as large as $5,000,000 and surplus of 20 per cent. Executors or trustee stockholders are not personally liable to assessment, but the estates they represent are.

These National banks are constituted depositories of public monies except customs receipts. They may be employed as financial agents of the government, and the secretary of the treasury may require them to give satisfactory security for deposits, etc. They must take and receive at par all the National currency bills which have been paid into the Government for interest, revenue, or for loans or stocks. Any State bank may become a National bank.

Obtaining and Circulating Notes

Before it can begin business, each National bank must deliver to the treasurer of the United States at least $30,000 of United States bonds and not less than one-third of its capital stock paid in; and this proportion of 30 per cent. must be maintained when the capital is increased. These bonds are held in trust for the bank and as security for circulating notes; the controller of the currency and the United States treasury act together. Banks whose capital is $150,000 or less, need not deposit bonds of over 25 per cent. of their capital. A bank can deposit lawful money and withdraw a proportionate amount of bonds. Circulating notes are delivered to the bank equal to the par value of the bonds deposited, but not in excess of its capital paid in. In order to keep these notes in circulation it was originally provided that if they were presented for redemption, the bank could not increase its circulation again for six months, but for obvious reasons this section was repealed. It was for the same purpose, however, that the law provides that the secretary of the treasury cannot be compelled to redeem more than $9,000,000 circulating notes in any one month and "first come, first served." It is this feature of rigidity that is found so objectionable in practical operation. Each man and each business enterprise requires enough money for purposes of exchange, and, at certain seasons of the year more currency is needed than at others. The moving of the crops in the autumn necessarily employs a large volume of circulation, and it seems absurd that the business of the country generally should be disturbed, and the value of money should be enhanced to borrowers all over the country while this beneficent work is being accomplished. As stated at the outset, a proper currency system should be adequate in amount for all purposes, and should automatically expand and contract as the need for it arises and ceases. There should be a daily system of redemption going on, so that there should neither be too little nor too much. This element of elasticity is one great defect in our bond secured currency, and it is clear that the act was never designed to furnish this needed flexibility.

(To be continued)

ROTARY CONVERTERS

PART III

BY E. J. BERG

Ratio of Copper Losses

They show, also, that the ratio a of the armature copper losses of a given machine, when run as rotary converter and direct current generator, is as follows:

$m = 2, \ a = 1.42$
$m = 3, \ a = 0.57$
$m = 4, \ a = 0.377$
$m = 6, \ a = 0.266$

The relation between the total armature heating of a converter at any power factor, and the machine as a direct current generator, is as follows:

Let i be the effective value of current corresponding to the energy output, and let $\cos\phi$ be the power factor; thus, with full energy output, the wattless leading or lagging component of the current is $i_a \tan\phi$.

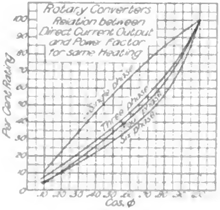


Fig. 1

With inductive load, the armature copper losses are increased in the proportion of the square of the wattless component to the square of the resultant energy component previously discussed.

Copper Losses at Different Power Factors

The effect of the wattless component is, however, not a uniform addition of losses all around the circumference. The coils near the collector rings carry relatively more current than with non-inductive load; thus the distribution of heat with wattless current is less favorable than with non-inductive current. This distribution is, however, improved with an increased number of phases.

It has been previously shown that the ratio between the effective value of the alternating current in the armature and the direct current, is:

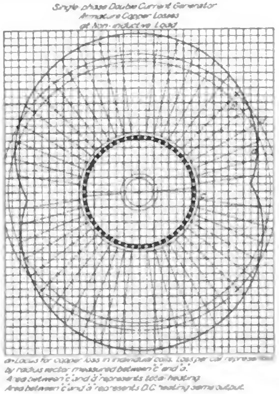


Fig. 2

$$\frac{2\sqrt{2}}{m \sin \frac{180}{m}}$$

Thus the wattless current, expressed as a function of the direct current, is:

$$\frac{2\sqrt{2}}{m \sin \frac{180}{m}} \tan\phi$$

and the heating due to this current, as a percentage of that obtained with direct current, is:

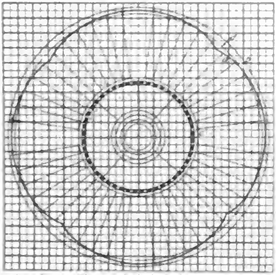
$$\frac{8 \tan^2\phi}{m^2 \sin^2 \frac{180}{m}}$$

At a power factor $\cos\phi$, the heating as a percentage of the direct current heating, is, therefore:

$$100\left(0.57 - \frac{8\tan^2\phi}{m^2\sin^2\frac{180}{m}}\right)$$

Where the value of α is obtained from the above table—for instance, in the case of a three-phase converter operating at 90 per cent. power factor ($\cos\phi = 0.90$), we have:

Two-phase Double Current Generator
Armature Copper Losses
at Non-inductive Load



a-Locus for copper loss in individual coils. Loss per coil represented by radius vector measured between 'c' and 'a'
Area between 'c' and 'd' represents total heating
Area between 'c' and 'b' represents D.C. heating same output.

Fig. 3

Percentage heating =

$$100\left(0.57 + \frac{8\times0.484^2}{9\times0.866^2}\right) = 83.4 \text{ per cent.}$$

For a six-phase converter the corresponding heating is:

$$100\left(0.266 + \frac{8\times0.484^2}{36\times0.25}\right) = 47.4 \text{ per cent.}$$

The power factor which will give the same armature copper loss as that with direct current is found by the following equation:

$$\alpha + \frac{8\tan^2\phi}{m^2\sin^2\frac{180}{m}} = 1$$

$$\tan\phi = .354\, m \sqrt{1-\alpha}\,\sin\frac{180}{m}$$

Tan ϕ being known, $\cos\phi$, the power factor, is directly obtained from trigonometric tables.

Example: Find the power factor for a six-phase rotary converter which will give the same armature copper loss as direct current only.

$$\tan\phi = 0.354\times6\times\sqrt{1-0.266}$$

$$\cos 60^\circ = 0.905$$

thus $\cos\phi = 0.743$

Example: How much shou'd the rating of a three-phase rotary converter be reduced for a power factor of 90 per cent.?

We then have:

$$\alpha = 0.555$$

$$\cos\phi = 0.9 \qquad \phi = 25.5^\circ$$

$$\tan\phi = 0.474 \qquad \tan^2\phi = 0.225$$

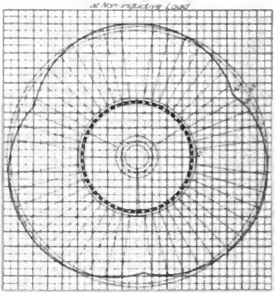
Substituting:

$$C_c = \sqrt{\frac{0.555}{0.555 + \frac{8\times0.225}{9\times0.75}}} = 0.82$$

Thus the output should be reduced to 82 per cent. of the rating.

In a rotary converter it is of importance to know how much lower the direct current output will be when the power factor of the alternating current is not unity. To illustrate the method of determining this, let the direct current i_c in the winding at full

Three-phase Double Current Generator
Armature Copper Losses
at Non-inductive Load



a-Locus for copper loss in individual coils. Loss per coil represented by radius vector measured between 'c' and 'a'
Area between 'c' and 'd' represents total heating
Area between 'c' and 'b' represents D.C. heating same output.

Fig. 4

load be 1; the alternating current (see equation 4) in the winding is then:

$$i = \frac{2\sqrt{2}}{m\sin\frac{180}{m}}$$

and the heating due to these currents is α.

With a direct current in the winding of C_c, the alternating current in the winding,

$$C = \frac{2\sqrt{2}}{m \sin \frac{180}{m}} C_c;$$

and the heating of the machine as a converter is $C^2 a$.

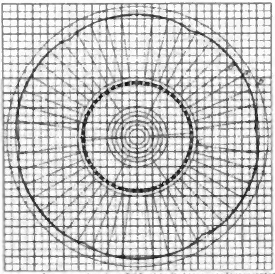
At a power factor of $\cos \phi$ the wattless component of the alternating current in the winding is:

$$C \tan \phi = \frac{2\sqrt{2}\, C_c \tan \phi}{m \sin \frac{180}{m}}$$

Thus the heating, due to the current which is not compensated for, is proportional to:

$$\left(\frac{2\sqrt{2}\, C_c \tan \phi}{m \sin \frac{180}{m}} \right)^2$$

Six-phase Double Current Generator
Armature Copper Losses
at Non-inductive Load



a–Locus for copper loss in individual coils. Loss per coil represented by radius vector measured between "c" and "a".
Area between "c" and "a" represents total heating.
Area between "c" and "b" represents D.C. heating same output.

Fig. 5

Thus the total heating is proportional to:

$$C_c^2\, a + \frac{8C_c^2 \tan^2 \phi}{m^2 \sin^2 \frac{180}{m}}$$

This value should be the same as for rated load, thus:

$$C_c^2\, a + \frac{8C_c^2 \tan^2 \phi}{m^2 \sin^2 \frac{180}{m}} = a$$

$$\text{and } C_c = \sqrt{\frac{a}{a + \frac{8 \tan^2 \phi}{m^2 \sin^2 \frac{180}{m}}}}$$

Since these values are of very great practical importance, Fig. 9 has been prepared, which shows these relations for the various types of rotary converters.

The interesting characteristics of the various types of rotary converters are tabulated below, where:

A gives type of converter.
B " power factor.
C " ratio, $\frac{\text{A.C.}}{\text{D.C.}}$ no-load voltage.
D " ratio, $\frac{\text{A.C.}}{\text{D.C.}}$ line current.
E " ratio, $\frac{\text{maximum value A.C. current}}{\text{direct current}}$
F " ratio armature copper loss as rotary and D.C. generator for same output.
G " ratio of rating as rotary and D.C. generator for same armature copper loss.
H " power factor for same energy output and copper loss as rotary and D.C. generator.
M " number of collector rings.

A	Single-phase		Three-phase		Four-phase		Six-phase	
B	100	90	100	90	100	90	100	90
C	.707		.613		.5		.353	
D	1.414	1.57	.945	1.05	.707	.785	.472	.525
E	2	2.22	1.54	1.71	1.414	1.57	1.333	1.48
F	1.43	1.88	.555	.82	.377	.60	.26	.46
G	.84	.73	1.34	1.11	1.63	1.29	1.94	1.47
H	....		85		78.5		74	
M	2		3		4		6	

Figs. 10, 11, 12 and 13 give diagrammatically the distribution of armature losses in single-phase, three-phase, two-phase and six-phase double current generators. These diagrams are calculated in a similar manner to those for the rotary converter. Instead of the alternating current being $+ i_{max}$ in the first position, it is $- i_{max}$ and the direct current and alternating current are thus in phase.

It is of interest to note that, with the same output on the direct current and alternating current side, the actual armature copper loss in all but the single-phase case, is less than if all output was given as direct current, the relative ratings being:

Six-phase machine	106.8 per cent.
Four-phase machine	105. " "
Three-phase machine	102.5 " "
Single-phase machine	93. " "

(To be continued)

WOOD MANTELS PRODUCED BY ELECTRICAL POWER

By John P. Judge

The Felippe A. Broadbent Mantel Company of Baltimore, Md., operated their factory for several years previous to 1904 with mechanical drive. During that year they built an entirely new factory, and after considerable investigation, determined to have all of the woodworking tools driven separately by electric motors. The new equipment was started on January 1, 1905, and therefore has now been in operation for more than two and one-half years. The fact that the owners are pleased with the results obtained is well shown by the accompanying letter.

"We take pleasure in stating that we are more than satisfied with our electric equipment in every way; the writer having in person examined a number of woodworking plants (some of which were the largest in the world) and is confident that we have the most perfect electrically-equipped woodworking plant in this country.

"Certainly, anyone seeing this plant, who knows anything about the equipping of woodworking machinery, could not help but state that it is almost as near perfect as it could be made; the application of the electrical equipment to the machines being such as to almost entirely do away with belting, thus saving us great expense in the constant stopping of the machines to take up belts, etc. We are particularly well pleased with the equipment of the turning lathes, which does away with the belts entirely. The doing away with these and the pulleys we find particularly advantageous, as it eliminates the collection of dirt on the latter, which was constantly dropping on the work. The belts were always in the way.

"I had, of course, considerable apprehension as to the delays we might suffer in running the plant electrically equipped, until the same was in thorough working order, but I must say that this apprehension was entirely uncalled for; for, though the men had never run machines of this kind before, we have had very little trouble, and only a few slight delays since we have started.

* * * *

"We do not believe the lighting could be improved upon, and the men in some cases prefer it to the daylight.

* * * *

"Were we to build another plant, certainly nothing would be used but electricity. The economy, of course, is very great, as the power is entirely saved whenever the machines are not in use, and it is really astonishing to know the difference between the horse-power in motors, and the horse-power which is being consumed.

Fig. 1. Interior of Power House. Felippe A. Broadbent Mantel Company

"After running two years and a half, we find we have spent less than $200.00 in repairs for electric equipment."

* * * *

(Signed)
Yours very truly,
Felippe A. Broadbent Mantle Co.,
F. A. Broadbent, Pres.

The factory is located in a low part of the city, near the harbor, and in that section basements are usually avoided, because of trouble from tide water.

Before the system for driving had been determined upon, the architect had prepared his plans, and the building was about ready for the roof. A careful consideration of the matter impressed the owners with the advantages to be gained by having the motors for the heavy machines placed in a basement. Fortunately, the first floor had been laid out for a 22 foot pitch; this was cut down to 17

Fig. 2. Automatic Rip Saw, Belt Driven

feet, and by digging down about 3 feet further a basement was secured 7 feet high, in which all of the motors for driving the heavy machines on the first floor could be located. This permitted standard motors, without covers or artificial ventilation, to be used. Although a considerable expense was incurred, the owners are well satisfied with the results, and feel assured that the money involved was well invested.

The generating plant consists of two engine-type generators, rated:

MP-6-100 kw.-270 r.p.m.-250 volts,
MP-6- 50 kw.-280 r.p.m.-250 volts

each mounted on the base of a horizontal engine, running non-condensing.

Fig. 3 Automatic Rip Saw Driven by 15 h.p. Constant Speed Motor Located in Basement

The switchboard consists of seven black enameled slate panels with instruments, including among the latter a recording wattmeter for each generator panel.

In this installation the owners acted along broad lines, with the fundamental intention of securing a maximum of output with a minimum of cost, and to obtain a motive power free from delays and interruptions, due to break-downs and improper attention.

Forty-five motors, aggregating 398 h.p., are installed, all of them being 230 volt, continuous current machines.

A characteristic of many woodworking machines is that the speed of the cutting tool remains constant, while the feed should be varied in accordance with the work being done. This applies especially to sanders, planers, jointers, and machines of this class. These machines were fitted with a constant speed motor for the cutting tools, and a variable speed motor-controller for the feed, and the results have been most satisfactory.

The old method involved the use of considerable shafting and belting with cone pulleys, giving only a few feed speeds, while with the variable speed motor a much greater range of feed speed can be obtained, with more gradual increments, resulting in better work, greater production and less wear and tear. This is especially noticeable in the large sanders.

60" Triple Drum Power Feed Sander Driven by 25 h. p. Motor Direct Coupled to Counter Shaft, which is Located in Basement Below the Machine

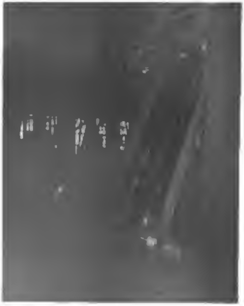
There is no overhead belting on the first floor, and in fact, very little on any of the floors. On a number of the large machines having several working cylinders, it is necessary to use one belt to each cylinder, but even with these machines there is a striking difference between the old and new systems.

Many of the machines now in use were employed in the old shop, while others were designed especially for electrical driving. For large machines requiring several belts, the main motor is coupled directly to the counter shaft, while the feed motor is belted to the feed shaft.

Under the old system, the large automatic lathe for turning up columns required an elaborate installation of counter shafts and belts, with tight and loose pulleys. This lathe is now belted direct to a motor overhead, and is giving much better service and a materially increased output.

Each of the swing saws is operated by a 3 h.p. motor, mounted in the arbor of the saw. We found very little difficulty in mounting these motors, even in the saws moved from the old factory.

The double end sander was another machine taking up a large amount of room, because



60" Triple Drum Power Feed Sander—Belt Driven

Fig. 6. Motor Driven Swing Saw

Fig. 7. Motor Driven Bench Lathes

it was necessary to use a counter shaft and three belts. The new equipment consists of two motors, each carrying a disc 30 in. in diameter, with external shafting or belting.

Perhaps the greatest simplicity was secured in a number of small lathes used for sand-papering, filling, veneering, etc. On each of these the motor takes the place of the head

Fig. 8. Variety Molder—Driven by Two 5 h.p. Motors with Vertical Shafts

stock, and is furnished with a standard shaft, the end of which is threaded for such chucks or discs as the owners may require, and which are supplied by them.

The putty mixer is an adaptation of the standard J. H. Day, three-barrel dough mixer, and is used for mixing compositions consisting principally of whiting and glue. An ordinary batch consists of one barrel of whiting, with the proper quantities of glue and other materials, and the actual mixing requires only about 5 minutes. Mixing the compositions by hand, under the old system, required an hour and a half for this work. The owners say the product as now obtained from the electrically driven machine is much better than formerly, the materials being more thoroughly mixed, and require less time to dry; this latter item being one of considerable importance.

Fig. 9. Variety Molder Belt Driven

Of the total motor rating of 398 h.p., the shaving blowers, which run constantly, require 95 h.p. The average load is about 150 kw., but for short periods it goes up to 200 kw., with momentary jumps as high as 225 kw.

Eliminating the blowers, the load factor on the woodworking tools varies from 30 to 35 per cent.

The entire mill is lighted with General Electric multiple D.C. 110 volt arc lamps, with concentric diffusers, run two in series, on a 250 volt circuit.

SOME NOTES ON WIRING AND WIRING SUPPLIES FOR MINING SERVICE.

By F. A. Barron.

Part II

In many coal mines it is customary, for underground illumination, to use incandescent lamps only in the mine shaft, in approaches to the foot of the shaft, at track switches, and for visual signalling; relying on the headlights of the locomotives and the miner's lamps for illumination in other parts of the mines. Miners have become so accustomed to working by the dull glare of their head lamps, that even where conditions are favorable and power is available for general lighting of the gangway and chambers, they appear quite indifferent to better illumination. The method of supporting the lighting circuits along the gangways, air ways, walls and roofs, to their destination, is by porcelain or glass insulators mounted on wooden cleats; and the same care and precautions are exerted here as in exposed circuit wiring in wet places, except that owing to the presence of sulphuric acid in the moisture and water of the mines, bare wires are frequently used in preference to insulated ones. The feeders for trolley wires and pump motors, where exposed to mechanical injury, are usually encased in iron conduit.

Fig. 1. Weatherproof Lamp Socket

The lamp sockets used in mines are usually of the 125 volt keyless weatherproof type, made of porcelain, or mica and hard rubber compounds. The latter will stand more hard usage, as they are tougher and less brittle than the porcelain, and are therefore more generally used in places where the sockets are exposed to injury. These sockets are provided with leads for connecting them directly to the circuit wires, allowing the lamp to hang suspended, and enabling it to swing if struck. These sockets are shown in Fig. 1.

Where lamps are mounted rigidly to side walls, they are usually attached to receptacles which are similar to those shown in Fig. 2.

Where portable lamps are required, they are frequently connected to the circuit by heavily insulated flexible cord, and are protected by an extra heavy steel ribbon lamp guard, like that shown in Fig. 3.

In the largest mining plants, the power required for illumination above and below ground rarely exceeds 20 to 25 kw., and most of this is used above ground in the power station, coal breakers, washeries, and other buildings. The wires in the coal breakers and washeries are now required to be run in iron conduits in the most approved manner, and controlled from distribution panels where each circuit has its individual devices for protection. On account of the accumulation of coal dust in the breakers, and moisture in the washers, all protective devices must be enclosed in cabinets; and keyless weatherproof sockets, suspended by reinforced lamp cord, must be used. The mine inspector insists that all wiring be maintained in such a condition that absolute reliability and immunity from even a temporary interruption to the service is secured.

Fig. 2. Wall Lamp Socket

Where alternating current motors are used, they are provided with individual controlling panels as shown in Fig. 4. These panels are designed by the General Electric Company for motors of from 25 to 450 h.p., for voltages up to 2080 volts, and are made of blue Vermont marble, 28 in. high, 16 in. wide, and 1½ in. thick, mounted on pipe frame supports, and attached to the pipes by malleable iron clamps. The total height of the panel and of the supports are 64 and 72 in., respectively. The 72 in. supports provide the space necessary for mounting the compensator, when this is used for starting the motor. These panels are usually mounted as near to the motor as conditions will permit, and are equipped with an ammeter and oil switch, the latter designed to automatically open the circuit in case of overload or trouble on the line. When controlling motors of moderate size, the wiring to and from these panels consists of multiple conductor lead armored cable, protected by metal conduits. Where motors of large capacity are used, three separate lead armored cables are enclosed in a single iron conduit, the latter in each case being connected to ground.

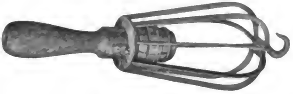


Fig. 3. Lamp Guard

The trolley wires used for mining locomotives vary in size, depending upon the particular haulage problem under consideration, and many features found desirable in trolley wire construction for passenger transportation are often taken advantage of in mining haulage. The grooved trolley wire possesses some advantages over the round type in that it provides a groove into which the ear may be securely clamped, making a neater job than a soldered construction, with less obstruction to the passage of the trolley wheel, and at the same time avoiding the ill effects of heating the wire necessary in the operation of soldering. The clamped ear may be readily removed when a change of location is to be made, and is interchangeable on Nos. 00, 000 and 0000 wires. The grooved trolley wire permits a larger cross section of copper without increasing the diameter of the contact surface. A diagram showing how the clamping ear holds the grooved trolley wire is shown in Fig. 5.

The underground trolley wires are suspended from either the roof or side walls of the gangways, the choice depending upon the nature and material of the roof and walls, and upon which is the more secure and convenient.

The following is an approximate estimate of the cost of 1,000 ft. of trolley construction in coal mines, including rail bonds:

36 single bolt roof suspensions	$15.00
30 straight ears for grooved wire, GE Cat. No. 19432	
6 curved ears for grooved wire, GE Cat. No. 19433	6.00
1000 ft. of 0000 grooved trolley wire (641 lb.)	94.00
210 ft. of 00 bond wire (85 lb.)	12.00
175 ft. channel pins, GE Cat. No. 17315	5.00
Labor and other material	50.00
Additional labor, if necessary, to drill rails for bonds with a hand drill	15.00
Total cost per 1,000 ft	$197.00

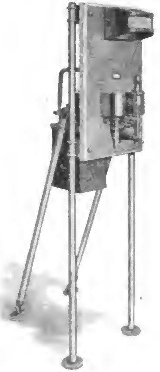


Fig. 4 Alternating Current Motor Panel on Pipe

Other sizes of trolley and bond wires may be readily substituted in the above estimate.

The constructional details of electric circuit wiring in subterranean workings of coal mines have, in common with electric wiring in other fields, very much improved in recent years, although the predominating blackness, and the wet, rough, and rugged surroundings are not an incentive to the ordinary electrician to attempt a neat and symmetrical job of wiring.

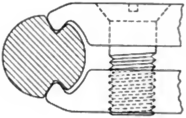


Fig. 5. Suspension for Grooved Trolley Wire

The essentials of every department of mining service—utility, safety, and a rugged simplicity—are usually the guiding considerations in running electric circuits in coal mines.

The United States government in its effort to protect the miners from the gases of the mines, has placed certain restrictions on the use of the miners open lamp in mines where gas is emitted in such quantities as to be detected in the presence of an open flame. In the anthracite coal region of Pennsylvania there are mines which, a few years ago, were considered as non-gaseous, but which, in the extensions of recent years, have shown such an increase in the quantity of gas emitted as to come within the restrictive measure framed by the government for gaseous mines. In the discussions that have arisen in the enforcement of the use of locked safety lamps and the restrictions to the further extension of electric circuits in the working sections of these mines, the miners have in many cases agreed with the operators that the open lamp is safer than the safety lamp, since the open lamp enforces a better ventilation, while with the use of the locked safety lamp, ventilation may be considered as not so essential.

CHARACTERISTICS OF ELECTRIC MOTORS*

How the Work to be Done Determines a Motor's Continuous and Intermittent Capacity and Its Design and Rating

BY EDWIN H. ANDERSON

To perform a given amount of continuous work, the motor should be designed both electrically and mechanically for continuous duty, and rated on the continuous basis. Let us suppose that the work is driving a machine requiring 50 horse-power continuously, there being no variation in the load. The motor for this purpose should have a constant speed, capable of delivering 50 horse-power continuously, with a temperature rise which will not injure the materials with which it is insulated, when operating under conditions of proper speed, voltage and ventilation.

Let us suppose the work consists of 50 horse-power for five minutes and 10 horse-power for 10 minutes; the cycle to be repeated every 15 minutes and the speed to be constant. The speed characteristics of the motor require a shunt excitation, that is, a definite exciting current in the field regardless of the load in the armature. The average load of the motor is:

50 × 5 minutes = 250 horse-power minutes
10 × 10 minutes = 100 horse-power minutes

Total.......... 350 horse-power minutes

$$\frac{350}{15} = 23.3 \text{ horse-power average.}$$

This average load will not produce the heating that the cycle will, for the reason that the copper loss varies as a square of the current. The root mean square or equivalent heating will be produced by the following:

$50^2 \times 5$ minutes = 12,500 h.p. square minutes
$10^2 \times 10$ minutes = 1,000 h.p. square minutes

Total.......... 13,500 h.p. square minutes

By dividing this over 15 minutes, we get the average square as 900, which is 30 horse-power. This is the root mean square load or a load which will produce the same heating, if applied continuously, as would the intermittent work.

Again, suppose the work is neither constant nor entirely intermittent. The motor must be designed with reference to both, and rated at a certain value continuously and a certain higher load for a given time. The specification of a motor for the intermittent work noted above would be one capable of delivering 30 horse-power continuously with normal temperature rise, and 50 horse-power as a maximum intermittent load. If the work to be done is the same as given above, except at 50 horse-power, the revolutions per minute of the armature should be 500; if at 10 horse-power the revolutions per minute should be 750, and, should the load be thrown off and the motor allowed to run free with full voltage applied, the speed must not be over 1000 revolutions per minute. The motor must therefore be able to deliver 30 horse-power continuously as before, have a shunt winding on the field to give a definite and sufficient field strength so that the speed will not be greater than 1000 revolutions per minute, have sufficient series-field turns so that when taking 10 horse-power of current the field will have sufficient excitation to cause the speed to be 750 and, when taking 50 horse-power of current, will further magnetize the fields so as to produce a speed of 500 revolutions per minute.

If we suppose the work required to be 50 horse-power for five minutes at 500 revolutions per minute and 10 horse-power for 10 minutes at 1000 revolutions per minute, there being no time in which the motor runs without load the field may be entirely series and adjusted properly for the respective loads. The continuous capacity will still be 30 horse-power as before, may be so rated, and have an intermittent capacity of 50 horse-power.

Street Railway Motors

Should the work be that required of railway motors under ordinary street railway conditions, there being no continuous load but a series of intermittent loads, the natural rating is the normal maximum intermittent load for which the motor is designed, both electrically and mechanically. By common usage this rating has become the horse-power output at the car axle which the motor will carry for one hour and not have a rise in temperature, as measured by thermometer, greater than 75 degrees Centigrade. The motor is started cold and run on the stand. The starting or pulling effect at the rating is usually the starting effect used in accelerating the car.

A motor of the usual direct-current series type may be looked upon as one which will deliver continuously about one-third of its hourly rating, or its hourly rating for one-third of the time, the cycle of operation being

* Reprinted from the American Machinist, Vol. 30, No. 50

limited to, say, 10 or 15 minutes. The series characteristic which gives the high speed at light loads and low speed at heavy loads is ideal for street railway work.

The intermittent loads of operating a car may be represented by the following table:

50 horse-power for 10 seconds, accelerating
40 horse-power for 2 seconds
30 horse-power for 6 seconds
20 horse-power for 20 seconds
15 horse-power for 60 seconds
No horse-power for 20 seconds, applying brakes
No horse-power for 10 seconds, stopped
128 seconds per cycle

The average horse-power output is as follows:

$$50 \times 10 = 500$$
$$40 \times 2 = 80$$
$$30 \times 6 = 180$$
$$20 \times 20 = 400$$
$$15 \times 60 = 900$$
$$\text{Total} = 2060 \text{ horse-power seconds.}$$

The average horse-power over the whole cycle is, therefore,

$$\frac{2060}{128} = 16.1 \text{ horse-power.}$$

The current, corresponding to the horse-power which will produce the same copper loss as in the above cycle, will be the root mean square as follows:

$$50^2 \times 10 = 2,500$$
$$40^2 \times 2 = 3,200$$
$$30^2 \times 6 = 5,400$$
$$20^2 \times 20 = 8,000$$
$$15^2 \times 60 = 15,500$$
$$\text{Total} = 34,600$$

The root mean square for 128 seconds is therefore 21.1 horse-power. The motor has been working on a voltage and current for 98 seconds out of the 128, or 75 per cent. of the time. The continuous capacity then may be approximately a current which corresponds to 21.1 horse-power (root mean square) based upon full voltage and an applied voltage which is 75 per cent. of the normal. This is approximate and not to be relied upon for accuracy. The method, however, serves to illustrate that there is a continuous current and voltage which could be applied to produce the losses and temperature rise of the motors in service. This continuous capacity, however, does not serve to test the motor on its full intermittent capacity at full voltage and, as stated before, it has become general to rate the railway motor on its intermittent capacity of 50 horse-power. The electrical and mechanical design is made with reference to the intermittent rating.

Characteristic Curves

Fig. 1 shows the characteristic curves of the usual direct-current series motor, such as used on street cars, hoists, cranes, and for intermittent work generally. The applied voltage across the motor is 500. The values of speed in revolutions per minute, efficiency, torque at one-foot radius and horse-power output at the armature shaft are shown as ordinates and plotted to amperes input to the motor as abscissas. It will be noted that the curves show the values in the accompanying table.

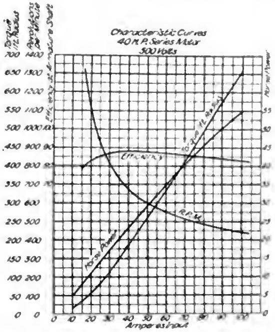


Fig. 1.

Amperes	Efficiency	Speed	Torque	H.P.
100	83	440	660	54.7
80	85	485	493	45.5
60	87	550	334	34.7
50	88	595	258	29.3
40	88	675	185	23.4
30	87	810	110	17.4
25	85	925	80	14.5
20	83	1100	55	10.8
15	78	1400	32	7.6

The measure of magnetizing force is ampere turns. Ampere turns is the product of amperes by the number of turns of wire around each field pole. When the magnetizing force is great, the strength of the magnetic pole is great, and *vice versa*. The applied pressure or voltage across the motor is resisted by two counter-pressures; first, that consumed in forcing the current over the copper wires, similar to friction in water pipes; second, a counter-voltage generated by the armature winding revolving in the magnetic field. This counter-voltage is proportional to the product of armature speed and the strength of the magnetic field. The torque at the armature shaft is proportional to the product of the armature turns, amperes and the strength of the magnetic field.

Should the motor be running at full load and delivering the torque at its armature and this torque be reduced, the motor will increase in speed, raising the counter-voltage and allowing less voltage to be consumed in driving the current through the windings. The current therefore is decreased. The decreasing of the current decreases the magnetizing force of the poles and in turn the strength of the magnetic field; this in turn requires the armature to run at a higher speed in order to generate the counter-voltage; thus the speed at large current input is slow and light current high, producing what is known as a series speed characteristic. With decreased field strength and current, the torque is reduced in proportion to the product of both. The motor almost instantly adjusts itself to the torque required.

We will assume 500 volts applied and 50 volts used in driving a given current through the winding. The counter-voltage produced by the armature revolving in the magnetic field would then be 450. We will now assume 250 volts applied for the same given current as above; thus 50 volts will be consumed in pushing the current through the windings and the counter-voltage produced by the armature will only be 200. Thus the speed at the lower voltage will be in a ratio of 200:450. Should we now assume only 50 volts impressed on the motor, this will all be consumed in pushing the given current through the winding and no counter-voltage will be required. The motor will therefore not run but stand and deliver the same torque as it did under speeds with 250 and 500 volts applied.

The above, while elementary in a way, serves to show that the torque is practically constant for given amperes at various speeds corresponding to various applied voltages and, furthermore, serves to show how the speed of a series motor is affected by the application of various currents and voltages. To perform other work more intermittent than the railway motors, the rating would naturally be on the intermittent basis for a shorter time say three-fourths or one-half hour, or in very intermittent work, such as lift or drawbridges, the rating may be on a 15-minute basis.

Any design must be made with special reference, both mechanically and electrically, to the maximum requirements, as well as to the continuous requirements, should there be any. Should the duty be continuous, the losses in the motor should be properly proportioned between the copper and the iron. The copper loss increases as the square of the current input to the motor, while the iron losses remain practically constant. Should the motor be designed for continuous operation and be operated on an intermittent overload, the copper loss becomes quite high and a better and cooler operating motor for intermittent work might have been made for the same weight and cost. In order to decrease the resistance of the copper circuit, a greater amount of steel may be used. This, however, naturally increases the iron losses but allows a lower copper loss for the same overload. In other words, a motor designed for intermittent work is considerably better than the motor designed for continuous load. A continuous-load motor has usually a small amount of iron with many turns of copper. The intermittent load motor has a large amount of iron with few turns of large copper.

The preceding explanation of the design and rating of motors is given so that the user of motors may appreciate that the character of the work to be performed shall control the design; that motors designed for continuous duty are not well adapted for intermittent work and that motors designed for intermittent work are not well suited for continuous load.

Crane Motors

We will next consider the crane motor. The weight to be lifted requires at the speed an output of 50 horse-power at the armature shaft. The distance to be lifted is, say, 30 feet at 3 feet per second. The time is then 10 seconds with load. The crane is moved down the shop and the weight lowered by a very slight use of the motor. The crane is then run back and the cycle repeated every 100 seconds. The power is on 10 per cent. of the time, and the average load is 5 horse-power. The root mean square load, however, is 15.7 horse-power. The time that the voltage is applied is 10 per cent.; thus the average load, or the root mean square load at 10 per cent. of the normal voltage, becomes no test nor measure of the motor. The rating then is its intermittent capacity of 50 horse-power at full voltage for a given length of time. A motor properly designed for this load with respect to efficiency will have a low temperature rise in service, so the rating will properly be its intermittent capacity for some length of time as will produce the temperature rise in service, say 30 minutes.

Draw-bridge Motors

We will now consider a motor for draw or lift bridge work. To lift the bridge requires 50 horse-power at the motor shaft for one minute, the bridge to be lifted every 100 minutes. The time for which power is on is one minute out of each 100, or 1 per cent. of the time. The average power of the motor is ½ horse-power and the average voltage applied 1 per cent. of the normal. Obviously no continuous rating at 5 horse-power (square root of mean square), or average ½ horse-power at 1 per cent. of the normal voltage would serve to test the motor. The proper test will be its intermittent rating of 50 horse-power on full voltage for a short time, say, 15 minutes. Obviously a motor of 50 horse-power continuous capacity is too large; what is needed is a motor with as small a continuous capacity as consistent with efficiency but of 50 horse-power intermittent capacity for 15 minutes.

Summary

In the foregoing I have endeavored to show that the characteristics of the work to be performed determine not only the design of the motor, but the method of its rating.

a. For constant and continuous capacity a motor should have a continuous rating only, with no overload of intermittent capacity.

b. For part continuous and part intermittent work a motor should have a continuous capacity with a certain overload or intermittent capacity.

c. Where variable speed is wanted, the motor should have a series field or a combination of shunt and series excitation.

d. For intermittent work, such as railway motors, the field windings should be series and rated on their intermittent hourly capacity.

e. For crane and hoist motors the series field is required on account of speed characteristics, and the rating should be its intermittent capacity for a short time, say one-half hour.

f. For lift- or draw-bridge motors the series field is required, and the rating should be its intermittent capacity for a still shorter time, say 15 minutes.

PORTABLE VENTILATION SET

By E. F. Dutton.

The portable ventilation set, three views of which are shown on page 150, is designed to meet the requirements of the United States navy for temporary ventilation of compartments which are not supplied by the ship's ventilation system, such as coal bunkers, double bottoms, etc. The set is ordinarily placed in some convenient location near the entrance to the compartment, and the air delivered through a temporary hose or pipe.

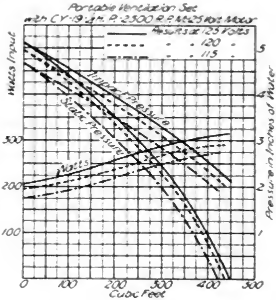


Fig. 1

The outfit consists of a cast shell fan driven by a one-quarter horse-power totally enclosed series motor, having a normal speed of 2500 r.p.m. at 125 volts. The motor may also be wound for 80 or 220 volts.

The navy requirements for this set are 425 cu. ft. of air per minute. The complete action of the fan is shown in Fig. 1, where the impact and static pressures and watts input are indicated for air deliveries obtained with outlets varying from an entirely closed to an unrestricted opening, these curves being taken with the motor running on 115, 120 and 125 volt circuits.

The navy specifications are prepared with a view to obtaining a light and compact set, and in this design particular attention has been given to these requirements, the dimensions and weight being as follows:

Length parallel to shaft, 12¾ in.

Height, 16⅞ in.

Width, normal to shaft, with horizontal discharge, 16¼ in.

Outside diameter of outlet, 411/16 in.

Weight, 80 lb.

The general construction is shown in the exploded view of Fig. 2. The fan shell is attached to the magnet frame of the motor, and the complete set is supported upon a malleable iron tripod situated beneath the motor. The bolts for attaching the casing to the magnet frame are spaced 90° apart, allowing the casing to be assembled for horizontal or vertical discharge, as shown on page 150. Handles are provided for convenience in transportation.

Fig. 2. Exploded View of Portable Ventilation Set

The circular magnet frame is of cast steel, and is provided with a front end shield which has two openings for access to the commutator, these being closed by covers swinging horizontally and held by latches. Suitable protecting binding posts are to be supplied. The armature and fan wheel are carried between two ball bearings, one of which is located in the end shield, and the other at the fan inlet.

The fan casing is of cast iron, with an opening in each side of sufficient diameter to allow the removal of the wheel. The wheel is of sheet steel, the side next the armature being of such a diameter and shape that it acts as a separating plate between the fan and motor.

No starting rheostat is required with this set.

AN INTERESTING APPLICATION OF SINGLE-PHASE MOTORS

The accompanying cut illustrates a very interesting and up-to-date application of a General Electric single-phase motor, in connection with the manufacture of gas stoves.

Some years ago, shortly after the advantages of the application of motors to machine tools had been practically demonstrated, a few progressive establishments initiated the practice, now largely in use, of machining heavy castings *in situ* by bringing the various tools required to perform the successive boring, planing or grinding operations, to the work; and the new method, having been found very economical and capable of eliminating a great deal of delay in shifting heavy masses from machine to machine, with the attendant lining up, has extended widely throughout the whole domain of machine shop practice.

The advantages of moving the electrically-driven machine to the work, rather than the work to the machine, have now become so apparent in the case of machine shop practice, that a general movement along these lines has invaded a great many other classes of manufacturing industry. In the manufacture of stoves, for instance, it is essential to blacken and polish them very carefully before they are shipped from the factories where they are made, both in order to protect the iron from rust, and to give them an attractive appearance to facilitate their sale. In most factories, until recently, it has been necessary to transport the stoves on hand trucks, one or two at a time, from the assembling department to the polishing department, and after the polishing was completed, to remove them by the same method to the store room.

By means of an electrically-operated polishing apparatus, which has been perfected by the Coates Clipper Manufacturing Co. of Worcester, Mass., manufacturers of stoves are now enabled to carry the polishing

Fig. 1. Stove Polishing Apparatus Driven by 1/2 h.p. Single-Phase General Electric Motor

machine from point to point, and thus avoid a great deal of heavy handling, which is not only expensive, but frequently results in more or less damage to the goods handled. Several manufacturers of gas and coal stoves have adopted these equipments, and find them of the greatest utility.

The illustration shows a ½ h.p. single-phase General Electric motor and starting box, mounted on a special truck provided with swivelling castors. Connected to the motor is a Coates flexible shaft, leather covered, carrying an angle head to which various brushes, suitable to the work in hand, may be immediately attached or removed. The motor is fed from the electric supply through a long heavily insulated flexible cord, adapted to the rough handling incident to its usage in a stove works.

It is quite evident that outfits of this character not only serve a very useful purpose in connection with the manufacture of stoves, but may also be used to great advantage in stove stores for keeping the stock free from dust and dirt, and for renewing the polish of the black portion of the stove, as well as that of the nickel trimmings.

THE LOCKING SOCKET

The necessity for a special socket to protect customers from the petty thief who makes a practice of stealing lamps has led the General Electric Company to design a socket with a locking device.

This socket is intended for use in public buildings and similar places where lamp stealing is often a great nuisance.

The design of this socket is such that in order to insert or remove a lamp from the socket it is necessary to turn a key in the locking device. When the lamp is in position it swivels freely, and cannot be taken out except by locking the socket with the special key, thus clamping the screw shell and preventing it from turning. It may be worthy of mention that this feature is contrary to custom, since it is necessary to unlock the device in order to make it proof against thieves.

Fig. 1. Locking Lamp Socket and Key

The socket and the locking key are shown in the accompanying cut and it should be noted that the locking feature has been introduced without in any way detracting from the neat appearance of the standard socket.

TWO DOLLARS A YEAR TWENTY CENTS A COPY

GENERAL ELECTRIC REVIEW

VOL. X, No. 5
PUBLISHED MONTHLY BY
GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU
SCHENECTADY, NEW YORK
APRIL, 1908

Towers of the South Staffordshire Mond Plant, Power Gas Corporation, Ltd., Dealing with Gas for 30,000 H.P.

(See page 199)

General Electric Company

Edison GEM Lamps

50 Watts 20 C.P.

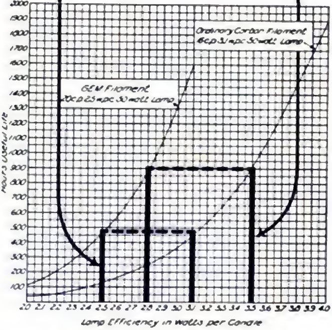
Edison Gem
50 Watt Lamp

gives central stations using 3.1 w.p.c. lamps the same output per lamp as at present, thus avoiding the necessity of increasing number of consumers or lamps connected per consumer

The 50 Watt Edison GEM Lamps give 25 per cent. more light

and consume but 2.5 w.p.c. with the same useful life as carbon lamps at an efficiency of 3.1 w.p.c.

Can also be operated at 2.8 w.p.c. to give the same useful life as carbon lamps at 3.5 w.p.c.



Useful life curves of New GEM Filament Lamp and present Carbon Filament Lamp

Main Lamp Sales Office: Harrison, N. J.

Sales Offices in All Large Cities

GENERAL ELECTRIC REVIEW

VOL. X, No. 5 | APRIL, 1908

CONTENTS

2,500 Kw. Twin Tandem Gas Engines, California Gas & Electric Co., San Francisco, Cal.

Vol. X, No. 5 SCHENECTADY April, 1908

GENERAL ELECTRIC REVIEW

GAS POWER*

By H. H. Suplee
Editor of Cassier's Magazine

It is not my intention to talk about the gas engine from the beginning, or to describe the details of construction, or go into the elementary matters in connection with it. I think most of you are familiar with those points. What I shall try to talk to you about is the important transformation which has been going on during the past ten years in the generation of power by the use of gas engines of large size, in power plants for which the gas engine was formerly considered altogether inadequate.

It was long ago recognized that an air engine, as it was then called, using air or some fixed gas (a gas which does not change its state as steam does, from water to vapor and from vapor back to water again) would be an efficient medium for the conversion of heat into power, and Professor Rankine clearly defined the theoretical possibilities of the air engine many years ago. The practical obstacle to its use lies in the fact that it is very difficult to heat a large body of air from the exterior. It was not until the gas engine became extensively used, burning its fuel in gaseous form within the body of air, that the air engine was shown to be a commercial possibility. The gas engine is really an air engine in which the fuel is burned in the midst of the air instead of being consumed on the outside and heat conducted through the walls of the chamber.

Later Type of Blowing Gas Engine as Built by The John Cockerill Works, Seraing, Belgium

* Lecture before the Schenectady Section A.I.E.E. February 6, 1908.

The early gas engines of small size, using city gas and driving printing presses, etc. were used only because they were convenient. The high cost of the fuel made them expensive, but they were convenient because they could be started and stopped instantaneously, and cost money only while running, and thus had certain advantages.

About fifteen years ago a brilliant idea occurred to Mr. B. H. Thwaite, of London. This was, that in the combustion of coke in a blast furnace for the manufacture of pig iron, there are produced large volumes of gas suitable to be used in the cylinder of the gas engine. There is thus here a tremendous amount of cheap fuel all ready for use, and at once engineers began to consider the possibility of using that fuel in the gas engine. A portion of this gas had been burned under the boilers to supply steam for the engines, and some was used in heating the air blast, but a large portion of it was wasted. This discovery proved to be the inducement to build large gas engines. In 1894, Mr. Thwaite published a short statement calling attention to this fact, and soon after he made some experiments in Scotland with a small gas engine fed by blast furnace gas, and found that it worked very well. Almost at once builders of heavy machinery, particularly those interested in iron works and iron manufacture, began to consider the possibility of use of gas engines, at first for blowing the blast to the furnaces and then for the generation of power to drive the machinery. About the time that this was being considered, the Paris international exposition of 1900 was held, and among the mechanical exhibits there shown was one attracting the attention of everyone interested in mechanical matters. Up to that time the largest gas engine in service was about 250 h.p., and this was considered a very large one.

1,000 Kw. Cockerill Blowing Engine. Exhibited at the Paris Exposition in 1900

In 1898, Mr. Dugald Clerk, one of the leading experts in gas engine design, and the inventor of an important type of gas engine, made a prediction. He said "There is little doubt that in ten years gas engines of 1000 h.p. will be as common as engines of 100 h.p. are now." Mr. Clerk's ten years have ex-

16-2000 Kw. Gas Engines in the Power Plant of the Lackawanna Steel Co.
Built by the De La Vergne Machine Co., New York

8-1000 Kw. Gas Engines in the Power Plant of the Lackawanna Steel Co.
Built by the De La Vergne Machine Co., New York

pired and gas engines up to 4000 h.p. are in use, and his prediction has been abundantly fulfilled.

At Paris in 1900 there was one gas engine of 1000 h.p. exhibited by the John Cockerill Works of Liège, in Belgium. This was built for a blast furnace blowing engine. I happened to be in Paris in the spring of that year, and went to the exposition, and saw this engine and admired it exceedingly. I was called away from Paris, and two months later went back. There was a large sign hung over this engine stating that this machine had been sold 95 times. They had taken orders for 95 of these machines by showing one. Some time afterward I saw the mate to it driving a blowing engine at the Cockerill Works. It was running beautifully and giving excellent service. In another room was a 200 h.p. gas engine belted to a dynamo, and furnishing power for service in the works. That was in 1900, and at that time all the rest of the power was furnished by steam engines. Each year since then they have been installing gas engines more and dropping off more steam engines. To-day the estimated power output in that works is twenty-four million kw. hours, all produced by gas-power from gas taken directly from tops of their blast furnaces. That gives you an idea of the advance that has been made.

In this country the first attempt was made by the Lackawanna Works when they moved from Scranton to Buffalo, and they naturally had some difficulties to face. They are running to-day a plant consisting of 16 blowing engines of 2000 h.p. each, and one of 8 electric units of 1000 h.p. each of General Electric make.

1700 H.P. Gas Engine for Driving Electric Generator. Built by the William Tod Co., Youngstown, Ohio, for the Carnegie Steel Co.

The U. S. Steel Corporation is now having a large number of gas engines built for use in its plants and at its new Gary plant. The Westinghouse Machine Co. has built two 3000 h.p. blowing engines for the Edgar Thomson Works.

Coal is a natural source of energy, but our supply of it is limited and we have been using it at a wasteful rate. Broadly speaking, a gas engine will produce a horse-power with about one-half the amount of coal required for the steam engine; that is, the coal supply of the world, if used in the generation of power, would either produce twice as much or last twice as long if used with the gas engine rather than the steam engine. Coal can be burned in the gas producer and the gas used in the gas engine with twice the efficiency obtained in burning it under a boiler. Furthermore, an advantage of gas power lies in the possibility of the utilization of the fuels of low grade which cannot be used so successfully under the steam boiler.

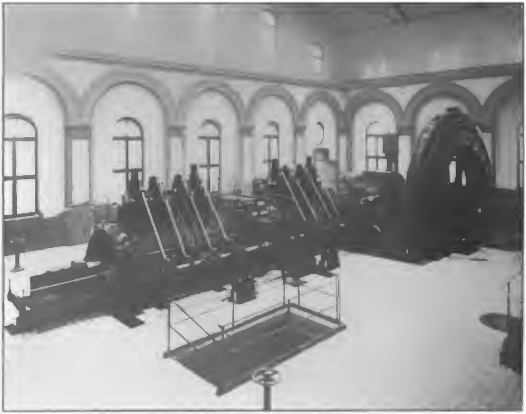
500 H. P. Gas Engine Built by the Sargent Engine Co., Driving 300 Kw. Direct Current Generator

Lignites, peats, bone coal, soft coal, coals having a large proportion of impurities, such as sulphur and ash, all these are capable of being used to good advantage in the gas producer; so that in the efforts for the conservation of our supply of natural energy, the gas engine is going to be an important element. The importance of this will be realized when it is understood that the national government has taken up the matter of preserving our natural resources, endeavoring to check the enormous waste of our natural sources of wealth, including the question of the waste of fuel.

Although the gas engine is still in its infancy, the heat efficiency is practically double that of the steam engine. The vertical type of machine works well with city gas, and in places where natural gas is available. The gas is clean, and this type works well; but there is a certain amount of dirt and dust in blast furnace gas, and this sometimes gets into the machine and causes trouble. The blast furnaces in Belgium, where the first engines were built, produced a fairly clean gas and there was little trouble experienced. When similar engines went to different parts of Europe, and were installed in works producing dirty gas, the dust and dirt soon gave trouble. Then it began to be realized that something more must be done, and a good deal of the seven years' experience has been devoted to the cleaning of gas. To-day, however, there are a number of devices by which the gas may be satisfactorily cleaned; but no matter how well the gas is cleaned the dust will accumulate upon the top of the piston in a vertical engine. With the horizontal type it will generally blow out without doing serious harm.

In the gas turbine the turbine part is practically the same as the steam turbine. The gas has to be produced continuously and delivered against the buckets or blades of the wheel in the same manner as steam in the

1200 H. P. Nürnberg Double-Acting Single Tandem Gas Engine Driving 825 Kw. Three Phase Alternator at Powell Duffryn Coal Co.



Blast Furnace Gas Engine Built by the Gas Motoren Fabrik, Nürnberg steam turbine. That means ordinarily that the fuel has to be burned in a closed chamber under pressure continuously, maintaining combustion at constant pressure. Air has to be blown through a nozzle and mingled with the gas under pressure, and the gases produced by the combustion discharged upon the blades of the wheel. This means the accomplishment of two very difficult things. In the first place, air must be supplied under pressure continuously and efficiently; and secondly, very high temperatures have to be dealt with. Some good experimental work has been done and more will follow, and I should not be surprised if the gas turbine should ultimately become an important prime mover as well as the reciprocating engine, each in its place. There is room for each, but in many cases the advantages of continuous rotary motion will outweigh any deficiency in economy, and it is possible that we may improve the gas turbine and get a higher power for weight and volume than with the reciprocating engine.

The illustrations cover only a portion of the work which has been done in late years, but they will serve to show the extent to which the large gas engine has been developed during the past seven or eight years.

Among them will be seen the large gas engine built by the John Cockerill Works at Seraing, near Liège, in Belgium. This is the engine which was shown at the Paris Exhibition of 1900 and to which I have already referred. It was designed for operation with blast-furnace gas, but at the Exposition it was run for a short time each day with city gas. It is shown directly connected to the blowing cylinder for supplying air to the blast furnace and it developed 600 h.p. with furnace gas, or about 1000 h.p. with city gas. Shortly after the Paris Exposition I visited Liège and saw a similar engine to this in continuous operation supplying blast for the furnaces there. This is the first gas engine, to my knowledge, which attained 1000 h.p., and I believe the companion engine is still in operation at the Cockerill Works.

A later design of blowing engine of the same company is also shown, the principal modification in these engines having been in mechanical details, such as provision for more effective cooling by water circulation, and by the introduction of arrangements to provide for the expansion and contraction strains.

In engines of this sort the power varies according to the richness of the gas but not to such an extent as might be imagined since

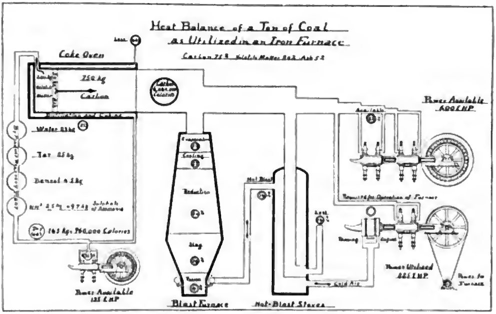
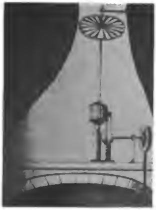


Diagram Showing the Possible Utilization of a Ton of Coal in the Coke Oven, Blast Furnace and Gas Engine it is the heating value of the *mixture* of air and gas which is put into the cylinder which determines the power and not the calorific value of the gas itself. With a rich gas a greater proportion of air is used, while with a lean gas a greater quantity of gas in proportion to air is put into the mixture. As a matter of fact, the heating value of illuminating gas or natural gas is six or seven times that of blast furnace gas, while the difference in power in the engine, using the different gases will vary only about 40 to 50 per cent.



The "Smoke Jack"
The First Gas Turbine

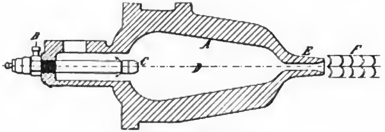
thus are enabled to make one power stroke every revolution.

Among the other American gas engines of large size illustrated will be seen a set of 1700 h.p. engines of the four-cylinder, double-acting type, in course of erection in the shops of the William Tod Company of Youngstown, Ohio. built for the United States Steel Corporation and also a 500 h.p. Sargent gas engine, belted to a 300 kilowatt, direct current generator in the Works of the Wellman-Seaver-Morgan Company, at Cleveland, Ohio.

There is also shown a view of the large plant of the California Gas and Electric Power Company at San Francisco containing four sets of twin tandem gas engines, each pair developing 2500 kilowatts. These engines were built by the Snow Steam Pump Company of Buffalo.

Other views show German engines built by the Nurnberg Works, the details being given under the illustrations.

A special form of German engine illustrated is that of the Oechelhauser type, this being especially designed for blast furnace gas. In these engines the cylinder is open at both ends and contains a pair of pistons, the gas being run between them and forcing them apart at each stroke. This involves a double set of cranks, but it simplifies the valve construction, and this design has been extensively used in Germany in connection with the development of power from furnace gas.



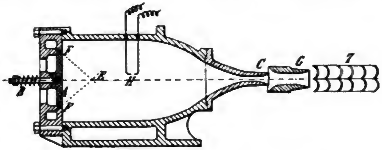
Combustion Gas Turbine
A.—Combustion Chamber. B.—Fuel Inlet. C.—Fuel Sprayer. E.—Expansion Nozzle. F.—Turbine.

Among the illustrations also will be seen the views of the plant of the Lackawanna Steel Company, near Buffalo, these being Koerting engines of the two-cycle, horizontal type. In one room there are sixteen engines of 2000 h.p. each, driving blowing cylinders, and in the other there are eight engines of 1000 h.p. each, direct connected to electric generators. These engines are provided with separate pumps for the air and the gas and

An interesting diagram is that prepared by M. Leon Greiner, of the Cockerill Works for illustrating the power to be obtained from a ton of coal. The coal is first delivered to the coke oven, from which, in addition to the coke and the chemical by-products, a surplus of valuable power gas is obtained, capable of producing 135 h.p. for every ton of coal coked.

The gases discharged from the blast furnace are used, a portion for heating the blast, and a portion for driving the blowing engines and machinery of the furnace, this requiring gas equivalent to 225 h.p. for each ton of coal burned. The balance of the gas from the blast furnace is capable of producing 600 h.p. available for sale, so that by taking advantage of all the possible opportunities for the saving of fuel, there is developed 735 h.p., over and above what is needed for the operation of the furnace.

Probably the oldest form of gas turbine is the old-fashioned "smoke jack," of which an illustration is shown, taken from Bishop Wilkin's "Mathematical Magic" dated 1680, although such a machine was described by Cardan as long ago as 1550. The propeller wheel in the chimney was caused to revolve by the ascending current of hot gases from the fire, and the motion was transmitted by gearing and belting to the spit on which the joint of meat was carried before the fire. The amount of power developed by such a machine was not great, but since it replaced the labors of the turnspit dog formerly employed, we must admit that it was at least one "dog-power."



General Arrangement of Explosion Gas Turbine

An early form of gas or hot-air turbine is that of Stolze, this consisting of two turbines on one shaft, one acting as an air compressor, and the other as a power turbine, that air being forced through a heating chamber between the two wheels, but this machine, although operative, has not been commercially developed. Other designs for gas turbines are shown in the diagrams, one interesting form being the explosion turbine.

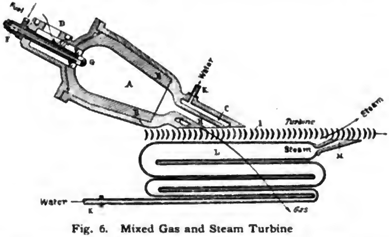
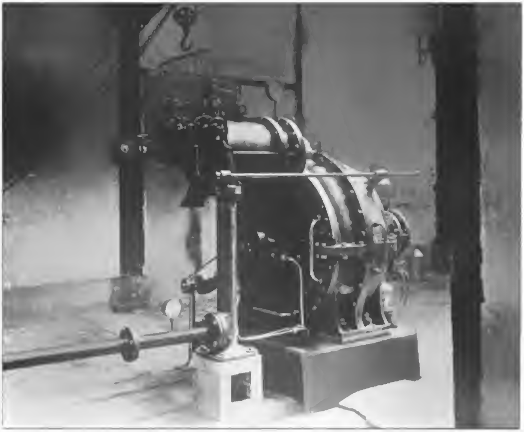


Fig. 6. Mixed Gas and Steam Turbine

Air enters at D, fuel at F, the ignition is made at G. The combustion chamber A is lined with carborundum. The nozzle H is water-jacketed, and the hot water passes to the steam generator L, which is heated by the exhaust gases from the turbine. The steam acts to propel and cool the wheel by the nozzle M

This consists of a combustion chamber, one end of which is closed by a large valve opening inward, this valve having the small openings for the gas in the face of the valve-seat. It is a well-known fact that when a mixture of gas and air is exploded there is first a sudden expansion, followed by the formation of a partial vacuum, due to the combination of the hydrogen and oxygen to form water. This fact was utilized in the old Otto & Langen gas engine under a piston, and is here applied in a combustion chamber. The mixture is ignited by the electric spark, and the explosion discharged against the blades of the turbine wheel. The formation of the vacuum draws in another charge which is ignited and the operation is repeated. Such an apparatus has made 60 to 80 explosions per second, and gives practically a continuous discharge upon the wheel. So far this apparatus has not been developed, and its efficiency is very low, but it has possibilities.

In the case of the pressure gas-turbine the air and gas are delivered under pressure to a combustion chamber, where a continuous combustion is maintained, the products being discharged upon the buckets of a turbine wheel. In practice such a chamber is lined with carborundum, backed with an elastic filling of asbestos, the nozzle being made of carborundum also. The chamber is water-jacketed, and the water discharged into the nozzle as steam to cool the gases. The exhaust gases are also delivered over the pipes of a coil boiler and the steam thus produced delivered upon the same wheel. These principles are used in the gas turbine of Armengaud and Lemale, and an illustration of such a machine of 300 h.p. is shown as erected in the experimental shops of the Société des Turbomoteurs at Paris. M. Rateau, the well-known designer of the steam turbine which bears his name, has designed a rotary turbine compressor for use with this machine, which gives an efficiency of 65 per cent., and tests and studies of this machine are now under progress in France.



The Armengaud and Lemale Gas Turbine, Showing Combustion Chamber, With Air and Fuel Connections

Thus we see what has been accomplished in the generation of power from gas since Mr. Clerk made his prophecy in 1898. The power of blast-furnace gases is being utilized, the gas turbine is well on its way, and the fuel cost of the steam engine has been cut in two.

I do not wish to encourage invidious comparisions between the cost of power from steam engines and gas engines. Both motors have their place, and gas power is not going to drive out steam any more than electric lighting drove out gas lighting. More important than mechanical details in the development of gas power is the development of the commercial side of the industry. Selling power is a very different business from the selling of pig iron, and iron manufacturers may find all the value of the power produced from their waste furnace gases consumed in marketing it. Probably the solution of this portion of the problem will be found in the development of selling companies, taking the power from the iron works in quantity, and attending to the distribution and general details of the business independently. It is often said that it costs as much to market a product as to make it, and probably gas power is no exception to this rule.

The gas engine has passed the stage when it was considered as a small affair for the operation of printing presses, laundry machinery and the like, and it has become an important type of prime mover for many purposes. The power house engineer will find it of continually increasing importance in many departments of his work, and even for the driving of electric machinery, such as alternators in parallel, and similar exacting work, it will be found capable of holding its own with the best modern forms of steam engine. Its progress during the next ten years cannot be predicted, but a motor which now drives practically all our automobiles, which is making the aeroplane a possibility, and yet which has risen in capacity from 250 to 4000 h.p. within ten years past cannot fail to have future possibilities worthy of consideration.

CURRENCY AND FINANCE

Part II

By Henry W. Darling

Treasurer of The General Electric Company

Reserves

Let me now touch upon the subject of reserves. Those responsible for the National bank system evidently thought, that in authorizing the establishment of small banks in country districts, the management would probably devolve upon men untrained and inexperienced in the science of banking; and as some sort of safeguard, they provided in advance for the maintenance of a certain fixed percentage of reserve, in lawful money of their total deposits.

Certain cities, usually one in each state, were appointed as "central reserve cities," and all National banks in these cities are required to hold in lawful money twenty-five per cent. of their total deposits. Other cities were called simply "reserve cities," and the banks therein must also maintain a reserve of twenty-five per cent., but of this one-half may be on deposit in a bank in a central reserve city. Banks in smaller places are required to maintain a reserve of fifteen per cent., of which three-fifths, or nine per cent. may be on deposit in a bank in a reserve city or in a central reserve city.

There is a weakness here which should be pointed out, and which has been the subject of comment: Under this reserve system, deposits of \$10,000,000 in non-reserve city banks would call for a reserve in lawful money in their vaults of six per cent., or \$600,000. They could carry and count as reserve \$900,000 on deposit with reserve city banks, which would make up the fifteen per cent.

These reserve city banks would be required to have only \$112,500 cash, and might deposit an equal amount of \$112,500 in central reserve cities, who in turn would hold twenty-five per cent. of this on hand, or \$28,125 in cash. Thus, the country bank keeps but six per cent. in cash, and of the reserve deposits of the country banks the city bank keeps but 1.4 per cent. in cash. There is therefore but 7.4 per cent. cash, or \$740,625 unloaned anywhere against this deposit of \$10,000,000 in country banks. If for any reason there should be a drain, or a reduction of \$150,000 in the deposits of the country banks out of \$10,000-

000,—*i. e.*, only 1½ per cent.—it would call for more cash or reserve money than is kept on hand for the whole $10,000,000 in reserve banks.

Under such a condition of affairs it is easy to understand how a crisis can assume the phase of a bank panic.

The system of a bond secured circulation offers no help in any sudden call for deposits. The bills cannot be got quickly, and the purchase of bonds for their security requires as much money as they furnish. The principle of adequate reserves in banking is fundamental, but wholly unscientific when a rigid regulation by law is attempted, and the various amendments to the law which have been suggested are unlikely to improve matters.

It must be manifest that different classes of deposits require larger or smaller proportions of reserves. Moreover, the character of the loans in which the bulk of the deposits is invested, their maturities, and the security upon which they are based, have a most important bearing upon the subject. Of what avail is an extra 5 or 6 per cent. of reserve if the bulk of the deposits are invested in a fixed or semi-fixed form and not readily available? Banking is just as much a science as navigation or surgery, and the man who will excel in either must undergo the necessary training and study and have wide experience. Caution and vigilance, foresight, and the most thoughtful study of conditions, together with an intimate knowledge of the circumstances of depositors and borrowers, will alone keep the bank safe. It is in times of stress and panic that these matters are severely tested. The prudent banker must always be prepared for the unreasoning demand of an alarmed and panic-stricken community.

The questions of reserves and circulation are closely allied, and are now the subject of keen discussion by legislators, bankers and business men. The resort to an emergency currency to be issued by the secretary of the treasury is more likely to increase than to allay the want of confidence.

This proposed emergency currency based on municipal and approved railroad bonds, is to be heavily taxed to insure its speedy retirement when the exigency has passed; but how can the issuing bank which has to pay the tax control its disposition or compel its return? It is in the hands of the public, which has no interest in it or in the bank of issue, and is entirely indifferent as to what bills it uses or hoards, and all the issuing bank can do is to wait for the return of this currency and refuse to reissue it.

It is a question whether the attempt to fix a proper proportion of reserves to be maintained by law, irrespective of the character of the deposits and of the loans of the bank. does more harm than good. It may have served a useful purpose in years that are past, but in the older states and in the large cities, we have a body of trained and experienced bankers, many of great eminence, to whom such legislative enactments are neither useful nor restrictive. They must be disregarded in times of stress, because that is precisely what reserves are for, and when business is dull and money is a drug, the law is of no account.

Returning for a moment to the question of a bond secured circulation, it is not difficult to predict that before many years it will be entirely abolished, displaced by a system more scientific and perfectly safe.

The National banks have now been in existence for a long enough time, and have come through such periods of prosperity and panic that something very positive can be affirmed as to their stability as a whole.

I do not see any good reason why they should not be organized into State associations, and mutually guarantee the circulation of each and every National bank in the state, by depositing with the treasurer of the United States a percentage, say five, or six, or seven per cent. of the average monthly circulation of each bank, based upon the previous six months; and let this fund, still remaining the individual property of the contributing bank, be available to make up any loss sustained by the insufficiency of assets of a failed bank to provide for its circulation.

The state association would establish a redemption city in every state in the union—preferably another national bank—where the bills issued by the banks in the State of New York, for example, would be daily redeemed in legal tender and swiftly returned for redemption to the issuing bank. By this daily system of redemption it would be impossible to keep afloat more money than is actually required for the wants of commerce, and therefore it would be perfectly safe to allow each National bank to issue its own bills up to the full amount of its paid up and unimpaired capital. The percentage of the guarantee fund would necessarily vary in the different states. It could be made even larger than seven per cent. at the outset, until experience had established a safe minimum rate.

One of the advantages of this mutual guarantee would be the interest taken in one another by all the banks in each state. No bank should be allowed to do business with a smaller capital paid up than $200,000 or $300,000; and in place of small struggling banks, in sparsely settled communities, with too limited business to enable them to pay adequate compensation to trained managers, we would expect to see branches of the banks with large capital and resources, the operations of which would be directed from their headquarters. This was originally the Scotch system, and is now the British system and in successful operation in England, India, Canada, Australia and in all the British Colonies.

It has many advantages, not the least of which is the school that is thus established by each large bank for the training of officers, by transferring them from branch to branch in various capacities. In this way they become heir to the accumulated traditions which are the result of generations of experience.

The theory that deposits gathered up in one locality must necessarily be loaned in that community, irrespective of the character of the business done therein, has long been exploded, and yet it was seriously repeated, and branch banking damned with faint praise, in the report of the commission on banks recently appointed.

The Importation of Gold

"France once accommodated America with gold at a time when the exchange relations between the two countries did not justify a movement of the metal to this side. When the exchange relations between the two countries do not justify a movement of metal, how does one country accommodate another?"

"But after all is said, the probability is that America will have to worry along without getting sixty million dollars from Paris, and there is the even less consoling reflection that the nominal engagements, made everywhere since the present import movement began a month ago, must be scaled down very materially, if one is to avoid having an altogether exaggerated idea of the amount of the metal that is now headed towards this country. Nominally the announced engagements have reached a total of about $98,000,000; actually they are probably a little more than $75,000,000."

Regarding the above paragraphs, clipped from a newspaper, should America obtain a large sum of money from Paris, upon what securities would the money be transferred to America? Would the actual bullion be transferred, and if so, upon what security?

As a matter of fact, the exports of the country were enormous this fall. In the ordinary course of affairs we would have adjusted the balance between imports and exports by what we call bills of exchange.

These bills are dealt in by bankers and brokers just like any other commodity, and the rate fluctuates according as the balance is in favor of this continent or the other. This is not invariably the case, as the market is sometimes influenced by other considerations.

There is no truth in the statement that the gold recently imported was borrowed. The trade conditions gave the tendency to an inflow of gold to America, and the premium on our currency made it possible and profitable. Taking November and December together, the exports amounted to the enormous aggregate of $411,653,000, and the net export balance reached $208,821,966. France accommodated America by making a price upon her surplus stock of gold that attracted the buyers. Had France felt too poor to spare it she would have put up the price. The Bank of France would have entered the market and paid a price high enough to keep the gold in the country. The actual bullion was bought and paid for. It might have been in bars or in coin. In all probability it was both. Gold is bought and sold like any other commodity.

How is gold transferred into currency?

Gold is the best currency. If a bank can get gold it needs nothing more. It was found more convenient during the panic to import gold than to purchase Government bonds as a basis for obtaining national bank currency.

Clearing Houses

What is the practical operation of the National Bank Clearing House?

The Clearing House is simply a voluntary association of the banks of a city, established for the promotion of their interests, and for mutual protection. They adopt certain rules or by-laws for the conduct of their business and agree with one another, under penalties for violation, to abide by them. One important function that the Clearing House facilitates is the adjustment of balances between its various members. Each day each bank presents the cheques received the previous day against its fellow members, and in turn it is presented with the cheques drawn against it, negotiated by all the others, and the balance is adjusted in favor of or against each bank in legal tender. At the close of the transactions for the day the total debits and credits will just offset one another, the Clearing House being merely the medium of settlement. The total volume of business as tabulated from day to day forms a useful barometer as to the relative activity of financial transactions. During a panic or monetary crisis the Clearing House banks stand by one another on the theory that a failure must affect them all more or less. As in the so-called "Morse-Thomas" chain of banks, a demand upon the part of the Clearing House committee of management for a member bank to purge itself of a dangerous element in its directorate or officials, must have instant attention, or its death knell will have rung. Disregard of proper safeguards or practices, which is contrary to the principles of sound banking, when brought to the notice of the governing board, results in the immediate disciplining of the offending member, and the proper remedy must be applied, or the bank's existence will be imperiled.

On the other hand, a member bank which is unable, through stress of circumstances, to settle the balance against it in legal tender, may deposit satisfactory securities from its treasury assets with the appropriate committee and obtain from this committee a certificate which is received as the equivalent of the legal tender. This certificate is in turn received by some other bank to whom legal tender for the balance due it is not essential. Thus the strong help the weak, and in the presence of a common danger they stand together. In some cities these Clearing House certificates were issued in small denominations, and were used as, and served all the purposes of ordinary bank notes, thus performing the functions of "emergency currency." The necessity for their use having now passed, they have been almost wholly retired, and so far neither loss nor trouble therefrom has been reported.

What is the process from special government action to relieve stringency to the point of actual currency relief?

The Treasurer of the United States is a self-contained banker. His receipts from customs, duties, etc., which as before remarked, are payable in a special form of currency, are withdrawn from circulation and hoarded in the treasury. These payments are usually heaviest when there are the largest demands for currency for other purposes; and this results in stringency and an increase in rates of interest to borrowers, because of the lack of elasticity in the system. The banks have always complained of this withdrawal of currency just when it is most needed, as an unwarranted interference with the ordinary business of the country, causing inconvenience by the fluctuations in the value of money. The secretary of the treasury is not bound to make a deposit of any of this money in the National Banks although he may do so at his discretion. During the recent panic he used this privilege liberally, and even stretched his authority by issuing treasury notes and Panama bonds as a basis for bank circulation in the hope that public alarm might be allayed, and that a normal condition of financial affairs might be restored. For this action he is now being severely criticized.

Money and Rates of Interest Thereon

> "Yesterday renewals were made at 7%, against a rate of 9% charged on Monday, and in the afternoon a supply of funds was offered at 3%, even this low rate failing for a time to attract borrowers."

When a statement is made as above, for what period does the interest apply, the interest being one morning at 9% and in the afternoon dropping to 3%? What influx in bullion or accepted securities can account for such a drop in the rate of interest, assuming that market operations are on a rational basis?

Money is a commodity like anything else. There is a market for money, and there are brokers who deal exclusively in money. There are usually plenty of borrowers. Banks and financial institutions have what they call surplus money to loan from day to day. The rate is governed by the law of supply and demand.

In the morning it may appear as if there were a large demand for money and as if loanable funds would be scarce. As the day passes, the demand slackens or the supply becomes plentiful, or it may be just the opposite, and the rates fluctuate accordingly.

The term of the loan for such funds is until noon of the following day, and assuming that the collateral and the rate are satisfactory, the loan may be continued from day to day. If there has been a great change in the value of money, either up or down, the banker may hear of it in the first instance from the borrower, who fixes the rate high enough to insure his keeping the loan if he is needy, and must have it, or down to the lowest rate that he knows he can get the money for elsewhere.

THE ELECTRIC MOTOR IN THE SILK INDUSTRY

By Andrew Kidd, Jr.

It is only within the last few years that silk manufacturers in this country have realized the many advantages of installing electric motors in their mills. The system of transmitting power from the engine room by a belt or ropes to line shafting in the mill, the running of belts through ceilings to operate machinery on the floor above, and the conveying of power by means of shafting, belts or ropes from one building to another, is no longer considered by manufacturers who are contemplating the erection of a new mill or an addition to an old one.

The old system of long line shaft drive, running the full length of the weaving room, and counter shafts driven from this main line shaft, as shown in Fig. 2, is a very inefficient means of transmitting power. One striking example of the extravagance of this system was recently called to the writer's attention. In an old mill an engine of 100 h.p. capacity was delivering power to looms and necessary preparatory machines. All looms and machines were stopped, and it was found that 42 h.p. was lost in transmission. This represents what is ordinarily termed "friction load," and is the power required to drive simply the shafting, belting and loose pulleys on the machines, when the machines themselves are idle. It is the friction load under this condition, but under this condition only, for as soon as the belts are shifted to the tight pelleys and the machines are placed in operation, this friction load is undoubtedly greatly increased. No method has as yet been devised to determine accurately the extent of this increase in the friction, but the fact remains and should never be lost sight of, that the friction load under operating conditions is greater than when the machinery is

Fig. 1. Silk Warper Driven by General Electric KG 3/4 H. P. Motor

While the cost of power is a small part of the total cost of finished silk, yet, with competition keen, the enterprising manufacturer will grasp every opportunity to reduce the cost per yard of his manufactured article, and the electric motor has assisted him materially in this respect.

The three methods of driving are:

Mechanically, by line shafting, belts or ropes;

Electrically, by grouping looms or preparatory machines under one motor; and,

Electrically, by an individual motor for each machine, particularly looms.

idle; and it is the power necessary to overcome this increased friction load that must be paid for by the manufacturer, and for which he receives no return. This loss gradually becomes worse as the belts stretch, shafts and pulleys become more and more out of alignment and the bearings wear.

In this system the maintenance items, such as cost of attendance, care and renewals of belts, oil, etc., are to be seriously considered. Then there is the liability of an accident to the shafting causing the whole, or a part of the mill to go out of commission, which accident would show up materially in the total output of finished product for the day or the week, depending upon the amount of repairs necessary.

There is also the ever-present danger of dripping oil falling upon the raw material or the finished product.

In the motor-driven mill, the first thing to be considered is whether the current is to be direct or alternating.

Under some conditions where the electric motor is used, a slight variation in speed is not objectionable; in fact for machine tools, printing presses and railway service a decided variation in speed is required, and under this condition the direct current motor is almost indispensible. However, inasmuch as the conditions in a silk mill demand constant speed a little consideration will show that the alternating current motor offers marked advantages.

If direct current is used, provision must be made to take care of the speed changes, which cannot be eliminated in the design of the motor. The reason for the variation in speed is that when the motor is started up, the field windings are cold and, consequently, their resistance is low, allowing an excess of current to flow through them. This excess of current tends to keep down the speed, and as the motor is being heated, say for three or four hours, the current slightly decreases, and the resistance and speed increase.

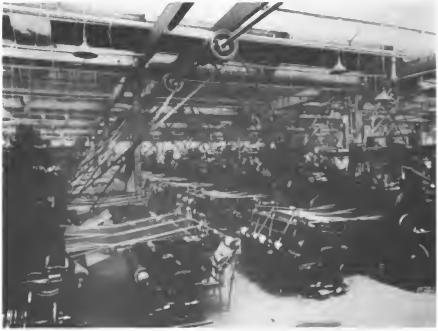


Fig. 2. Weaving Shed, Driven by Line Shafting and Belting, Showing Complication of Belts

The speed of a 40 h.p. direct current motor will vary 7 per cent. during the time the motor is heating up. A loom operating at 120 picks per minute would start off each morning at 111 picks per minute and gradually increase the number as the speed increased, until the motor reached its normal temperature when the looms would operate at 120 picks per minute for the balance of the day.

In order to compensate for these changes a resistance box or rheostat must be inserted in the field circuit, and the strength of the field regulated frequently in such a manner as to keep the speed of the motor constant.

The speed of a direct current motor will also vary if the voltage on the circuit changes, which change sometimes happens when a heavy load is thrown on or off the generator in the power house.

With alternating current motors none of these difficulties are experienced. The speed of the motor does not vary when under constant load, but depends solely upon the speed of the engine which drives the generator. There are no brushes nor commutators, and no frictional parts, except the bearings; therefore, in comparing direct with alternating current motors, the latter should decidedly be given the preference for silk mills.

The grouping of machines under one motor is looked upon favorably by many engineers and manufacturers, and very good results can be obtained from this system if particular attention is given to the arrangement of the shafting and the selection of the proper motor for the work to be performed. This system is used extensively where the machines being driven are run continuously, such as the preparatory machines used in a silk mill. The motor used should work up to its full capacity, in which case the highest economical efficiency is obtained.

A group of 48 in. looms, say 75 to 100 in number, can be driven by a 40 to 50 h.p. motor. As the torque required to start a loom is 100 per cent. above normal running torque, this size motor would be ample for operating these machines successfully, since it is unlikely that a sufficient number of the looms would be started at the same moment to load the motor beyond its overload capacity.

As in the case of the mechanical drive, the group system drives the shafting and belting continuously, whether one of the machines is in operation or all are. The efficiency is greatly improved with the group system, since a 75 kw. (100 h.p.) dynamo has a full load efficiency of 91 per cent. and a 50 h.p. motor has an efficiency of 89 per cent. Allowing a 3 per cent. loss in the line, this will give an efficiency of 78.5 per cent. from the engine shaft to the motor shaft. This group system has the advantage of greater flexibility than the mechanical system, due to the fact that any group may be run independently of another, and should a break-down occur the particular group involved would be the only part of the mill affected.

The production of the looms is greatly increased, as the slipping of the belts is confined to one section, which gives a more constant speed. By reason of this more constant speed, the wear and breakage on the loom and the work of the loom "fixer" is greatly reduced. All heavy line shafting, hanger bearings and heavy belts are eliminated.

Fig. 3. Weaving Shed with Individual Drive, Showing Absence of Belts

The General Electric Company, within the last few years, has equipped several of the largest silk mills with individual motors direct connected to looms. This Company has done more work in this line than any other electrical concern in this country, having sold over 1500 motors for the driving of as many looms, for the weaving of silk, worsted and velvet. Wherever this individual drive has been tried it has always met with success, as its many advantages are soon brought to light.

Fig 4. Side View of Crompton-Knowles Silk Loom Driven by General Electric KG 1 2 H. P. Motor

A direct current motor is not to be recommended in silk mills for individual drive, as it is uneconomical and unsatisfactory for the conditions existing in silk mill operation. Therefore, the following remarks apply to the alternating current motor

The method of installation is very simple, and is, in the majority of cases, entirely successful. In place of the belt pulleys used on mechanically-driven looms, and the friction clutch pulleys also used on such looms (and also advocated by some supporters of the individual electric drive), there is mounted a gear which meshes into the motor pinion. This gear is equipped with a special device, the duty of which is to protect the loom from excessive shock when the loom "bangs off," and which provides the same degree of elasticity as is obtained through the slipping of the belt and by the friction disc pulley ordinarily provided. A bracket bolted to the frame of the loom supports the motor. This bracket is so arranged that a vertical motion of the motor is allowed, as the different speeds of the loom are obtained by changing the motor pinion. The motor may also be supported from the jack shaft of the loom, in which case an eccentric bushing is provided which keeps the motor in perfect alignment and allows for the vertical movement necessary for changing the pinion. In all cases the motor is held to the loom in a very substantial and rigid manner.

It is generally preferable to stop the motor with the loom, thus saving all unnecessary losses and reducing the wear on the motor and its connections to the loom.

An oil switch is furnished with this equipment, and is held to the frame of the loom and connected to the shipper handle in such a manner that the weaver, to operate the loom, starts the motor instead of shifting the belt. The friction gear referred to in the preceding paragraph permits this to be done without damage to the machinery or to the fabric in the loom.

By any method of driving, either electrical or mechanical, that employs shafting and belting, certain losses appear at all times, due to friction and the slipping of belts, whether the looms are idle or in operation.

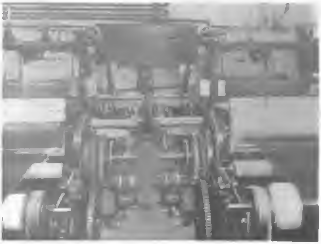


Fig. 5. Group of General Electric KG 1 2 H. P. Motors Driving Crompton-Knowles Silk Looms. Distribution Board in Rear.

These losses are eliminated entirely by the individual drive, as this arrangement requires energy only when actual production is being carried on.

The most beneficial result of the individual drive is the increased production. This is conservatively figured at 5 per cent., and is entirely due to the constant speed of the loom owing to the absence of all belts.

The maintenance item is reduced to a minimum, since there are no belts, line shafting or hanger bearings to be considered, the only frictional parts of the equipment being the motor bearings and gearing. The repairs on the loom are very much less for the group drive than for the mechanical system, and much less on the individual drive than on either. This installation is ideal, inasmuch as the looms may be placed to the best advantage for light, regardless of location to the generating plant. There is no dirt or oil overhead, and the pulleys and belts, which continually stir up dust through the atmosphere, are no longer required.

Fig. 6. Silk Winder Driven by General Electric KG 1 2 H. P. Motor

The first cost of installation for the individual drive is somewhat more than for the group drive, but when the increased production, decreased maintenance, unrestricted light, and the absence of all dirt and dust, are taken into consideration, the manufacturer will agree that he will very soon be fully reimbursed for the extra expense incurred.

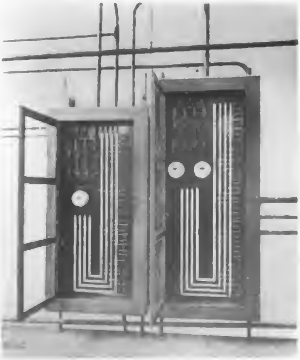


Fig. 7. Main Distribution Cabinets. Lighting Panel on the Left. Power Panel on the Right

The accompanying photographs were taken at the Empire Silk Company's plant at Wilkesbarre, Pa., and show one of the recent installations of this system where no line shafting or belts are employed, as each loom, warper, quiller and winder is driven by its own individual motor. The looms were purchased from the Crompton-Knowles Company and the motors from the General Electric Company.

GEOLOGY OF JAMAICA *

By Rossiter W. Raymond, Ph. D.
Secretary of American Institute of Mining Engineers

I did not use this subject because I wished to teach the geology of Jamaica, for I am going to say very little about it and I shall mention only enough to introduce the real subject, which is not the geology of Jamaica but the history as controlled by the geology. The subject of the controlling influence of the natural environment upon the history of man is the opposite to the subject of man's effect upon the environment. Thirty odd years ago a great book, called "Man and Nature," was written on that subject by George T. Marsh, a book I hope all will read who have not already done so.

I have never seen or heard of a better or more striking illustration of the effect of geology on history than that afforded by the Island of Jamaica, where I spent some time about a year ago. The geology of the Island has been very admirably described by Mr. Robert R. Hill, an American geologist, and if the reader wishes to go into details I would refer him to this account.

The shores of the Gulf of Mexico, taken together with the islands constituting the Greater and Lesser Antilles and Leeward Islands, form what Mr. Hill calls the American Mediterranean. The Caribbean Sea is a part of this group, and is shut off by chains of islands and by the solid mainland of the continent from other portions of the Atlantic Ocean. In the middle of the sea rises a steep peak of a mountain range. This peak is Jamaica.

The water is very deep at some points along the coast, and even this has had a curious effect upon the history of the island's geology, because geologists could not identify the rocks with those of other islands. The water here is so deep that shallow water specimens can not live beneath it, and therefore fossils which are present on other islands are absent on the coast of Jamaica.

Planter's Residence, Oxford Penn

The Island of Jamaica is about 145 miles long and 45 miles across in the widest place, and consists principally of an upheaval, the highest point being about 7400 ft. above the sea level, which is quite a height to look up to. There are, of course, points in the Rocky Mountains much higher than this, but due to

* Lecture delivered before the Schenectady Section, A.I.E.E. January 25, 1908

the altitude of the surrounding country, the apparent distance up is less than is the case with Jamaica.

One of the peculiarities of the scenery is that it combines the sublimity of the Andes with imitation of glaciers, with the canyons of the Rocky Mountains, and with the tropics thrown in, clothed with luxuriant vegetation.

The summits, subjected to the tropical torrential rains, are sharply accentuated. The general topography, or at least the upper part, is illustrated by the story of Columbus crumpling up a handkerchief, and saying "It looks like that." A little further down, 2500 ft. above the level of the sea, is another and later formation. This is a horizontal plateau of limestone which surrounds the central core as if it were a ruffle around the neck of Queen Elizabeth, the mountains rising from the middle. This plateau of limestone has peculiar formations in the nature of "cockpits," which are great funnels 250 to 500 ft. deep in which the water of the heavy rains disappears, and no doubt drains through the limestone rock to the underlying core. At the edge, this limestone plateau breaks off into bluffs, 100 to 200 ft. high. Below these are the lowlands of the coast on which lies the debris of the bluffs consisting of graveled limestone such as is found along the coasts of the other islands. Along the edge is a series of navigable bays.

That is all of the geology I am going to give, and it will be seen how these features have illuminated and foreordained every chapter in the history of the island.

No gold has been found in Jamaica, which fact is rather remarkable considering that Cuba has gold, San Domingo has gold, and the mainland opposite is a very treasure house. If the Spaniards did not find gold in Jamaica, the island gave them something else; namely, those bays that I have told you of, which became the lurking places of the buccaneers, who ran into them and hid. Kingston, or the locality near it, was the great commercial center or metropolis of the whole of the Spanish seas, where the buccaneers came and sold their plunder, bought what they wanted, lived riotously, got supplies, made repairs, and were off again. Now buccaneering is not legitimate commerce, but it is commerce just the same, and after the lawlessness got knocked out, the commerce remained; so from that day to this the towns of Kingston and Port Antonio, and some of the other ports in Jamaica, have been the very centers of the great West Indian trade. They will be even more prominent in this respect when our Panama Canal is finished, for Jamaica is just off the Panama Canal, and there will then be more trade than ever.

One of the most important results of this great commerce was that the ships which

Bringing in Sugar Cane to Mill House

entered the harbors of Jamaica during all these times of the buccaneers and the subsequent West Indian trade brought with them, sometimes voluntarily and sometimes involuntarily, seeds of new plants and trees, varieties of animals and livestock, straw, manure, and all sorts of things which might easily bring forth new vegetation in a new country. So, first of all, it came to pass as a result of this commerce that new growths began to flourish, and the outcome to-day is that Jamaica is a country in which nearly

East India Coolies at Their Midday Meal

everything that we consider characteristic of the country is exotic, and was imported there. I have a little memorandum which states that when Columbus was sitting in his mouldering ship in the bay, there was in Jamaica no sugar cane, bamboo, oranges, lemons, limes, citron, grape fruit, coffee, kola, cinnamon, rice, bread fruit, bananas, cocoanuts, etc., although there is some doubt as to whether cocoanuts should be included in the list.

Essentially, the whole flora which now covers the island of Jamaica has been imported. All the animals, the fauna as well as the flora, come under this head. There is not a single living animal in Jamaica of the kind that was there when Columbus discovered it, except perhaps the cony, which is scarce, but which is said to be seen occasionally among the rocks. All the other animals of Jamaica have been imported, even to the mongoose, which was brought in to fight the rat, this latter pest having found its way there in the ships. When the mongoose arrived it killed the birds as well as the rats, the birds are consequently very much scattered, and the inhabitants are fighting the mongoose to exterminate the species.

Not only have the plants and the animals been imported, but the men also. The original Caribs appear to have been very peaceful, and although they may have eaten one another occasionally, nevertheless they were very gentle. If they were cannibals, they were so simply for the same reason that has made cannibals of many other tribes—a superstitious belief that they might increase their courage by eating the heart and drinking the blood of brave men.

The Spaniards, not having found gold in Jamaica, and not at first having brought the sugar cane and started its cultivation, which required labor, captured the Caribs and sent them off to be peons and laborers in gold mines, and in that way the race absolutely disappeared. I do not believe there is a trace of them left on the island. Then, as the Spaniards afterwards needed laborers for the cultivation of sugar cane, etc., they brought slaves from Africa. Do not let us make the mistake of thinking Africa a small country and every native just like our negroes. East Africans, West Africans, South Africans and Ethiopians are as different as different races in other countries, and one of the first things which strikes one in reading and studying the history of Jamaica is this difference of races

View of Mountain Village

among Africans. The Spaniards brought over a lot of African slaves who sprung from a very different race from those England brought over afterwards.

In the time of Oliver Cromwell, an expedition was sent out to capture some certain island; the expedition lost its way and captured Jamaica from the Spaniards instead. The Spaniards did not fight long, but they did a crafty thing. They called together the African slaves and gave them their freedom, taking from them a promise that they would never be slaves to anyone else and would never surrender. These freed slaves of the Spaniards received the English afterwards very much after the fashion of the guerrilla warriors of Spain. They retreated from the coast, which was generally inhabited for commercial reasons by the whites, to the limestone plateau and into those cockpits, filled, you must imagine, with dense vegetation. I have traveled through some of those jungles and gone through their villages without seeing any people, everyone being hidden in the dense vegetation of the trackless jungles. These people are called Maroons, the word Maroon being a corruption of a Spanish word signifying outcast. These Maroons, as I have said, retreated to the high land, where they were concealed in their mountain fastnesses, and from which they descended from time to time to raid the settlements below. These settlements gradually became a very active sugar-producing colony of England, and the English brought negroes there to work. These slaves were negroes from Africa, but not of the same race as the Maroons. The proud Maroons, who had never been slaves to any country but glorious

Loading Banana Steamer from Lighters, Annoto Bay

Spain, hated and despised other kinds of negroes. It is very curious that these people actually were proud that they had been slaves to Spain but never to England. The cockpits gave them another world as it were, from that on the coast; a world in which they could retreat, manœuvre and hide forever, making it almost impossible for the English to deal with them. These slaves and their descendants kept up a fierce war with England for 150 years. Expedition after expedition was armed and sent out to overcome them, but never came back. The English were trapped, ambushed and massacred, no one living to tell the story. At last, in 1738, an English general managed, not to conquer the Maroons, for they were never conquered, but to get

On the Way to Market

them still long enough to hear what he had to say, and negotiated a treaty. As the Indian tribes in our country have been treated as independent, so the Maroons were treated by the proud kingdom of Great Britain as independent, and a treaty was made by which they became allies of the English. After that, as they were friendly, it did not make so much difference about their living in the cockpits and jungles up on the limestone plateau. They came down occasionally to trade, and the governor would go up once a year probably, blow his horn and call them together and issue some sort of rations to keep them good natured

About the year 1830 slavery was abolished in Jamaica. The result was disastrous to the island, not because slavery ought not to be abolished, but because its abolishment destroyed the plantation system of labor in Jamaica. The negroes, having their freedom, wanted to exercise it, as did our negroes after the war, by realizing their right to move about from place to place. The negroes in Jamaica were greatly encouraged in restlessness and indolence by the fact that a very little work goes a long way in that island for the support of a family. Negroes do not need much to eat, or many clothes, and nothing more in the way of a house than a roof; consequently a man with limited breeches and an umbrella could get along first-rate in Jamaica. On the other hand, about thirty days' work now and then was enough to raise in abundance whatever was needed. The plantations fell into neglect, and the negroes congregated in idleness and lived with little concern because there was little required of them by the climate. By and by they began

H.M. Mails and Post Office

to be restless and discontented, and in 1865 the terrible rebellion broke out in Jamaica, concerning which so much has been said and written. The older people will remember how the governor was criticized for the course he pursued, by Huxley, Spencer, Gladstone and others, while on the other hand, another party was equally strong in his defense. I can see that Governor Eyre did what was necessary, and that without his swift, sharp and even cruel action, the rising would have resulted in the massacre of the entire white population, which was only 3 per cent. of the total, the other 97 per cent. being negroes. There was one massacre—some of these tribes arose and killed all the whites in one town, creating a tremendous panic. The governor made reprisals which were awful, but the most terrible thing he did was probably largely unintentional at the time. He called upon allies whom he was afterwards unable to control—the Maroons up on the limestone plateau. He sent to them to come down and attack the others; and these men, resting in idleness and dreaming of the old days, woke up, sounded their battle cry again, and descended. The horrors of what they did to the blacks constituted the chief charge against Governor Eyre. He did not intend that the Maroons should do all that they did. He could not control them. After slaughtering right and left, and plundering until they were tired, they retired to their abodes on the plateau, and have hardly been heard of since. This was nearly fifty years ago.

There is one more race to be mentioned to complete this collection which has been imported to Jamaica; namely, the Hindoos. Ten or fifteen thousand of these coolies were brought over from East India on time contracts. The cost of transportation was taken out of their wages, and when their time was out they had the option of going home or staying on the island, and many of them stayed. The color of their skin is an attractive black—not a dense black—and they possess straight noses and thin lips. They are lithe and slender, with small hands and feet, and dress in white suits, with wrappings rather than trousers to the knee, scarlet jacket and turban; and as you go along the roads and meet them they give you a greeting of good morning or good afternoon, with an oriental salaam. Small as they are physically, they are very good laborers. They bring their wives and children out with them, and load the women with jewelry. The men are good silversmiths, and as you walk along you see the women with their curious silver ornaments, necklets, bracelets, chains, etc., and you can buy anything they have on. This is the way they exhibit their wares, and the next morning they will be out with a fresh supply.

Another thing with which the geology has had much to do is the great variety of climate. There are different climates at different elevations and on different sides of the island. The bananas and cocoanut palms require plenty of water, and are found in the lower regions, while further up are the coffee plantations.

The Government has established a most wonderful garden for the promotion of agriculture, and tries the raising of plants from all parts of the earth, those that are suitable for the climate and soil being propagated. Practically everything will grow in Jamaica.

The government of Jamaica built a railroad which crosses the island, and which goes through 28 tunnels in 30 miles. It does not pay. It is too long, and it is too expensive for the chief products, such as bananas and cocoanuts. The United Fruit Company do a great banana business, and have 65 steamers of two or three thousand tons running all the time between Jamaica and the United States, and the way they get their cargoes is thus: The steamer will go to the principal headquarters, Kingston, Port Antonio, etc., and unload; it then sails around the island and into the different bays, and as the steamer comes in the banana growers are found waiting with their product. It is not more than ten or twelve miles from any banana plantation in Jamaica to the ocean. The United Fruit Company also sends carts through the island to gather up the fruit for market, and if a negro wants a little money he takes a bunch of bananas and sits down by the side of the road and waits for the cart to come along. The driver takes the bunch of bananas and the negro a copper check good for money. The result is that small producers have a way of getting what money they require without a great deal of trouble. It is pretty hard to arouse the negroes in the present generation to a state of excited ambition—they are too comfortable. I do not suppose there is another country in the world where one class of labor will look on complacently while another class steps in and takes its work. The Jamaican negro to-day looks with the utmost pleasure and complacency upon the East Indian coolie who has come over to do the work he did not like. The whole race, in fact, has something of that attitude—the consequence of their climate.

Although the present condition of Jamaica is not wholly prosperous, the conditions for prosperity are there. The new life of Jamaica, as we call it, has been brought about by the geology. The negroes of Jamaica to-day are supplied, through the commerce of the United Fruit Co., with the opportunity to make money, and the children are showing signs of real ambition to better their condition. I found a few cases of black men who have got rich, and it is possible for any one of them to save money if he has the desire to do so. The Government of Jamaica has started primary schools in great numbers.

The geology of Jamaica has produced this wonderful variety of climate, and has filled Jamaica not only with tourists, but also with products that will restore her wealth in a much more healthy and beneficial manner than that brought about in the days of the buccaneers or the Jamaican slave owners. Besides the public schools there are technical schools and a university, and from this university any man of sufficient ability is eligible for the Rhodes scholarship at Oxford, England, and some of these men have taken it already. The next best thing to good schools which the government can furnish toward civilizing and elevating the people is good roads. This little island has 4000 miles of roads as good as we can furnish in any of our parks. They are made of the limestone from the coast, and wherever you go you see little piles of stone waiting to be reduced to the ordinary size for macadamizing. When one of the natives wants to earn a little money he sits down and breaks stone, and when a certain amount has been broken the inspector gives him a ticket for that amount.

Geological Formation on South Coast. Coral

ROTARY CONVERTERS

PART IV.

BY ERNST J. BERG

Heating of Rotary Converters when supplying Unbalanced Load in a Three Wire System, the Neutral being derived from the Transformers

As a limiting case it will be assumed that full load direct current is supplied from one side of the three-wire system only; one brush therefore carries full load current, the other no current.

In this case the direct current output is one-half of what it would be with balanced load, and the maximum value of the alternating current will be one-half the value determined for the case of heating considered in the first part of the discussion. In that particular instance a direct current of 2 was considered, and the corresponding maximum values of the alternating current were:

2	for the single-phase converter.
1.54	" " three- " "
1.414	" " four- " "
1.33	" " six- " "

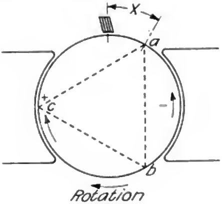


Fig. 14

In this case, therefore, the maximum value of the alternating current in the winding is:

1	for the single-phase converter.
0.77	" " three- " "
0.707	" " four- " "
0.665	" " six- " "

In the analysis given below the three-phase converter is considered.

The circuit of the direct current is from the brush to the line, then to the neutral of the transformers, returning to the brush over the three lines a, b, c, and the winding between the brush and a, b, c.

One-third of the line current enters through each of the three lines a, b, c. In each case the current can enter the brush by two paths in parallel, and the proportion of the current in each will depend upon the resistance of the path.

Assume as before that the armature has 48 slots, and denote the position shown in Fig. 14 as No. 1; the resultant current in phase ab will be determined for each 7.5 degrees revolution. A current flowing clockwise will be considered as positive, and counter-clockwise as negative, as indicated in the figure. The current in a enters the brush in a negative direction over the coils x (in this case $x=4$), and in a positive direction over coils $48-x$. Therefore, the current will divide as

$$\frac{48-x}{48} \text{ is to } \frac{x}{48}$$

The positive current is $\frac{x}{48} \times \frac{2c}{3}$,

and the negative current is $\frac{48-x}{48} \times \frac{2c}{3}$,

or for $c=1$

$$a_- = \frac{48-x}{48} \times 2/3$$

$$a_+ = \frac{2}{3} \times \frac{x}{48}$$

In a similar way we find that

$$b_- = \frac{32-x}{48} \times 2/3$$

$$b_+ = \frac{16+x}{48} \times 2/3$$

and $$c_- = \frac{16-x}{48} \times 2/3$$

$$c_+ = \frac{32+x}{48} \times 2/3$$

In section $a\ b$ we have a resultant direct current of the negative currents of c and b,

Errata. In the third section of this article, which appeared in the March issue of the REVIEW, Figs. 1, 2, 3, 4 and 5 should have been numbered 9, 10, 11, 12 and 13, respectively.

and the positive current of a. Thus the resultant direct current c_0 is:

$$c_0 = -\frac{(16-x)\,2/3}{48} - \frac{(32-x)\,2/3}{48} + \frac{x\ 2/3}{48}$$

$$= -\frac{16-x}{24}$$

This equation gives the following values to c_0 for the positions listed:

Position	x	c_0	Position	x	c_0
No. 1	4	−0.5	No. 15	18	+0.083
2	5	−0.46	16	19	+0.125
3	6	−0.417	17	20	+0.166
4	7	−0.373	18	21	+0.208
5	8	−0.333	19	22	+0.25
6	9	−0.292	20	23	+0.292
7	10	−0.25	21	24	+0.333
8	11	−0.208	22	25	+0.373
9	12	−0.166	23	26	+0.417
10	13	−0.125	24	27	+0.46
11	14	−0.083	25	28	+0.5
12	15	−0.0417	26	29	+0.54
13	16	−0.	27	30	+0.582
14	17	+0.047			

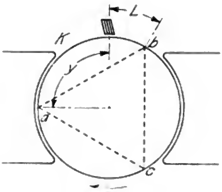


Fig. 15

When the armature has turned more than 28×7½ degrees, or 210 degrees, each section of phase $a\ b$ carries a different value of current, as may be seen from Fig. 15.

Under these conditions we have:

$$a_+ = \frac{48-y}{48} \times 2/3$$

$$a_- = \frac{y}{48} \times 2/3$$

$$b_+ = \frac{16-y}{48} \times 2/3$$

$$b_- = \frac{32+y}{48} \times 2/3$$

$$c_+ = \frac{32-y}{48} \times 2/3$$

$$c_- = \frac{16+y}{48} \times 2/3$$

Section K carries all positive currents, and section L all negative currents.

Thus c_0 in $K = \dfrac{32-y}{24}$

and c_0 in $L = -\dfrac{16+y}{24}$

which give the following values to c_0 for sections K and L, for positions 29 to 45, inclusive:

Position	y	K	L
No. 29	16	0.66	−1.33
30	15	0.707	−1.29
31	14	0.75	−1.25
32	13	0.79	−1.21
33	12	0.834	−1.16
34	11	0.875	−1.12
35	10	0.917	−1.08
36	9	0.96	−1.04
37	8	1.00	−1.
38	7	1.04	−0.96
39	6	1.08	−0.917
40	5	1.12	−0.875
41	4	1.165	−0.834
42	3	1.21	−0.79
43	2	1.25	−0.75
44	1	1.29	−0.707
45	0	1.33	−0.66

For the remaining position we can again use the first equations, since all coils in phase $a\ b$ carry the same direct current; thus

$$c_0 = -\frac{16-x}{24}$$

Position	x	c_0
No. 46	1	−0.625
47	2	−0.583
48	3	−0.54

The instantaneous value of the alternating current for any position is:

$I = 0.77\ cos\ \phi$, where $\phi = 0$ for the first position, and each successive value of ϕ corresponds to 7.5°.

Thus, for instance, the heating which is proportional to the square of the current is in position No. 8, which is determined as follows:

$C_0 = -0.208 \quad I = 0.77 \cos(7\times 7.5^\circ) = 0.468$

Resultant current = 0.26

and current² = 0.0678.

These calculations are carried out for each coil and position, and the results are:

For a three-phase rotary converter with only one side loaded, 70 per cent. of the rated output can be carried. For a four-phase and a six-phase rotary, 73 and 77 per cent., respectively, of the rated output can be carried at one-half voltage.

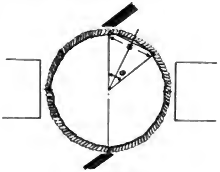


Fig. 16

In other words, the current going out from one of the brushes and back over the neutral can, in the first case, be 40 per cent. greater than the normal full load, and in the last case 54 per cent. greater.

Armature Reaction in Rotary Converters

Sometimes the total magnetomotive force of the armature is considered as armature reaction, often as the resultant magnetomotive force per pole, and most frequently as the product of the direct current in the conductor and the number of turns per pole in the armature.

In the following discussion the armature reaction is taken as the resultant magnetomotive force of the armature per pole.

It may be expressed as

$$R = \sqrt{2}\, k\, k_1\, i\, t$$

where k and k_1 are constants, depending upon the system considered and upon the distribution of winding, respectively; i the effective value of the alternating current, and t the number of armature turns per pole and phase. With direct current, where the winding is uniformly distributed, k_1 is the ratio of the diameter to one-half of the circumference, or $\frac{2}{\pi}$; and k is unity.

In an n-phase closed circuit alternator (Fig. 16), run as a rotary converter, k_1 becomes

$$\frac{S}{2\pi r} \div \frac{360}{\phi} = \frac{360\, S}{2\pi r \phi} =$$

$$\frac{360 \times 2r}{2\pi r \phi} \sin\frac{\phi}{2} = \frac{360}{\pi\phi} \sin\frac{\phi}{2}$$

$$\phi \text{ is obviously } = \frac{360}{n}$$

thus $k_1 = \frac{n}{\pi} \sin\frac{180}{n}$

k, as stated above, depends upon the system, and gives the relation between the resultant armature reaction of all phases and the armature reaction of one phase.

In an n-phase machine, the windings of the respective phases are displaced $\frac{360^\circ}{n}$; thus, at a given time, the currents a, b, c, etc. (Fig. 17), are expressed as:

$$I,\ I\cos\frac{360}{n},\ I\cos\frac{2\times 360}{n} \ \ldots\ I\cos(n-1)\frac{360}{n}$$

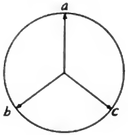


Fig. 17

Each of these currents has a component in phase with I, which is the product of the current and the cosine of the angle; thus the combined magnetomotive force of all phases is:

$$I\cos 0 + I\cos^2\frac{360}{n} + I\cos^2\frac{2\times 360}{n} + \ldots\ I\cos^2(n-1)\frac{360}{n}$$

Thus $k = \dfrac{\text{combined magnetomotive force}}{I}$

$$= \cos 0 + \cos^2\frac{360}{n} + \cos^2\frac{2\times 360}{n} +$$

$+ \cos^2 \frac{n-1}{n} 360$, to n terms, n being the number of phases.

In a single-phase converter where $n = 1$, we thus get $k = \cos 0 = 1$.

In a three-phase machine ($n = 3$), k becomes $1 + \frac{1}{4} + \frac{1}{4} = 1.5$.

In a similar way, for a four-phase machine $k = 2$, and in a six-phase machine $k = 3$. In general $k = \frac{n}{2}$.

It has previously been shown that the relation between the effective value of the alternating current and the direct current in a conductor is:

$$\frac{i}{i_c} = \frac{2\sqrt{2}}{m \sin \frac{180}{m}}$$

Considering a bipolar machine for the sake of simplicity, and denoting the direct current output by i, we get $i_c = 0.5\, i_d$

$$\text{thus } \frac{i}{i_d} = \frac{\sqrt{2}}{m \sin \frac{180}{m}} \qquad (7)$$

With t turns per pole, the number of turns per pole and phase are $\frac{t}{n}$.

Substituting these constants in equation

$$R = \sqrt{2}\, k\, k_1\, i\, t$$

we get the alternating current armature reaction

$$R_a = \sqrt{2} \times \frac{n}{\pi} \sin \frac{180}{n} \times \frac{n}{2} \times \frac{\sqrt{2}}{m \sin \frac{180}{m}}\, i_d \frac{t}{n}$$

Since in a multi-phase converter the number of phases n is the same as the number of collector rings m we get:

$$R_a = \frac{i_d t}{\pi}$$

The direct current armature reaction R_d is:

$$\frac{2}{\pi} \times \frac{i_d}{2} t = i_d \frac{t}{\pi} \qquad (8)$$

It is therefore proven that the true armature reaction is the same for direct current and multiphase alternating current, no matter how many collector rings there may be.

(To be continued)

STORE LIGHTING WITH ENCLOSED ARC LAMPS

By G. H. Stickney

The purpose of a store is to sell merchandise, and the purpose of artificial store lighting is to promote the sales. That arrangement of store lighting is the most satisfactory which produces the greatest margin of profitable sales over the cost of illumination.

Artificial lighting contributes towards the satisfactory sale of merchandise in the following ways:

1. By helping to make the store attractive and pleasant for customers.
2. By displaying the merchandise to advantage, so that the customer may be induced to purchase.

Fig. 1 Ceiling Diffuser

3. By showing the merchandise approximately as it will be seen afterwards, so as to avoid disappointment, especially where color selection is involved.
4. By making the store attractive and healthful for the employees.

Appearance of the Store

It is unquestionably true that on entering certain stores, the customer is agreeably impressed, and the store becomes at once attractive to him, while in certain other stores, an opposite or unpleasant impression is received, resulting often in a large loss of business. While there are many elements, more or less concrete, which go towards influencing customers favorably or unfavorably, we are interested in them in this discussion only so far as they relate to the artificial lighting of the room.

It is evident that an artistically arranged store will be more pleasing than one which is

Fig. 2. Interior View of John G. Meyers Co.'s Store, Albany, N. Y., Lighted by Selective Ceiling Diffuser System

Fig. 3. Interior Fraas & Miller Store, Brooklyn, N. Y., Lighted by Selective Ceiling Diffuser System

disorderly and which lacks design, and therefore the lighting fixtures should, as far as practicable, conform to the general tone of the surroundings.

Usually, the lighting fixtures are more conspicuous as fixtures by daylight than by their own light, and their appearance in the store in daylight should therefore be considered. Where the lighting fixtures are of a stock pattern, it is especially desirable that they should be simple, and as inconspicuous as possible.

To a certain extent, some proportion should exist between the size and height of the room and the size and capacity of the lighting units. In a large room a comparatively small number of large units generally appears to better advantage than a large number of small units. Such an arrangement also gives life and character to the illumination. In a small or low room, a relatively small unit is preferable, for the sake of appearance as well as for the effective distribution of light.

Most people prefer a bright, cheerful store to a dark and dingy one, and experience shows that, as a rule, the bright store gets the business.

Lamps of high intrinsic brilliancy, when hung low, produce a blinding effect which is not only annoying and tiring, but which makes it difficult to view the merchandise satisfactorily. Even with sufficient light on the counters, if there is no light on the ceiling, the store is likely to appear dark and dingy. The light itself should be steady and approximately white. Colored lights do not mix effectually with daylight, and when a considerable portion of the light is to be thus mixed, it is desirable that the artificial lights should be as nearly white as possible. We may therefore conclude that a store can most easily be rendered attractive, as far as the lighting is concerned, by the use of simple, inconspicuous fixtures, with units of a capacity well proportioned to the size of the room; the light sources being high and of relatively low intrinsic brilliancy and so arranged as to distribute a soft, even and approximately white light throughout the store.

Lighting of Merchandise

A person's attention is usually attracted to the point of strongest illumination, and for this reason it is desirable that the merchandise displayed should have a relatively strong illumination compared with that of other parts of the room. This illumination should be fairly uniform, rather than spotted, so that the area for the effective display of goods may be as large as possible. Especially should harsh lighting and dense shadows be avoided.

Where colored materials require accurate selection in order to match some particular material or to produce some particular color effect, it is very important that the light be of the proper color. Many disappointments on the part of customers are due to a lack of proper attention to color considerations in the lighting of stores. The annoyance and inconvenience caused the customer may frequently be of greater moment than the value of the material itself. Since the larger part of the goods sold in a store is ordinarily used and seen by daylight, the store light should approximate daylight as nearly as possible. On the other hand, there are materials which are intended to be used principally in the evening, and consequently under a yellow tinted light. Means should therefore be provided for exhibiting this class of materials under such a light, and is ordinarily accomplished by providing an "evening room." The strong white light, while it shows up a fine material to its best advantage, also shows up the defects and imperfections of low grade material. On this account, it is observed that a poor illumination is usually preferred in a store where inferior materials are displayed.

Cheerful and accommodating attendants constitute one of the most important elements in the art of drawing trade to a store. Since each customer spends a relatively short time in a store he may be unaffected by lighting, which, to the clerks, may become almost unbearable. The ill effects of poor illumination in producing headaches and other discomforts is too well known to require any discussion. It therefore frequently happens that the comfort of the employee sets a higher standard upon the production of a fine soft illumination than do the requirements of the customers.

Economy

Store lighting would present much simpler problems if it were not for the necessity of giving so much consideration to the cost.

It is not particularly difficult to provide a strong, even illumination if it is permissible to consume an abundance of power and distribute the light through sufficiently dense globes.

It is not the first cost which requires the most serious consideration, but the after expense of operating. It is neither good engineering nor good business to burden a store with a running expense for illumination higher than its commercial advantage warrants. On this account, the elements which affect these conditions should be carefully weighed.

For example, in New York City, where the standard of illumination is high and competition keen, the amount of business per

Fig. 4. Suspended Type Light Balancing Ceiling Diffuser

square foot of floor is great and a relatively strong illumination must be provided even at a considerable cost. On the other hand, in a small town where the opposite conditions hold, the amount of light must be curtailed to keep down the expense.

In both cases, however, economy is important, and it is the province of the engineer to ensure his client a lighting installation that shall best meet the conditions.

Enclosed Arc Lamps and Competitors

Owing to the development of the more refractory materials for incandescent lamp filaments, particularly tungsten, the efficiency and color of this type of lamp is being improved. These improvements, together with the practicability of increasing the candlepower capacity, are requiring a readjustment of the boundary line between the arc and incandescent lighting fields.

Unquestionably, the tungsten lamp is more suitable in some places where, previous to its development, the arc lamp would have been selected. Just where this dividing line will ultimately lie still remains to be worked out. It can not be determined until we have had further experience with the tungsten lamp. The cost of electric current will often be the determining factor.

Experience seems to indicate that high current enclosed arc lamps, fitted with proper diffusing devices, form the best equipment for the general illumination of large dry gooods and department stores.

In this connection it should be remembered that a 6½ ampere D.C. enclosed arc lamp consumes but 30 per cent. more power than a 5 ampere lamp, while it emits over 45 per cent more light. Similar comparisons for A.C. multiple enclosed arc lamps show that a 9 ampere lamp consumes 50 per cent. more power and gives over 70 per cent. more light than a 6 ampere lamp. The increased efficiency and advantages obtained with increased current seems to have been generally overlooked in efficiency comparisons. Moreover, the light from the high current arc lamp contains, if anything, slightly more yellow than average daylight. This is very desirable, as it gives a pleasing quality to the light without detracting seriously from its color selective value.

Diffusion

The demand for a more even distribution of light and the softening of contrasts and shadows resulted several years ago in the development of certain forms of diffusers. By the use of these accessories the distribution and diffusion of light was greatly improved, and although the first forms were crude and inartistic in appearance, they

Fig. 5. Form C Light Balancing Selective Ceiling Diffuser

demonstrated the great effectiveness of diffused light. Since then new designs and improvements have been made and are still in progress. The enclosed arc lamp may be provided with a fixture suitable for use among the most beautiful surroundings, and at the same time efficiently and effectively fulfill the exacting requirements of high grade illumination.

ELECTRIC MOTORS AND THEIR APPLICATION

By C. F. Lawrence

The subject of electric motors and their application is a very broad one, and as space is limited, I will deal with it only in a general way.

It is interesting to note that while at first the use of the electric drive was thought to be of value merely in the saving of power through the elimination of the losses due to friction in the line shafting, a higher economy has been found to lie in its remarkable effect upon the production factor of a shop.

In the average manufacturing plant, the cost of power varies from 2 to 6 per cent. of the cost of the finished product, the labor being the most important factor in manufacturing, amounting usually to upwards of one-half the total cost of the product.

The application of the electric motor to individual machines, and for driving in groups, naturally results in greater reliability of operation and increased production; as each machine or group of machines is rendered independent of all others in the shop, and yet at all times, either day or night, is fully as effective as though connected directly to the prime mover. A better control and a more constant speed is secured, and smaller shafts, lighter belts and the elimination of all heavy belting and main line shafting are obtained, these results naturally tend to a more economical operation and an increased production.

There is still a diversity of opinion as to the relative advantage of the so-called individual and group driving. The latest developments indicate a tendency towards the use of both the group and individual drive, it being generally agreed that the larger tools should be equipped with individual motors, such as machines that are intermittently driven, or where they are started and stopped to make ready or take off work. This class of machinery would include printing presses, boring mills, planers for working iron, engine lathes, certain classes of woodworking machinery, and many others.

In many shops the use of the individual drive is being extended to small tools, as well as to the large ones. It has been found that in the average machine shop at any one time during the day there is only from 30 to 40 per cent. of the tools in actual use, although all the shafting and belting is running all the time during working hours.

For small shops, the horse-power required to drive the shafting and belting alone, averages from 20 to 40 or even 50 per cent. of the engine power, and in large shops and mills from 30 to 65 per cent.

In laying out the electric drive, it is necessary to study the conditions in each individual case, as there are no two cases exactly alike.

In a printing plant where the individual drive is used, the horse-power in motors should be double the horse-power required to drive all the machines in one group by one motor. The reason for this is that it requires a little more power to start up each machine; for, with the group drive, all the balance wheel effect of all the shafting helps to start any one machine; but as it is seldom that there are more than 50 per cent. of the machines in operation at any one time, individual drive is a great saving of power. A greater advantage is gained by doing away with all belting and shafting, which always throw oil and dust, and which cut out a great deal of light. When a press is belt driven a printer has only three or four cone speeds at his command, whereas, when it is motor driven, from 8 to 15 speeds may be obtained. By having a great number of speeds, the printer is certain to secure increased production.

Before going further, I would like to speak of the advantages and disadvantages of the various types of motors, so that the proper one may be selected to run a certain class of machine.

Direct Current Motors

First, we will take up the direct current motor, the simplest type of which is the series wound machine. The series motor is used largely for driving street cars, automobiles, centrifugal pumps, cranes and hoists, being especially well adapted for electric cranes, as it will automatically regulate its speed to the weight to be raised, exerting a very powerful torque at low speed for a heavy load. The speed is regulated by either a flat or drum type controller which introduces a resistance in series with the motor, and which is usually hand controlled. When a series motor is used, it should invariably be geared or direct connected to the machine to be driven; because if a belt were used and it should slip off, the motor, being relieved of its load, would run away and might cause considerable damage.

The series wound motor is ideal when direct connected to a centrifugal pump. Assuming that the motor is large enough for the work, and that you have a certain head of water to pump against and a certain suction lift, the motor, having a certain load, will run steadily; but if the suction lift or the head should change, the load would instantly vary, causing the speed of the motor to go up or down according to load. A great many of these motors are attached to centrifugal pumps which are used to automatically fill tanks. The motor may be started or stopped by placing a ball float in the tank, this float being connected to a special quick throw switch. This arrangement will automatically start or stop the motor, depending upon the level of water in the tank.

The shunt wound motor is next to be considered. This machine will run at constant speed irrespective of load, and the torque will always be in proportion to the load.

The shunt motor may be used to run all machines where a steady, constant speed is required, such as small printing presses, ventilating fans, group driving and those machines that do not demand a heavy starting torque.

The speed of the shunt wound motor is usually regulated by means of a rheostat that inserts resistance in the armature step by step. If you have a 1 h.p. motor and wish to cut the speed down to 50 per cent. of the normal, the armature regulator not only cuts the speed in half, but also reduces the horse-power in the same proportion. The power consumed at this low speed is still 1 h.p., the other half horse-power being wasted in the resistance in the form of heat. It is not well to use this method of regulation in sizes larger than 1 or 2 h.p. This does not apply to shunt wound motors driving ventilating fans, however, because at low speed there is practically no load on the fan, but as the speed increases the power increases about in the ratio of the cube of the speed. Motors for fan work, with this means of regulation, can be used in sizes from the smallest to about 10 h.p. In larger sizes it is better to use the combined armature and field control, as it is much more economical.

The armature method of regulation is not an economical one, nor is it suitable for most machine tools, because if the speed of the motor is cut down to one-half, and the load lightens up, the speed will go up, thus giving a very unsteady drive. The speed will always be dependent upon the load, within certain wide limits.

For example, take a boring mill cutting a large circular casting, one quarter of which is cast out of reach of the boring tool. We will assume that the tool is cutting on the portion of the casting which is three-quarters of the circle, and that the motor is running at one-half speed; then, as soon as the cutting tool reaches the end of this three-quarters, the machine does no work, and the motor immediately speeds up. After the tool traverses the open quarter of the circle and strikes the casting again, the speed is so great that the tool is either likely to be broken or the casting injured.

The only proper method of speed control is to insert resistance in the field coils. With this arrangement the power remains the same throughout the entire speed range, from normal speed to maximum speed, and at any one point in this range the motor will run at practically constant speed from no load to full load.

When a machine, with a reciprocating motion which reverses and tends to lower the speed, is to be electrically driven, or when a machine is required to start with a heavy load, a compound wound motor is necessary.

In this style of motor the proportion of the shunt field ampere turns to the series field ampere turns is in the ratio of 4 to 1, this winding enabling the motor to develop a powerful starting torque. For steady speed running the compound wound motor almost equals the shunt wound machine, and can be used to great advantage for operating flat bed printing presses, planers, elevators, rock crushers, punches, shears and air compressors, and any machines which have a varying load.

In adapting motors to individual driving of machines, we have found that a shunt wound, variable speed motor may be very successfully used. This type of motor is similar to the regular shunt wound machine, except that the field coils are made extra heavy. Instead of regulating the speed by inserting resistance in the armature, as is necessary for the series wound machine, the shunt wound variable speed motor is regulated by placing resistance in the field circuit. A 5 h.p. motor, with 3 to 1 speed range, and having a normal speed of 500 r.p.m., can be increased in speed by field control to 1500 r.p.m. This represents an increase of 1000 revolutions above the normal speed, and if a controller with 20 points is used, this range of 1000 revolutions is divided into 20 steps of 50 revolutions per step. When a motor is regulated by field control, the horse-power remains the same throughout the entire range of speed, due to a proportional decrease of torque with increase of speed, and vice versa. By this method, but little power is wasted in heat, as compared with the system of armature control.

for 500 volts, on account of the vicious sparking at the commutator on weak field. With the interpole motor this trouble entirely disappears. Railway motors and many types of generators are now being equipped with these commutating poles, and are very much improved by them.

Figs. 1 and 2 give a comparison between the performances of two 72 inch engine lathes of the same make, one being belt driven and the other motor driven.

Fig. 1 shows the cutting speeds and the time taken to face a 72 inch cast iron disc,

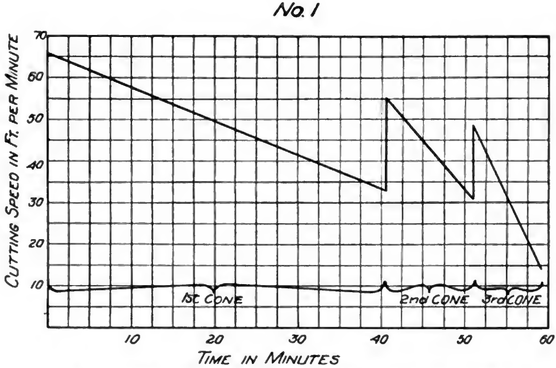


Fig. 1. Cutting Speeds and Time Required to Face a 72-inch Cast Iron Disk Using Three Steps on the Cone Pulley

from a maximum diameter of 72 inches to a minimum diameter of 6 inches, using three different steps on the cone pulley; the time for shifting the belt from one cone to the next not being included.

The cone pulleys on a mechanically driven tool do not permit the tool to start at the maximum cutting speed; and in this case, the mechanic, having no guide but his eye, did not change the speed on the cone pulley as soon as desirable for the greatest production.

Fig. 2 shows a test on a similar lathe doing the same work when driven by a motor. With the electrically driven tool, the cut

The variable speed motor is ideal for engine lathes, shapers and all machines where it is necessary to run steadily on any one point of speed, from no load to full load.

The larger sizes of shunt wound variable speed motors are being built with commutating poles placed between the regulator field magnets, the object of these being to prevent all sparking on the commutator when the fields are weakened. The winding on the interpoles is in series with the armature. This type of motor is also regulated by field control, and is especially satisfactory for use on 500 volt circuits, many motor builders refusing to build ordinary field control motors begins and ends at the maximum cutting speed permitted by the work.

As will be seen from the curves, the belt driven lathe required 59 minutes to complete the cut, while the motor driven machine did the same work in 31 minutes. The electrically driven tool, therefore, accomplished the work in 53 per cent. of the time required by the belt driven lathe.

Motors can be furnished semi-enclosed or totally enclosed, and when a motor thus arranged is run intermittently or with an intermittent load, it will deliver its full horse-power without overheating; but if the motor is run continuously, it will not deliver full rated power without an excessive rise in temperature. For example, take a 2 h.p. motor running without covers. You get 2 h.p. with a temperature rise of, say, 45 degrees, and a current of 15.7 amperes on 115 volt circuit. When semi-enclosed, the horse-power for continuous operation is 1¾, with a temperature rise of 45 degrees and a current of 13.9 amperes. When totally enclosed, the horse-power is still 1¾, with a temperature rise of 60 degrees and a current of 13.9 amperes. Take another size; for instance, a 15 h.p. moderate speed motor wound for 115 volts; when running open the motor develops 15 h.p. with a temperature rise of 45 degrees and a current of 111 amperes. When this motor is semi-enclosed for the same temperature rise the horse-power is 10, with a current of 74.5 amperes. When totally enclosed, with a temperature rise of 60 degrees, the horse-power is only 7, and the current 52.8 amperes.

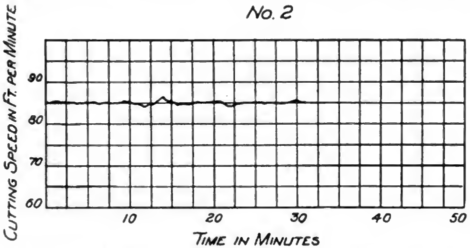


Fig. 2. Cutting Speeds and Time Required to Face a 72-inch Cast Iron Disk With Lathe Driven by Motor with Field Control

Induction Motors

The wide field of application of the polyphase induction motor is due to the many advantages inherent in its design. It is extremely simple and may therefore be built to withstand hard usage, and may be run continuously in exposed locations and under unfavorable conditions. The absence of a commutator contributes much towards this reliability, and at the same time reduces the items of maintenance and repairs. The efficiency obtained in this motor over wide load ranges, and the small amount of attention it requires while running, make it compare favorably in cost of operation with motors of any other type. Other advantages may be briefly summarized as follows:—

Ability to carry large overloads for considerable periods without serious overheating, entire absence of sparking, permitting it to be used in powder mills, gas houses and other places where direct current motors would be dangerous; quick and certain starting under full torque, and simplicity of starting gear.

In order to choose the proper motor to be used for a certain purpose, it is necessary to look into the advantages and disadvantages of the various types of induction motors.

First, we will take up the single-phase motor. The field for the use of these motors of moderate capacity is constantly growing by reason of the increasing tendency of central stations to generate polyphase current and feed a large portion of the lighting load through single-phase distribution. Power is frequently required near such circuits for the operation of light machinery.

The motor is rendered self-starting by means of a starting box containing resistance and reactance, and a double-throw switch for the 1 h.p. motors and larger. The switch is first thrown to the starting position, and when the rotor has attained almost full speed is quickly thrown over to the running position, the object being to first connect the resistance and reactance in circuit with the motor and then to disconnect it.

The starting box furnished with the $\frac{1}{4}$ h.p. and $\frac{1}{3}$ h.p. motors has a single-throw spring release switch. To start these motors, the operator holds the switch blades down on the lower contacts until the rotor has reached almost full speed, then upon releasing the switch handle, the blades spring up into the running position.

Next come the two and three phase induction motors; the latter being now the standard alternating current motor. The two and three phase machines are made in forms *K*, *L*, and *M*.

The form *K* motor has a low resistance squirrel-cage armature, and is started by means of an oil-immersed starting compensator. This motor can be used in dusty places, gas houses, powder mills, or where it is to be controlled from a distance. The use of this type of motor is limited in some places, on account of heavy starting current.

The form *L* motor has the same field windings as the form *K*, but the armature is wire wound, and has a starting resistance attached to the armature spider, which is cut in and out of circuit with the armature windings by means of a connecting rod or lever. This form of motor is used more than any other on account of the low starting current required. The operation of the *K* and *L* motors is the same when up to speed.

The form *M* motor is designed for variable speed service, such as cranes, hoists, dredges, etc. Speed changes are obtained by means of an external adjustable resistance in the rotor or armature circuit. This resistance is usually made up in the cast iron grid form, and is connected with a drum type controller having 8 or 14 points for speed control.

The terminals of the armature winding are brought out to collector rings mounted on the shaft and fitted with brushes, to which the wiring from the controller and resistance is connected.

Suitable resistance can be furnished for:

First. Starting duty only.

Second. Starting resistance only from zero to half speed, and from half to full speed. The resistance is made heavy for continuous operation on any one point, when used with motors hoisting with a long lift.

Third. For continuous duty on any point from zero to full speed. This is used when operating calender rolls for any length of time on any one speed.

The form *M* motor for constant speed continuous running is made from the same frame as the form *L*, and the armature fitted with collector rings. This same motor, when used intermittently for crane or hoist duty, can be rated 50 per cent. higher than the continuous duty motor.

The form *M* motor is especially suited for running hydraulic elevators, an outfit for this work consisting of a form *M* motor geared to a triplex pump, a drum type controller and set of starting resistances. The controller is fitted with a pinion and rack which is connected to a Mason water regulator, and this in turn is connected to the water service pipe in the building. The Mason regulator has a diaphragm which is set for a given water pressure in the receiver tank connected to the plunger elevator. When this pressure falls 5 lbs., the diaphragm opens the valve to the regulator, and its piston slowly turns the controller of the motor until the motor is up to speed. The motor continues to run the pump until the pressure has reached its normal point in the receiver tank; the regulator then shuts off the current to the motor and the pump stops, and remains at rest until the pressure in the receiver tank falls again. A number of these outfits are in daily use under severe conditions, and to my knowledge have never given one minute of trouble.

As a general summing up, the advantages of the electric drive are:—Saving of power; greater flexibility; better light and ventilation, since there is no obstruction by shafting and belting; absence of dirt and grease thrown about by shafting and belting; reduced fire risk; reduced cost of repairs; and entire absence of power loss when machines are not in operation.

INFLUENCE OF WAVE FORM OF E. M. F. ON CORE LOSS AND EXCITING CURRENT IN TRANSFORMERS

By L. T. Robinson and O. Holz

General Electric Standardizing Laboratory

One of the most important tests in connection with the manufacture and use of transformers is the determination of their core loss. This loss varies through quite wide limits when the determinations are made using waves of impressed electromotive force having different shapes.

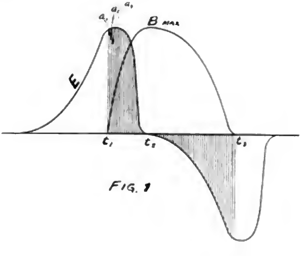


FIG. 1

On account of the existing difference between the core loss for various e.m.f. waves it is desirable to state all such losses in terms that allow of their direct comparison. For various reasons the sine wave is most desirable for general use and most modern generators are constructed to produce such a wave; therefore, any core loss should be stated in terms of the loss occurring on a sine wave, and any losses determined on other than sine waves should be corrected to that standard. The exciting current is also of interest and the effect of wave form variations on this quantity is also something which should be corrected for and the results reduced to the same standard basis.

The core loss consists of two components, that due to hysteresis, and that due to the eddy currents in the iron sheets.

The effect of wave form variations on these two components will be considered separately and in the order given.

The fact is well known that the hysteresis loss is proportional very approximately to the 1.6 power of the maximum magnetic density. It is, therefore, necessary to find the relation between the wave shape of e.m.f. and this maximum.

Neglecting the small $I R$ drop of the exciting current which is also out of phase with the impressed e.m.f., we have:

$$e = K \frac{d B}{d t} \qquad (1)$$

where e is the instantaneous value of the e.m.f. impressed and B is the corresponding density within the transformer iron. K is a constant, depending on the cross section of core, the turns of winding surrounding the same and the conventional relation between e and B.

$$\therefore e\, d t = K\, d B \qquad (2)$$

$$\text{and} \int_{t_1}^{t_2} e\, d t = K \int_{B_{zero}}^{B_{max}} d B \qquad (3)$$

$$\text{or } e \text{ average } (t_2 - t_1) = K\, B_{max} \qquad (4)$$

where t_1 is the time at the beginning of integrating and t_2 that at the end, $t_2 - t_1$ representing the time taken for the flux wave to pass from 0 to maximum value. Equation 4 expresses the fact that the maximum density is proportional to the area of the e.m.f. curve between t_1 and t_2.

The flux curve is at its maximum point when the electromotive force curve $\left(\frac{d B}{d t}\right)$ is zero; or conversely, the flux has reached its maximum when $e = 0$.

In an alternating current circuit as much flux enters as leaves the core; it follows that the positive area, expressed by $e\ (t_2 - t_1)$ of the e.m.f. wave must equal the negative area of the e.m.f. wave between t_2 and t_3, where t_3 is the point of maximum negative e.m.f.; that is, the area to the left of the maximum B ordinate must equal that to the right of the maximum; hence the area of the e.m.f. wave from t_1 to t_2 is proportional to the maximum flux B. Half the area of the e.m.f. wave determining the rise and the other half the descent of the flux wave.

It is sometimes desirable to draw the wave of flux from the wave of e.m.f. Bisect the area of the e.m.f. wave and plot B ordinates proportional to the small areas a_1, $a_1 + a_2$, $a_1 + a_2 + a_3$, etc., as shown in Fig. 1. The sum of all the small areas so shown is, $e\ (t_1 - t_2)$ and the sum of all the small flux increments corresponding to the areas a_1, a_2, a_3, etc. is the total or maximum flux or density B. Thus again ½ the area of the e.m.f. wave is proportional to the maximum B and consequently the whole area is proportional to this quantity also.

The area of any wave equals the average ordinate times the abscissa, and for different waves having the same abscissa or time, the areas and maximum fluxes are proportional to the average e.m.f.

To compare two e.m.f's. of different wave shape they must first be reduced to the same a.c. voltmeter reading, or effective value; consequently the core loss, due to an e.m.f., a, is to the core loss due to an e.m.f., b, as

$$\left(\frac{\text{average e.m.f. of } a}{\text{effective e.m.f. of } a}\right)^{1.6}$$

is to

$$\left(\frac{\text{average e.m.f. of } b}{\text{effective e.m.f. of } b}\right)^{1.6}$$

The ratio of the effective e.m.f. to the average e.m.f. is called the form factor of the wave. That is, the core loss due to a, which we want to compute from the core loss due to b (which latter we have found by test), equals:

$$\text{core loss of } b \times \left(\frac{\text{form factor } b}{\text{form factor } a}\right)^{1.6}$$

That is, the greater the form factor, the smaller the core loss.

The form factor for a sine wave is 1.11, for a rectangular wave 1.00, and for a pointed wave it can reach almost any assignable value; theoretically, the limiting value is infinity.

The flux wave may also be recorded directly by moving two brushes, separated by an angle corresponding to half a cycle, around a synchronously driven commutator to which is connected the e.m.f. to be investigated. The readings on a direct current voltmeter connected to the brushes are proportional to the instantaneous flux in the transformer core; and these readings, obtained step by step, and plotted or recorded continuously, will give the B curve.

The flux wave can also be found by means of the oscillograph and a reactance without iron (the resistance of which is negligible as compared with its inductance), by taking an oscillogram of the current flowing through it when connected to the e.m.f. wave whose corresponding flux wave is desired. In this case the current wave is identical in form with the flux wave that would be produced in a transformer core, varying permeability and hysteresis not entering as disturbing elements

The eddy current loss is equal to $\frac{E^2}{R}$

where E is the effective electromotive force induced in the sheet iron punchings, and which is of the same wave shape as the impressed e.m.f. R is the resistance of the laminæ to the eddy current. This eddy loss is not effected by wave shape unless self inductance is present, which cannot be as its presence would change the flux. This cannot occur as the flux is determined by the impressed e.m.f. This eddy loss is an $I^2 R$ loss, and is therefore proportional to the effective value of the eddy current, and is not influenced by its wave shape. The eddy currents could be kept near the surface of the individual sheets due to skin effects, but as the laminæ are thin, this effect cannot produce appreciable variations in the loss at commercial frequencies; especially as the skin effect varies only as the square root of the frequency. Supposing a transformer has an eddy current loss (as found by a separation test of losses made at different frequencies at the same e.m.f.), amounting to 20% of its total loss. Suppose it has an 80% hysteresis loss and that we have found the form factor of the wave to be 1.25. We want to know what will be the core loss with the transformer connected to a sine wave.

We have

$$W = .20 + .80\left(\frac{1.25}{1.11}\right)^{1.6} = 1.23$$

that is, the loss will be 23% higher than that found in the test.

The effect of wave form on the exciting current will be considered next.

(To be continued)

THE TANTALUM LAMP
THE SALVATION OF OVERLOADED SYSTEMS

By Oliver F. Brastow

The late President McKinley once remarked that the word "cheap" was not attractive to him, and in the same sense, the mere word "expensive" is meaningless. The first cost of an article cannot be considered high or low until its real value has been determined, not only from a utilitarian, but from an investment standpoint. This statement suitably sets forth the commercial position of both tungsten and tantalum lamps.

Fig. 1. Tantalum Lamp

The latter will be considered in some detail for the reason that this form of high efficiency lamp, at the present time at least, seems to be the most popular by reason of its availability in small units. This is, however, but a temporary consideration, because the tungsten already shows promising characteristics, and furthermore, the mechanical features of the tantalum lamp are essentially difficult to perfect. Many thousand tantalum lamps have been sold during the past few months; and it is gratifying to know that this type of lamp, now being produced on a large scale in the United States, shows a very marked improvement over the imported article that was first offered for sale in this country.

While exploiting the sale of the tantalum lamp in New England, the writer found some very interesting cases where the lamp in question served its purpose so acceptably well that its use was relatively not expensive.

In presenting the merits of tantalum lamps to prospective customers operating isolated plants, the first question which may profitably be asked by the salesman is, "Have you sufficient capacity?" If a negative reply is given, then the prospective customer can certainly be interested in the lamp. The writer has disposed of many thousand tantalum lamps to customers whose generators were previously overloaded, and in every instance the most satisfactory part of the transaction was that the customer was greatly benefited by his purchase, and realized the fact.

A concrete example will serve to illustrate the most practical application of the tantalum lamp. The superintendent of a certain small industrial plant was approached with the regulation preliminary question on the subject of his lighting, and it was found that a thousand 16 c.p., carbon filament lamps constituted a heavy and excessively dangerous overload on both his engine and generator. An indicating wattmeter showed that the lamps installed were taking 65 watts each, while the 20 c.p. tantalum lamp, of course, showed 40 watts. The proprietor was not slow to appreciate the difference that the new lamp would make, and an order for one thousand was secured. He had previously insisted on buying a very ordinary incandescent lamp because of its "cheap" price, its only cheap feature, however, being its first cost, as was sadly acknowledged later. Let us consider what the change from the cheap variety to the tantalum lamp was really worth in this instance.

A gain in capacity of 25 kw. was secured, and at an estimated cost of $100 per kw. (which is a fair valuation in this case, for engine, boiler, generator capacity, etc.), this amounts to $2500.00.

Interest on the above at 5 per cent.	$125.00
Depreciation at 6 per cent.	150.00
Taxes and insurance	25.00
Cost of operating 2500 kw. for 800 hours (the life of the lamp) at 2 cents per kw. hr.	400.00
	$700.00
Difference in *cost* of 1000 tantalum lamps and the cheap lamps formerly used	340.00
Saving	$360.00

This saving does not take into account the time and trouble necessary to make the change, although as an offset to this expense the remarkably enlarged capacity obtained from the existing plant with identically the same main or initial installation must be considered. Many other cases of a similar nature could be mentioned, but the one described is typical of many existing instances and clearly illustrates the value of high efficiency lamps in small units when used under proper conditions.

Another important consideration in connection with the tantalum lamp is the advantage to be gained by the use of any highly economical lamp when operating on a meter basis. This is made evident by a very simple calculation, which can be easily performed by the average laymen.

The tantalum lamp is but a forerunnner of better things to come, and the day is not far distant when the most humble cottage will be electrically lighted, and kerosene will have a most worthy and overwhelming competitor in a lamp giving light at about 1 watt per candle-power. At such a time the central station will enjoy a tremendous increase of patronage; it will be recognized as the only logical purveyor of power for illuminating purposes, and the general adoption of domestic heating units will be remarkable. Small isolated plants will disappear, and the new lamp will mark a definite advance in the achievements of civilization.

Light has been employed as an emblem of welfare, prosperity and happiness since the beginning of the world, and the producer of an inexpensive and satisfactory means of providing the small customer with good light will be numbered among the world's benefactors.

POLYPHASE MAXIMUM WATT DEMAND INDICATOR, TYPE "W"

By W. F. Howe

Commercial maximum demand indicators have hitherto been confined to devices which would indicate the maximum ampere demand only, and which were obviously not suitable for recording the maximum load on

Fig. 1. Polyphase Maximum Watt Demand Indicator

alternating current circuits of other than unity power factor and constant voltage. In many cases, particularly in motor installations, it is necessary to know the actual maximum watt consumption, and for this reason the General Electric Company has designed a Polyphase Maximum Watt Demand Indicator, two views of which are shown in Figs. 1 and 2.

This instrument will indicate correctly, within commercial limits, on two or three phase circuits, with balanced or unbalanced, inductive or non-inductive loads. It may also be used on single phase circuits by making the proper connections.

The device is, in its essential elements, a type "D-3" polyphase wattmeter with both electrical elements acting on the top disk,

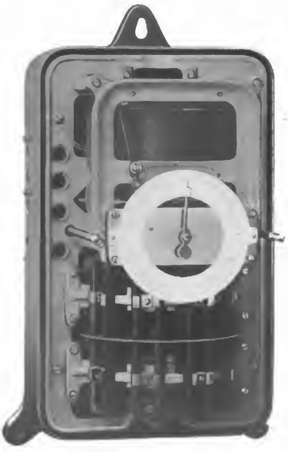


Fig. 2. Maximum Demand Indicator. Cover Removed

together with a very strong damping system acting upon the lower disk to provide the necessary time lag. In place of the usual register, there is provided a single graduated dial and two pointers, one of the latter being driven through a train of gears by the moving element of the indicator and indicates the energy passing through the device at any moment, subject to a correction due to the time lag. The second pointer is driven by the first, and is left at the maximum position reached by the latter, being held in place by a ratchet. This second pointer indicates, then, the maximum energy which has passed through the device since it was last set. The maximum demand pointer is re-set to the zero position by a thumb nut which may be sealed to prevent meddling by unauthorized persons. As this device is for the purpose of indicating, and not recording the amount of energy passing through it, the motion of the rotating element is opposed and controlled by phosphor-bronze springs.

The torque is proportional to the energy flowing through the device, and this, in connection with the spring control, gives a uniformly divided scale.

The degree of time lag, or in other words, the length of time required for the pointer to reach its maximum position, will depend upon the torque of the motor elements and the strength of the damping magnets. By changing these variables, the Polyphase Maximum Demand Indicator may be arranged for a time lag, ranging from one minute to thirty minutes. An indicator having a definitely rated time lag may, by an adjustment of the damping magnets, be given another time lag differing from the original by from ten to fifteen per cent. These indicators are rated by defining the time lag as 90 per cent. of full scale, for the reason that between 90 per cent. and 100 per cent., the movement of the pointer is very slow compared to the speed from zero to 90 per cent. The character of the pointer movement is shown in Fig. 3.

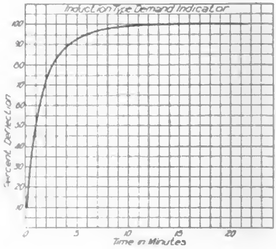


Fig. 3

The Polyphase Demand Indicators, in sizes above 25 horse-power capacity, are made with the same ratings as polyphase meter, for both secondary and primary circuits. Dimensions, connections and finish are practically the same as the "D-3" polyphase meter.

THREE-PHASE TO TWO-PHASE TRANSFORMATION WITH SPECIAL REFERENCE TO CORE TYPE TRANSFORMERS

By W. J. Wooldridge

Attempts have at times been made to operate regular single-phase core-type transformers on three-phase primary two-phase secondary circuits, and as these attempts are often not successful it seems advisable to point out as briefly as possible the reasons for such failures, with the hope that a clearer understanding of the conditions in the windings may prevent the trouble, sure to result from wrong practice in this particular.

In the transformation of power by means of the T connection there arise certain peculiar current and voltage relations which at first sight are liable to escape ordinary observation, but if disregarded are sure to result in serious unbalancing. The relation between the currents on the two sides of the primary winding of the main transformer make it absolutely necessary, if this distortion is to be avoided, to "balance" each half of the winding on the legs.

In the accompanying figure, a, b, A, are the primary and secondary of the main transformer in the T connection, and c, C, corresponding coils of the teazer transformer. Considering current I_s amperes drawn from the secondary A of the main transformer, an equivalent current must then flow through the primary a, b. With current I_s taken from the secondary C of the teazer transformer, the equivalent primary current must be

$$\frac{2}{\sqrt{3}} I_s$$

which is 90 degrees out of phase with the current in the main transformer. This teazer current divides into two parts; one half,

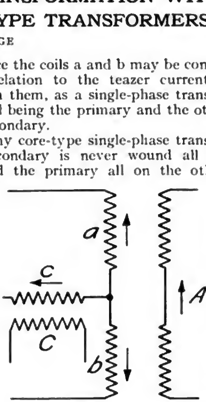
$$\frac{I}{\sqrt{3}}$$

flowing in main b, and the other half in main a. Since this current flows in opposite directions in the two halves, and, as above stated, is 90 degrees out of phase with the main current, it lags 90 degrees behind the main current in one coil and leads by 90 degrees in the other.

These extra currents have no equivalent secondary current in the main coil, since they are equal and flow in opposite directions in a and b, and therefore neutralize each other as far as magnetizing effect is concerned.

Hence the coils a and b may be considered, with relation to the teazer current which flows in them, as a single-phase transformer, one coil being the primary and the other coil the secondary.

In any core-type single-phase transformer, the secondary is never wound all on one leg and the primary all on the other leg,



because such an arrangement would introduce a large leakage flux, the effect of which is to increase the reactance of the transformer. The primary and secondary coils are always placed as near together as good insulation permits in order to reduce to a minimum the flux which does not link both coils.

If these same precautions are not taken in connection with the main coil of the T transformer, a large reactance drop will result. This reactance drop is 90 degrees ahead of the teazer current, and since the teazer current in the main coils lags 90 degrees behind the main current in one core, and is 90 degrees ahead of the main current in the other core, with a non-inductive load the reactance drop in one coil is in phase with the electromotive force across the coil, and opposite in phase to the electromotive force across the other coil. Therefore the reactance drop increases the voltage across one side and decreases it across the other side of the main coil.

The necessity of reducing the reactance between the two sides, by balancing each side of the main coil on each leg, to prevent this distortion, is easily understood with the above facts in mind.

ELECTRICALLY EQUIPPED HOSPITAL LAUNDRIES

By W. H. Rue

The Philadelphia Hospital Laundry affords a good example of the readiness with which electricity may be adapted to laundry work. The building in which this laundry work is done is a one-story substantial stone structure, having 10,500 feet of floor space divided into one large room and a boiler room. It is well lighted during the day by windows and a skylight extending the full length of the building, and by arc lamps at night. The boiler room contains one 95 h.p. and one 125 h.p. water tube boilers, which supply steam at both high and low pressures for the general laundry work. There is also in this room a 50 h.p. motor, belted to a shafting which extends the full length of the building.

The large room contains the washing machines, centrifugals, conveyors, hurricanes, mangles, etc., which are directly belted to the line shafting; the end of the room is used for the hand-ironing department. It was originally arranged for stove-heated irons, and little or no thought was given to modern construction, representing convenience and efficiency. One of the serious problems which the management had to face in contemplating a change in the methods then employed, was the fact that the inmates of the Institution did all the hand-ironing, and that whatever system was finally adopted, should be fool-proof, to avoid damage by overheated and soiled irons, as many of the inmates were feeble minded. The electric iron solved the problem.

Fig. 1. Electrical Laundry, Showing Boards in Position for Work

Mr. Search, manager of the laundry, devised a special arrangement of ironing-boards, which is unusually compact and convenient. Two horizontal pipes 1¼ in. in diameter, located three feet and seven feet from the floor, respectively, are supported by three vertical pipes extending from the floor to the ceiling. Above the second pipe is fastened a 1 in. by 6 in. board, on which are mounted, over each ironing board, a keyless receptacle and a single-pole knife switch. At right angles to the board, a horizontal arm 2½ feet long is secured, and to the end of this arm is fastened a spring for keeping the attaching cord taut when the iron is in use. Below the lower horizontal pipe, and parallel to it, is a semi-circular wire basket, used as a catchall.

The broad end of the ironing-board is hinged to the lower horizontal pipe, while the small end is supported by a movable arm, which, when in use, fits into a floor socket. Fig. 1 shows the position of the board when in service.

When not in use, the boards are raised to a vertical position, and are clamped to the switchboard, which is mounted on the upper horizontal pipe. Fig. 2 shows the position of the boards when not in service.

On the broad end of each board is bolted a special three-deck stand, having side clamps for holding the iron when the board is not in use and in a vertical position. The iron used is the standard 6-pound, 110 volt

Fig. 2. Showing Position of Boards when not in Service

cartridge unit type, built by the General Electric Company. There are 48 of these irons installed, and an average of 97,000 pieces are ironed here each month, with the inmates working eight hours per day. With the same number of irons, it has been found that from 20 to 30 per cent. more work is done now, than formerly, with the additional advantage of securing better work, and easier labor for the workers.

While the equipment of this laundry demonstrates the three distinct uses of electricity; namely, for purposes of light, power and heat, it shows particularly the value of electricity for *heat*.

NOTES

PERFORMANCE OF A SMALL TURBINE

The following letter, recently written by the Manager of the Lighting Department of the General Electric Company's Chicago office, to one of the Company's engineers at Lynn, gives an instance of the splendid service afforded by Curtis turbines, often under very adverse conditions:

"The engineer in charge of the train lighting equipments for the C. B. & Q. Railroad was in to-day and told me that only a few days ago they operated one of our 25 kw., 125 volt non-condensing Curtis turbines at 45 lbs. steam pressure, and were able to carry 180 amperes at 110 volts. This was such a remarkable showing that I was much inclined to question the accuracy of his figures, but he insists most positively they are right.

"He tells me that when the Chicago City train pulls out of Kansas City, the turbine is located in the rear end of the third car back of the locomotive, and that they never get over 60 lbs. pressure until after one or both of the mail cars ahead of the turbine car are cut out, but that notwithstanding this they are able to carry their load."

* * * *

PITTSFIELD SECTION A.I.E.E.

The Pittsfield Section of the A.I.E.E. held its seventh meeting of the season at Hotel Wendell on February 6th. Ninety members were present and heard a very interesting talk by Mr. E. J. Berg upon the "Phenomena Occurring on High Voltage Power Transmission Lines."

Mr. Berg accompained his remarks with a number of diagrams and formulæ and gave actual figures obtained by tests made under operating conditions. The subject was handled in a clear and effective manner.

A brief discussion followed the address in which interesting comments were made by Mr. C. C. Chesney, Mr. W. S. Moody, and others.

At the meeting of the Section held on January 4th, a new departure was tried and an informal smoker was held. Answers were given to a number of questions covering a wide range of subjects, which had been handed in previous to the meeting, the chairman calling on various members present for replies. As an experiment the results were satisfactory and it is probable that similar meetings will be held in the future.

The meeting scheduled for February 21st was postponed, due to a conflict of dates with the annual banquet of the University Club of Berkshire County, many members of the Pittsfield Section being interested in the latter affair.

* * * *

In the article on "Illumination of Niagara Falls" in the February issue of the "General Electric Review," we inadvertently omitted to explain the excellent view on page 119 and failed to give proper credit for it. The view is a photographic representation of the effect of night illumination of Niagara Falls, for which credit should be given to Mr. Geo. E. Curtis, the well-known Niagara Falls photographer.

BOOK REVIEWS

EXPERIMENTAL ELECTRICAL ENGINEERING

By V. Karapetoff

John Wiley & Sons. 790 Pages. Price $6.00

Up to within the past two or three years, there was a relative dearth of electrical books that dealt with the science of electrical engineering as a whole, and a student must needs have purchased a small library if he desired to familiarize himself with the different branches of the subject. One book would treat of generators and perhaps motors, another of railways, and yet others of lighting, power transmission, etc. Recently, however, several authors have written general treatises, "Experimental Electrical Engineering" by V. Karapetoff being the latest book of this description. This work is essentially a text book to be used under the guidance of a teacher and with his supplemental instruction, as a number of formulæ and mathematical expressions are given and the method of their deduction omitted. For this reason the book does not seem to be especially well adapted for self instruction.

The author advocates the so-called "concentric method of teaching" and the book is so arranged as to be used in this manner if desired. By the concentric method the student is first "introduced to the whole scope of his profession, though in a very elementary and popular manner," in order that he may secure a general view of the subject. Later, he covers the same subject a second, third or more times, the repeated courses increasing in difficulty as he advances.

In addition to its use in the college laboratory the book is of value as a reference work for engineers.

ELECTRICAL ENERGY, ITS GENERATION, TRANSMISSION AND UTILIZATION

By Ernst Julius Berg

McGraw Publishing Co. 198 Pages. Price $2.50

This book, which owes its origin to a course of lectures given during the last few years by Mr. Berg at Union University, is one of the most important and valuable additions to the literature of electrical engineering that has appeared during recent years. It deals with the application of the science of electrical engineering to the practical design and operation of modern electrical plants, covering the field in a manner that is thorough and at the same time very easily understood. That is, while mathematics is used when required, mathematical formulism is avoided wherever the problems and their solution can be made clear without it, and the book will therefore be very useful to those engineers who do not care for extensive mathematical investigations.

The most important and valuable feature of the book is the broad and general point of view from which the subject is treated. It is not written by a specialist in one branch of electrical engineering, who in dealing with general problems would necessarily look at them from the point of view of his special branch; but by a man who for fifteen years has had a wide experience in all branches of the art, and who is therefore qualified to weigh and discuss in an impartial manner the relative advantages and disadvantages of the different methods, systems and apparatus entering into the modern electrical system, in their relation to design, construction, and operation.

As our readers know, Mr. Berg has been for many years in the closest possible touch with the design of all electrical apparatus and systems as well as the investigation and development work of the General Electric Company. He has thus acquired a broad and comprehensive experience in the subject dealt with in his book.

The present volume deals in the first section with the transmission line, discussing the principles of design and calculation as affected by the practical requirements of operation under normal and abnormal conditions. In the second section the generating system is taken up and discussed in the same broad and thorough manner, not only from the electrical side, but also in regard to the question of prime movers, such as reciprocating engines, steam turbines, gas engines, etc.

As the book is easily read and well worth reading, an extensive review of the contents is hardly necessary. It is to be hoped that Mr. Berg will soon be able to follow this volume with a second one dealing with the receiving station and the uses of electrical power.

C. P. STEINMETZ.

TWO DOLLARS A YEAR TWENTY CENTS A COPY

GENERAL ELECTRIC REVIEW

VOL. X, No. 6 | PUBLISHED MONTHLY BY GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU SCHENECTADY, NEW YORK | MAY, 1908

100 WATT TUNGSTEN LAMP

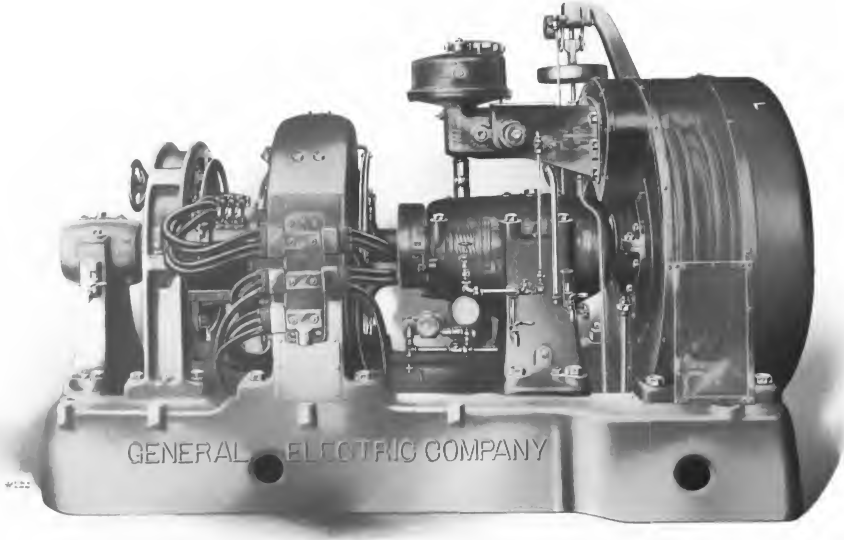
(See page 285)

GENERAL ELECTRIC REVIEW

VOL. X, No. 6

MAY, 1908

CONTENTS



Phantom View of Curtis Steam Turbine Direct Connected to 100 Kw. Direct Current Generator

(See page 286)

Vol. X, No. 6 SCHENECTADY May, 1908

GENERAL ELECTRIC REVIEW

STANDARD RAILWAY CONVERTER SUBSTATIONS

By J. E. Woodbridge

Railway Converter Substations

The requirements of direct current railroad substations are so similar in the majority of cases that it is possible to adhere to a general equipment which will be approximately uniform and at the same time incorporate all those factors which provide for safety, convenience of operation and economy.

The apparatus required can also be reduced to the smallest number of different elements by the adoption of certain standards, especially as regards voltages, machine capacities, switchboards, and details of arrangement affecting design, such for example as the location of terminals, with resulting advantages to both purchaser and manufacturer.

Fig. 1. 16 Pole, 2000 Kw., 188 R.P.M., 600 Volt Six-Phase Rotary Converter

The purpose of this article is to present the results of years of experience in railway substation practice, and to give the standard voltages and capacities of apparatus for railway substations which have been adopted by the General Electric Company.

The subject will be presented in the following order:

1. Standard transmission voltages.
2. Standard features of apparatus.

11,000 volts with delta connected transformers.

19,100 volts with delta connected transformers.

33,000 volts "Y" or delta connected transformers.

57,000 volts "Y" connected transformers.

These voltages step up in the ratio of the square root of three to one, allowing the voltage of any system to be raised in case of

Fig. 2. 10 Pole, 1500 Kw., 300 R.P.M., 575 Volt Six-Phase Rotary Converter

(a) *Converters*
(b) *Transformers*
(c) *Reactances*
(d) *Blowers*
(e) *Cables*
(f) *Switchboards*.

3. Typical station designs and details.

STANDARD TRANSMISSION LINE VOLTAGES

The following three-phase voltages have been adopted by the General Electric Company as standard for railway work:

extensions from one standard to the next higher by changing the transformer primary connections from delta to "Y." The lowest voltage (11,000), is the only one suited for direct generation without step-up transformers and is generally so installed. Such systems are not readily changed over, for which reason 19,100 volt transformers are delta connected only. On account of the prevailing use of 13,200 volts, transformers and switching apparatus can be supplied for this voltage also.

A frequency of 25 cycles per second has been adopted as the standard for railway work, 60-cycle apparatus being obtainable for railways fed from lighting or other 60-cycle systems.

Substation Apparatus

With the exception of cases where the alternating voltage must vary between unusually wide limits, or where the substation machinery must be used to correct low power factors of other parts of the transmission, rotary converters with transformers are preferable to motor-generator sets owing to their lower first cost, better efficiency, and simpler operation.

Converters

Standard rotary converters have been developed for 25 and 60 cycles. The standard railway machines are compound wound, the series field being designed for a compounding of 600 volts at no load and full load, when supplied from a source of constant potential with not more than 10 per cent. resistance drop and with 20 per cent. to 30 per cent. reactance in the circuit. The 200 and 300 kw. 25-cycle converters and the 100 and 200 kw. 60-cycle converters are wound for three-phase operation, all the larger machines being wound for six phases.

Foundations

The standard rotary converters up to and including the 1500 kw. size are supplied with cast iron bases of the type shown in Fig. 2. These bases make the machine self-contained, but it is nevertheless advisable to grout under all of the edges of the base so as to avoid undue strains. No holding down bolts are required for machines with cast bases and no holes are provided for such bolts.

With converters of over 1500 kw. capacity the pillow blocks and field frames are carried by sole plates which should be supported on a suitable foundation. The 1000 kw. and

Fig. 3. Virginia St. Substation of the International Railway Co., Buffalo, N. Y. 1000 Kw. Converters with Three-Phase Air-Blast Transformers

1500 kw. converters can also be furnished without base frames, but with sole plates.

Compounding of rotary converters is desirable where the load is variable, such as is the case with interurban railway systems. The purpose of the compounding is to compensate automatically for the drop due to line, transformer and converter impedances. On account of the low power factors caused by over compounding, and the fact that substations are customarily connected to the trolley at its nearest point without feeder resistance, over compounding is not recommended. An adjustable shunt to the series field is provided with each machine.

Shunt wound converters are entirely satisfactory for substations in large cities and similar installations where, due to the larger number of car units demanding power, the load is more nearly constant.

The Ratio of Conversion between the alternating and direct current voltages varies slightly in different machines, due to differences in design, and the best operating conditions exist when the desired direct current voltage is obtained with unity power factor at the converter terminals, when loaded.

The three and six phase machines require different voltages from the transformers, on account of the use of the diametrical connection instead of the double delta for six-phases. The no-load A.C. voltages delivered from the transformers and best adapted to compound converters designed to give 600 volts D.C. with a variable load, are 370 for three-phase converters and 430 for six-phase. This gives a lagging current at no load, a leading current on overloads and unity power factor at about average load.

Method of Starting

Three methods of starting rotary converters are feasible; first, the application of alternating current at reduced voltage to the collector rings; second, starting the machine as a D.C. motor; third, the use of an auxiliary starting motor mechanically connected.

The alternating current starting method has so many advantages over the other methods that it has been adopted as the standard by the General Electric Company. This method of starting is self-synchronizing, and therefore entirely eliminates the difficulty of accurately adjusting the speed under emergency conditions when the speed of the prime movers is liable to be variable. The ability to start a machine quickly and get it on to the line in the shortest possible time is a very great advantage inherent to this method of starting. It is possible for the converter to drop into step with its direct current voltage reversed from that of the bus to which the machine is to be connected, but the machine can easily and quickly be made to drop back a pole by a self-exciting field reversing switch on the machine frame. This method of starting makes the operation so simple that confusion and mistakes are greatly reduced under emergency conditions. As the apparatus used for starting is the same as that used for running, there is no need of any duplicate means of starting, thus reducing complications and simplifying operation.

The three-phase converters are started from one-half voltage taps in the transformer secondaries by means of suitable starting switches, and take approximately full load current from the line. The six-phase converters are started from one-third voltage taps and take three-quarters to full load line current. These currents are less than the usual railway load fluctuations and are indistinguishable from such fluctuations at any point of a loaded system. At light loads the effects of starting converters are more perceptible, but are quite negligible on apparatus capable of carrying the railway load fluctuations of the converters when running.

On account of the fact that 60-cycle converters take somewhat greater starting currents than 25-cycle converters, and are generally run from lighting systems where small voltage disturbances are more serious than on railway systems, methods for starting from either the alternating or direct current side are usually provided with such converters.

A motor-starting arrangement is considered undesirable on account of the complications introduced, without any compensating advantages.

Direct Current Connections

Single-pole switchboard panels are used, the positive main bus bar being the only one on the board. The negative terminals are connected without switches to the negative or ground return bus bar, which may conveniently be located beneath the converters. The series field is connected in the negative side, and the equalizer, series field, shunt and field break-up switches are all located on the machine frame as shown in Fig. 2. The purpose of the latter switch is two-fold; first, as stated above, to reverse the direct current polarity when the machine drops into step with the polarity wrong; and second, to open the field circuit at starting. In order to reduce the induced voltage strain upon the field insulation when the machine is started from the alternating current side, this switch is made with four poles to break up the field circuits.

These switches are mounted on the left hand side of the frame as viewed from the commutator end. This location should be kept in mind when arranging substations with the switchboard at one end, as these switches should be on the side of the machines toward the switchboards.

Mechanical Devices

A speed-limiting attachment, which automatically opens the direct current circuit breaker when the speed of the machine exceeds a predetermined value, is attached to the converter armature shaft on the collector ring end. This device is to provide against possible damage from excessive speed such as might occur when the alternating power is off, and energy, returning either through the direct current feeders or from a storage battery, causes the machine to run as a differential motor.

An end play device, or oscillator, is attached to the other end of the armature shaft to

Fig. 4. Interior of the Palisade Substation of the Public Service Corporation, Newark, N. J. 1000 Kw. Converters with Single-Phase Air-Blast Transformers

cause a slight reciprocating motion of the armature, thereby better distributing the wear of the brushes on the commutator and collector rings.

Transformers

Transformers are usually arranged on the unit system, that is, one bank of three single-phase or one three-phase transformer to each converter. These units are customarily of a rated capacity about 10 per cent. in excess of that of the converter.

The selection of the type of transformer is largely a question of individual opinion and local conditions, as all types are equally reliable.

Types of Transformers

General Electric transformers may be broadly divided into two classes, oil insulated and air blast. The latter are limited to work with a nominal line potential not exceeding 33,000 volts, and are perfectly satisfactory at this voltage, while the former may be used for higher voltages.

Air-blast transformers are always made shell type and are supplied either in the single-phase or three-phase form, in sizes suitable for all standard 25-cycle converters except the 200 kw. size. Their use is recommended particularly in large sizes where water is not available for cooling purposes, since this condition makes oil-insulated transformers large and expensive per kilowatt in order to give sufficient radiating surface for cool running. This applies, of course, to a greater extent with large than with small transformers, since it is more difficult to make a large transformer self-cooling than a small one.

Oil-insulated transformers may be divided into three general types:

First. The core type self-cooling listed as type "H" for the single-phase form and "HT" for the three-phase form. (See table below.) These transformers may be obtained for any voltage up to about 350 kw. in capacity; that is, in the three-phase form for 200 and 300 kw. converters and in the single-phase form for all converters up to and including the 750 kw. size.

Second. The shell type self-cooling listed as type "OC," and supplied for standard converters in the single-phase form only, and in any voltage for the 1000 kw. converter. Above this size self-cooling transformers are not supplied as standard.

Third. The water-cooled type listed as type "WC" in the single-phase form and "WCH" in the three-phase form for six-phase converters. This type is made in 550 kw. sizes and larger and may be used for any voltage in the three-phase form for 500 kw. converters and larger; and in the single-phase form for 1500 and 2000 kw. converters.

Table showing types of transformers available for standard converters, and customary rating of transformers.

Size of Converter	SINGLE-PHASE				THREE-PHASE		
	AB	H	OC	WC	ABT or ABH	HT	WCH
200		75				220	
300	110	110			330	330	
500	185	185			550		550
750	275	275			825		825
1000	365		365		1100		1100
1500	550			550	1650		1650
2000	735			735	2200		2200

Three-Phase Transformers as compared with three single-phase transformers of corresponding aggregate capacity have greater compactness, lighter weight and lower first cost.

Their use is recommended, except for stations with one converter where a spare transformer may be wanted, or in the largest sizes where the weight of the three-phase transformers may be excessive for handling purposes. In the self-cooling oil-insulated type "H" style, three-phase transformers are supplied only for 200 and 300 kw. converters, while single-phase transformers of the same style are supplied for larger converters.

Delta vs. "Y" Connections of Transformer Primary Windings

Delta-connected transformer primaries have been customarily used to permit operation with two transformers in case of trouble with the third. It has not usually been appreciated that, with the primary windings "Y" connected, with the neutral solidly grounded, and with the neutral of the generating system similarly grounded, either three-phase or six-phase converters may be started and successfully operated with two transformers per converter of the third phase are disconnected and short circuited. The output of the unit is limited in this case to the capacity of the two transformers or phases, instead of the three. The three-phase core type transformer, rated "HT" in the table, cannot be operated should one phase become inoperative.

Fig. 5. Water-Cooled Single-Phase Transformer; 25 Cycle, 900 Kw., 7500 Volts Secondary, 30000/54000 Volts Primary

in case of trouble with the third. The output in either of the above emergency cases is, of course, limited to that of the transformers in use. With the grounded "Y" connections, the service may be maintained in case of trouble on one phase of the transmission line, the other two wires and ground serving as the circuit.

Should three-phase shell type transformers be installed with high tension delta or grounded "Y" connections, two phases may be likewise operated provided both windings

Transformer Options for Converters of Different Sizes

For 200 kw. converters, self-cooled oil-insulated core type transformers single or three phase (types "H" or "HT") are the only forms available, while for the larger sizes up to and including 1000 kw. self-cooled oil-insulated single-phase transformers may be used for any voltages; or air-blast single or three phase transformers may be used for any voltage up to and including 33,000 volts, the self-cooling becoming more expensive than the air-blast when the capacity is increased beyond a certain size.

Begining with the 500 kw. converter, the water-cooled three-phase transformers become available. For 1500 kw. and 2000 kw. converters, air-blast and water-cooled transformers are the only alternatives. Either may be three-phase or single-phase, the water-cooled alone being available above 33,000 volts.

All railway transformers are supplied with taps on the primary winding to compensate for line drop and to provide a means of adjusting the alternating current voltage applied to the converter, so that the machine may be run at normal field excitation. There are provided four 2½ per cent. taps so as to allow for a drop of 10 per cent. Secondary starting taps are provided in all transformers.

In the rating of transformers the signification is as follows:

AB—Air blast shell type single-phase.

WC—Water-cooled oil-insulated shell type single-phase.

OC—Self-cooled oil-insulated shell type single-phase.

Fig. 6. Type H Oil-Cooled Single-Phase Transformer, 25 Cycles, 185 Kw., 19050 Volts Secondary, 33,000 Volts Y Primary

H—Self-cooled oil-insulated core type single-phase.

ABT—HT, etc.—Three-phase to three-phase.

ABH—WCH, etc.—Three-phase to six-phase.

All secondary windings are designed for delta connection for three-phase converters and diametrical connection for six-phase converters.

All oil-insulated transformers have both the primary and secondary leads entering through the top. All air-blast transformers have secondary leads issuing through the base and primary leads through top or base according to station requirements as outlined later. All air-blast transformers take air through their bases and are fitted with dampers to cut off the supply of air when out of service.

Reactances

To enable the D.C. voltage to be altered by the field rheostat or automatically by compounding, which calls for a corresponding change of the A.C. voltage, a three-phase reactance coil is provided between the low tension windings of the transformer and the converter. . Without such a reactance it is impossible to give the same voltage at full load as at no load without excessive leading and lagging currents and consequently excessive heating in the converter armature, unless the resistance drop from the source of constant potential is small or the natural reactance of the circuit is unusually high. If the converter field is weakened, a lagging current is set up which causes a drop in the reactive coil. If the field is strengthened a leading current is set up which gives a rise of voltage in the reactive coil. Under heavy load, the series field of a compound converter tends to produce leading currents, which tendency is practically balanced by the reactance, improving the power factor of transformers, lines and generators when loaded. The standard reactances are rated in k.v.a. equal to 15 per cent. of the kilowatt rating of the accompanying converters. For instance, a 300 kw. converter is supplied with a reactance in each phase in which the full load current, 500 amperes, causes a reactive e.m.f. of 30 volts or approximately 15 per cent. of the delivered e.m.f. Thus a lagging current or component equal to one-third full load causes a 5 per cent. drop in the reactance coil, and a leading component of the current of the same magnitude causes a 5 per cent. boost or rise of voltage. Six-phase converters use three-phase reactances with twice as high a voltage drop at full load.

Either the air-blast or oil-cooled type of reactance may be used for rotary converters of any capacity, with the exception of the 200 kw. converter, for which oil-insulated transformers and reactances only are available. Air-blast reactances should be used with air-blast transformers, and oil-cooled with oil-insulated transformers of either the self-cooling or water-cooled type.

All leads to and from oil-cooled reactances enter the case through the back near the top. Air-blast reactances are bottom connected. Air-blast reactances take air through their bases, and are fitted with dampers for cutting off the air supply when out of service.

Blowers

Air-blast transformers require a pressure varying between one-half ounce per sq. in. for the small sizes and one ounce for the large sizes. A line of blowers especially adapted to meet the conditions; that is, large volume and

Fig. 7 Three-Phase, Air-Blast, Form "D" Reactance; 25 Cycles, 300 Kw., 60 Volts, 1667 Amperes

comparatively low pressures, has been developed for this class of work. Standard blower sets consist of left-hand, down-blast, steel-plate fans direct connected, and driven by three-phase induction motors wound for the secondary voltage of the transformers.

For all installations of more than one converter, it is recommended that duplicate blower sets be installed, and that each fan have sufficient capacity to supply air for all of the transformers and reactances in the station with 10 per cent. margin for air-blast chamber leakage. In case, however, the total requirements are greater than 10,000 to 15,000 cu. ft. per minute, three blower sets should be installed, any two of which should be capable of supplying the total amount of air required.

Cables

For the 600-volt connections to the switchboard, and all secondary connections from transformers to the converters via the reactive coils and starting switches, the General Electric Company recommends the use of varnished cambric cable, manufactured for working voltages of 1000 volts or less, with asbestos braid and not lead covered. This may be run in porcelain cable cleats, if the substation has a basement, or in ducts; or in the case of the D.C. cables, in iron pipe.

Switchboards

The switching apparatus for this class of work has been simplified to the smallest number of elements, retaining every switch and instrument essential for convenient and reliable operation. The standard switchboard panels are as follows:

A.C. Main Panels:

(1) Incoming line panel.
(2) Outgoing line panel.
(3) High tension converter panel.

D.C. Main Panels:

(4) D.C. converter panel.
(5) D.C. feeder panel.

In addition to the above, there are various auxiliary panels not usually incorporated in the main switchboard, including A.C. starting panels, blower motor panels and control storage battery panels. The latter are used for 125-volt storage batteries, which are required for the operation of motor-driven oil switches. The above panels, excluding the auxiliary panels, are with certain exceptions 16 inches in width and 90 inches in total height, divided into three sections each. The exceptions are D.C. converter panels for 1500 and 2000 kw. machines and D.C. feeder panels of 4000 ampere or greater capacity, all of which are 20 inches in width; also double circuit D.C. feeder panels equipped with two ammeters, which are 20 inches in width.

The standard material and finish are dull black oiled slate, with instruments finished in lustreless black lacquer. All instruments are proportioned to indicate 100 per cent. overload, and all switches, current transformers, circuit breakers, etc. will carry a 50 per cent. overload of their corresponding machine or circuit continuously. All panels are supported on steel pipe frames with suitable attachments for the support of bus bars, field rheostats, etc.

D.C. Switchboard Details

As above-mentioned, all D.C. converter panels are single-pole and of positive or trolley polarity, so that the switchboard bus bar is continuous from the converter to the feeder panels, which are usually adjacent. The equipment of a standard D.C. converter panel comprises:

One carbon break circuit breaker with overload and low-voltage release. (The latter connected to the speed limit device.)

One illuminated dial ammeter with shunt.

One field rheostat.

One two-point potential receptacle.

One single-pole main switch.

One single-pole, double-throw station lighting switch.

One Thomson recording wattmeter. (Optional.)

The General Electric Company recommends the use of one such wattmeter per machine in preference to one bus bar wattmeter, on the score of better wattmeter load factor, readier calibration, easier extension of station capacity, etc. The station lighting switches are tandem connected to enable the lights to be supplied from any converter, on the machine side of its circuit breaker. The potential receptacles connect to one illuminated dial D.C. voltmeter on a swinging bracket, usually mounted at the end of switchboard.

The D.C. feeder panels are each equipped with an overload circuit breaker, ammeter, main switch, lighting arrester and choke coil; also one potential receptacle per feeder, by means of which the feeder voltage may be determined with the circuit breaker open in case the feeder is tied through to another substation.

A.C. Switchboard Details

The equipment of the A.C. panels depends somewhat upon the form of switch adopted, whether hand or electrically operated. In general, however, one ammeter is recommended on the converter or incoming line panels and three ammeters on the outgoing line panels, with automatic overload operation of the switches from one current transformer in the case of incoming line or converter panels, and from three current transformers in the case of outgoing line panels.

With hand-operated switches the overload actuating devices take the form of tripping coils combined with the switch handles, while for electrically-operated switches overload relays are used.

Switchboard Arrangement

In general the D.C. switchboard panels are arranged in a group by themselves, converter panels to the left and feeder panels to the right, with room for an extension of the converter panels to the left and feeder panels to the right. No attempt is made to group the between the location of panel and switch, and in this case it is customary to locate the A.C. line and high tension converter panels in line with the D.C. switchboard. No incoming line panels are used unless the lines are in duplicate, a single incoming line being tied to the substation bus bars without oil switches.

General Arrangement of Substation Apparatus

From the above it will be noted that the arrangement of the apparatus in the substation is largely dependent upon the nature

Fig. 8. Interior View of Locust St. Substation, United Railway Co., St. Louis, Mo. 1000 Kw. Converters with Three-Phase Air-Blast Transformers

oil switches, either hand or electrically operated, behind the main switchboard, the oil switches being invariably, in the more recent types of construction, located immediately adjacent to their banks of transformers or line entrances, or exits, as the case may be. For all stations using hand-operated switches, this makes it advisable to locate the A.C. line and high tension converter panels in a corresponding position. With electrically-operated switches there is no definite relation of the switching equipment. The following are further features of the switching equipment which intimately affect the station design.

Form "K" or hand-operated switches are invariably top connected, making it convenient to locate high tension bus bars above such switches; the high tension switches of the transformer and converter units being located immediately back of the corresponding three-phase transformers or three-phase groups of single-phase transformers. The line switches, if there are any, are located in line with and between the converter switches, the corresponding high tension panels being located in front of their respective oil switches and on the operating side of the transformers. For relatively large substations containing converters larger than 300 kw., or more than two converters, the division of the station by a wall between transformers and switches is recommended, with a crane spanning the converter and transformer room.

On the other hand, to suit a case with incoming high tension three-core cables underground, and motor-operated switches, these switches are bottom connected, making it convenient to locate bus bars and all high tension connections below the floor in a suitable compartment in the basement. The connections from the high tension converter switches to the transformers pass through the partition wall between the high tension compartment in the basement and air-blast chamber, the transformers in this case being bottom connected, that is to say, having both the high and low tension leads brought through their bases. This case also illustrates the above-mentioned arrangement of all main panels both A.C. and D.C. in one switchboard.

MISCELLANEOUS RECOMMENDATIONS

Ventilation

It should be borne in mind, in laying out a station, that even the normal operation of the machines will considerably increase the temperature, and some provision should therefore be made for good ventilation. This is particularly important where oil-cooled transformers are used and ample ventilators should be provided in the roof so that the temperature will not become unsuitable in the summer time. It is unnecessary to provide any auxiliary means of heating in compact substations which carry a station load factor equal to average practice, and which run 24 hours per day.

Drainage

Where air-blast transformers are used the walls of the air-blast chambers should be waterproofed and the substation built at such an elevation that water will not stand on the floor of the air-blast chamber. If this is not done the transformers may be damaged by the warm air from the blowers picking up moisture and depositing it in transformers which are not in service.

Where any cables come into the station underground the entering conduits should be sealed and suitable drainage provided so that water cannot leak into the cellar through these openings. When oil-cooled transformers are used it is well to install a pit of sufficient capacity to hold the oil from several transformers, and to provide drainage piping from the oil drain cocks on the transformers to the pit. This pipe should be of ample size so that the oil can be drawn off very quickly in case of emergency.

Crane

It will generally be found that the installation of a crane is justified not only for its convenience but on account of the actual economy of building floor area which is possible with its use. To get apparatus to the doorway, the space between machines, switchboards, etc., must be great enough to allow the largest piece to pass when laid flat on the floor, if no crane is provided. These pieces, such as rotary converter bases, etc., may be carried edgewise when a crane is used, and the saving effected often offsets the cost of the crane. The possible saving of time, when it becomes necessary to work on machinery rapidly, need hardly be mentioned, and the value of a crane at such times is obvious.

Air Supply for Blowing Out Apparatus

An air compressor is an item which should never be overlooked in a substation of any considerable size, as the life of any electric apparatus depends to a very large extent upon its cleanliness. It is generally most satisfactory to install a compressor similar to that used on one of the cars, and to furnish a storage tank capacity of about ten cubic feet. The air should be piped from this tank to various points in the substation where cocks should be provided for the attachment of a rubber hose. An air-pump governor provides a convenient means for keeping the air in the storage tanks at constant pressure.

Conclusion

The recommendations presented in this article are based on experience and have proved satisfactory in actual practice. This information is presented with the hope that it will be found of value to electric railway managers and engineers, and that they will co-operate in effecting a more complete standardization of substation design and railway transmission potentials.

A RETROSPECT

By Prof. Elihu Thomson

In this age of special tools, highly developed machinery and processes of construction, when materials are available with properties covering the widest range, it may possibly be useful or instructive to turn back to the time of the inception of the electrical engineering art and review the conditions as they existed approximately thirty years ago. Such a retrospect may assist those who have not had an opportunity to acquire a just perspective, and may help towards the appreciation of the better conditions which now exist for accomplishing work on a satisfactory basis, or for embodying ideals which, even if existent in the early days, were not accompanied by the means for execution.

Fig. 1. Punch Press Department, Schenectady Works, General Electric Company

One has only to visit the shops of a large electric manufacturing concern of to-day, and to notice the great variety of stock or material found in store in its stock-rooms, to be impressed with the fact that modern results come about by a combination of highly developed organization and methods. As an example, one may watch the elaborate machinery in the form of punch-presses and the like, which have to deal with the manipulation of sheet-iron or steel entering into the armature cores of dynamos and motors, without realizing that all of this development is but recent. There was a time in the art when it would have been futile to have made a design, however meritorious it might appear, involving the use of punched sheet metal in complex forms, for neither the material of proper quality existed, nor was the machinery for giving it the proper shape available.

In the early days of the electric industry the cores of dynamo armatures were commonly made of iron wire wound up into rings on cylinders; or, in other cases, of plates or forms of cast iron. When sheet iron was used it was generally in the form of heavy plate, cut out by crude machine processes or laboriously worked out by hand. The iron wire itself was not especially adapted to the purpose, and varied widely in its qualities, whereas about the only available sheet iron was stove-pipe iron, or the sheet iron from which sheet-iron utensils were made, and, of course, the existence of magnetic losses was not taken account of in its manufacture. The early worker had to put up with what he could get instead of what he wished he could have. He had to bend his designs and constructions to the use of such materials as were available, and the selection being a most restricted one, it will easily be understood that there was little freedom in designing in those early days. At the time referred to, cast iron was mostly used for magnet frames, although occasionally wrought material was employed.

Fig. 2. Thomson-Houston Arc Light Dynamo, Showing Regulator and Brush Mechanism

One had to put up with simple forms of the latter and with whatever quality of iron the foundry (generally a separate organization) happened to furnish. Steel castings now enter widely into electrical construction.

Even in the case of copper wire the limitations were severe. It was not obtainable in long lengths without joints or the necessity for making them. It was imperfectly drawn, frequently having slivers projecting through the insulation, and often varied in shape of section from round to oval; and the amount of the section varied. Round wire only was available for use. There were no square or rectangular sections to be had. Fine wire was not then drawn through jewels, and a coil would vary in section from one end to the other, owing to the wear of the dies. With the shunt magnets of series arc lamps it was sometimes quite necessary, in order to obtain any definite resistance in the coils with a given number of turns, to combine wires which varied in such a way that a portion of the coil would be of smaller section and another portion of the coil of larger section so as to get somewhere near the desired average section.

The designer or constructor was equally limited in the insulation which was available. Generally, he found that he had to rely upon paper or cloth for insulation, with shellac varnish. The paper itself was liable to be defective, as it might contain particles of iron or other metal, or bits of carbon, in case the paper mill was near a railroad. Mica was not at first available, its use being practically limited to clear and relatively very expensive sheets for stove doors, and the forms of colored and soft mica now so commonly found in use were not then mined, as there was no market for them. Flakes of mica, pasted upon paper by shellac and overlapping each other, were first used in the Lynn Factory in 1883 or 1884 and formed the first built-up mica employed. The sheets so built were used to separate the coils of arc light dynamo armatures. Insulation between commutator segments was originally shellaced paper, vulcanized fibre, or some similar substance, afterwards replaced by mica. The mica cone insulations for commutators came later, being some of the first mica pieces which were built up from flakes or out of small pieces, all of which were held together by varnish and heated in forms.

Very early commutators and other parts of machines were insulated with red fibre or vulcanized fibre, even then a manufactured product. It varied greatly, however, and was treacherous, as the process of production did not always remove the acid of chloride of zinc used in the treatment of the fibre. Defective material of this kind was the cause of many breakdowns. Reliance had to be placed upon wood, even for such things as switch supports and fuse boxes—as there was no electric porcelain manufacture; and even slate itself was not used, being unavailable, or not to be found readily on the market in suitable form.

Fig. 3. Smooth Core Armature in Process of Winding, Showing Wooden Pegs for Holding Coils in Place

At the time of the early introduction of arc lamps for street lighting and for interior lighting, the arcs were frequently burned bare, without globes or any other enclosure. Sometimes clear globes were used, and occasionally opal ones, but thin opal glass could not be obtained then, and the globes were made of heavy dense opal glass and absorbed about 60 per cent. of the light. The globes were also frequently misshapen and varied greatly in thickness. The carbons used in the working of the arc lights were also very imperfect at the start, many of them being so crooked that they would not stand opposed to each other without sliding by one another. The methods of manufacture had not been so fully developed but that a large proportion of the product was defective in straightness. Similarly in the chemical constitution of carbons, and in the heat treatment or baking, great variations occurred. Very often there were impurities present which caused the arcs to flame and sputter or hiss at intervals, while some carbons would burn out in much shorter time than others. For a time indeed, the question of getting satisfactory carbons was a very vital one in the development of arc lighting.

Fig. 4. Armature of Thomson-Houston Dynamo for Incandescent Lighting

Twenty-five to thirty years ago the only lines outside of telephone and telegraph lines, which extended any distance away from the station, were those for series arc lighting, and were generally of bare copper mounted on telegraph insulators. One of the first high tension experiments, and one which ended with some disastrous consequences, was the coupling of seven 40-light Brush arc light machines in series on a single bare wire circuit in Cincinnati, at the inception of the arc station there. The idea of high voltage apparently had not penetrated the consciousness of the people in charge of the installation, for it is said that immediately on starting up, several of the machines burned out. The total potential of the line would have been some 14,000 or 15,000 volts, and no special precaution had been taken to insulate for this relatively high pressure.

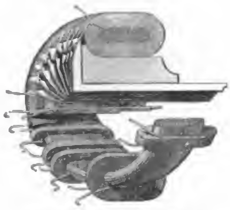


Fig. 5. Gramme Ring Showing Core Made Up of Iron Wire

Wherever in the early years, the factory building was not badly suited to the purposes of the business (as was too often the case), it generally happened that the engine power was either deficient or badly governed, or that the boiler capacity was much too small and the governing, which was good enough for most of the ordinary factory uses, was, of course, very defective for the demand of steady driving of electrical machinery. Along with the development, therefore, of electrical applications, it was a matter of necessity that engine power should follow and become more and more refined.

Not only was there difficulty in obtaining the proper power conditions in the manufacturing plant, but oftentimes the early electric station was in a building already existing and with an engine which had been given up for some other use and applied to the new demand, as an economy. Those were the days when arc light machines had frequently to be loaded up in the stations by lamps, making up for the deficiencies of the external or outdoor load; and it was not unusual to see 50 or 60 lamps or more burning in a station, consuming carbons merely as idle load to fill up circuits that did not have their full complement of commercial lamps. It was the unsatisfactory engine power and transmission by belts and the variations of load conditions which led us early to the adoption of means of regulation for constancy of current in arc machines or circuits; a remedy which practically accomplished all at one stroke. It made the circuit independent of the variations of engine or of its governing, and independent of the variations of load external to the machine.

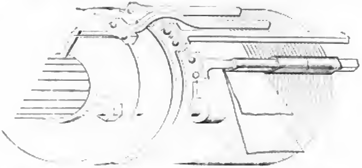


Fig. 6. Construction of Armature of Edison "Steam Dynamo"

for the engine; while frequently the testing of dynamos had to be made at a distance from the engine itself involving several belt transmissions. It will be readily understood that, with a slow-moving engine, badly governed, and such belt transmission, testing, under anything like standard conditions, was practically impossible. The modern engine of comparatively high speed did not then exist.

At the inception of what is now the modern electrical industry, it was practically impossible to find suitable instruments for measuring the values of current or potential; the only measuring instruments to be found were those of the cabinets of natural philosophy and of the telegraph systems. Such instruments of measurement as tangent galvanometers, astatic galvanometers, etc., depending upon the strength of the horizontal component of the earth's field did not work very satisfactorily when masses of metallic iron were nearby, or when, as in one instance within my knowledge, locomotives passed by on adjoining railway tracks or loaded cars stood on the tracks not far away. Even the instruments themselves were not adapted to the currents or potentials in use, and it was necessary, therefore, for the pioneer to construct his instruments to obtain such information as was needed. In fact, many of the early workers evidently got along without any information obtained from measurements of current and voltage. It may be said truly that it is not more than thirty years ago since any consistent investigation of measurements of the currents, voltages, and efficiencies of dynamo machines were made. In view of this fact, it is even in a measure extraordinary that some of the early work succeeded as well as it did, especially in the field of constant current generation which, as is well known, demands certain dynamo characteristics in order that the current shall be stable or not subject to

Fig. 7. Brush Armature with Its Coils in Position, Showing Unlaminated Core

surging or oscillation. The data for design was very meager, and the work had to be done by a sort of sense of what was needed; a feeling, as it were, that certain proportioning between armature and field would be required to make a successful machine.

In those days, too, the functions of the designer, inventor, engineer or electrician were very widely varied. He might partake of the work of works manager, salesman, patent expert, head draftsman; be engaged in construction and testing, and have various other functions more or less accidental or necessary. Also he had frequently to work under very great stress as to speed in getting work in shape. It might even be necessary that the plans and designs for a new size of dynamo should be ready within a day or so,

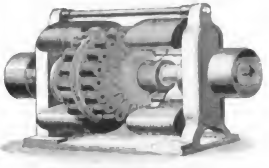


Fig. 8. Wallace-Farmer Machine

and this frequently led to his work being continued through the day and night. The only system that then existed was to get the thing done as promptly as possible, and anything which would in the least have interfered would have been swept out of the way ruthlessly. The important consideration was that a certain thing was needed at a certain time, as vital to the business, and therefore conditions should be controlled to obtain the desired result. Experimental or new work had frequently to be done in the open shop. There were no special experimental departments and, of course, such work was carried on often to the detriment of the actual commercial work. This was also a necessity of the case.

Oftentimes the machine equipment was —as in lathes, planers, etc.—so restricted that the designs had to be adapted, as it were, to the restricted manufacturing equipment. For example, work that ought to have been taken with one cut on a large planer was very frequently made on a small machine by turning the work about to make the separate cuts; and the designs of apparatus were frequently made to avoid the use of tools which did not exist, or which existed in very restricted size or number. This aspect of the subject can hardly be realized to-day unless one has had practical experience under the conditions. Doubtless some of the products of the early work seem from present standpoints to be very crude, and perhaps unnecessarily so, but this was often to be explained by the very fact that the equipment could not have met the demands of more perfect designs.

Dynamo armatures in the early days were mostly of the smooth core pattern, as these seemed to work more satisfactorily than forms which were made with projections. How completely conditions have changed in this respect may be seen by examining any of the forms of modern machines. In fact, the materials and means for using them were so imperfect and crude in the early days that armatures with projections obtained the reputation of giving bad commutator sparking, and so were avoided as the plague for a time. Since the projections were generally coarse, they would also produce considerable heating and losses with solid pole pieces. With the growth of lamination in other directions, lamination of the pole pieces was the natural remedy.

Some of the vagaries of design in dynamos and other machines were due to certain ideas which acted as fetishes, and which have since disappeared. Such, for example, was the idea that a drum armature should be of very great length, so that the idle wire on the armature, that is, the wire over the ends, would be small in amount in relation to that which was along the side of the drum. Other variations were due to patent conditions, preferred construction now open to all being subjects of patents then in force.

The brief outline given above could be amplified to almost any extent in the direction of showing the very great handicaps under which the early constructors labored, and the disadvantages which had to be met at every turn. The only advantage, perhaps, was the entire abandon with which new work could be undertaken and pushed to a conclusion, unhampered by matters or conditions which now sometimes complicate the process.

CURRENT TRANSFORMERS AS RELATED TO SWITCHBOARD DEVICES

By C. J. Barrow

Current or series transformers are a necessary intermediary between an alternating current circuit and various protective devices, meters, etc., when the voltage of the system is too high to be easily insulated and safely handled, or when the current is too high to be conveniently handled directly on such devices. Circuits in excess of 1100 volts should be supplied with current transformers, though certain apparatus designed for direct operation in 2300 volt circuits may be used in some cases. Ammeters, automatic trips, etc., of 300 ampere capacity may be had, but the maximum capacity obtainable in wattmeters and polyphase instruments is 150 amperes or less. In view of the above it is evident that current transformers will be used in all circuits of any considerable power; hence their performance and limitations under operating conditions are of general interest.

The series transformer is similar to a shunt transformer in having a laminated iron core and two windings insulated from the core and from each other. One of these windings (the primary) is connected in the main circuit, while the other (the secondary), which is well insulated from the first, delivers a current bearing a fixed ratio to the main current. The accuracy of the readings of all meters, etc., connected to the circuit will depend directly on the constancy of this ratio under varying load conditions.

Beginning with the main current in the primary as the source of energy, we have an alternating current circulating around an iron core and setting up a flux which induces in the secondary an opposing or demagnetizing current. The demagnetizing effect of the secondary current will always be somewhat less than the magnetizing effect of the primary, since some voltage is necessary to circulate the secondary current and must be generated by flux in the core. This flux in the core accounts for two components in the primary current which do not appear in the secondary —a magnetizing component necessary to energize the core, and a core loss component which supplies hysteresis and eddy current losses. Apart from these, the product of secondary current and turns equals the product of primary current and turns; and for a given primary current, that current most economically handled by secondary devices may be readily obtained by suitably proportioning primary and secondary turns.

Considering the components of the primary current more in detail, we have:—

1. That which magnetizes the core, a wattless component, varying with the flux density (volts across secondary load).

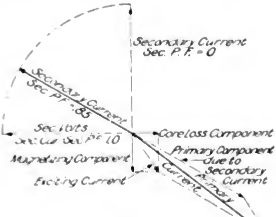


Fig. 1

2. That representing the losses in the core, an energy component, also varying with the flux density.

3. That which reappears in the secondary. Barring hysteresis, the flux will be in phase with the magnetizing component, while the counter e.m.f. of the primary and the e.m.f. of the secondary will lag 90 degrees. The core loss component, being an energy current, will be in phase with primary volts and will lead 90 degrees with respect to the magnetizing component. On non-inductive load the secondary current will be in direct opposition to the core loss current, but in quadrature with the magnetizing component; hence, with non-inductive secondary load, the ratio error is practically the result of the core loss component only. If secondary load is purely reactive, the current lagging 90 degrees from the voltage will be in direct opposition to the magnetizing and in quadrature with the core loss component, so the ratio will be influenced largely by the magnetizing component. Commercial loads usually contain both resistance and reactance, so both components will be active. These relations are shown diagramatically in Fig. 1.

The ratio error is compensated for by winding slightly less than the proportionate number of turns on the secondary. (Hence, a "step down" current transformer should not be used "step up.") An accurate ratio may be obtained in this way for given conditions of line current and secondary load, but with any variation from these conditions there is a change of flux, hence a change of magnetizing and core loss components which upsets the ratio. It is therefore necessary that these disturbing elements be reduced to a minimum, and to this end current transformer cores are worked at extremely low densities.

Low core loss and magnetizing components are further desirable that the phase displacement between primary and secondary currents may be as small as possible. The secondary current, being one of three primary components all of which are likely to be out of phase, may not be in direct opposition to the primary current (see Fig. 1). If the load is non-inductive, the secondary current will be in advance of direct opposition; if purely reactive, it will lag behind direct opposition. Somewhere between these extremes of load the two currents will be in direct opposition. Current devices will be subject to ratio error only, but devices operating with current and potential windings will be subject to both the ratio error and errors due to phase displacement.

Transformers are built in which these errors are negligible over the range for which the transformers are designed, but this range cannot be exceeded except at the expense of accuracy. The ratio will be maintained closely if the secondary impedance is such as not to require more than rated output at full load. As the impedance is increased the ratio increases, at first very slowly, but faster as the density increases; until at high densities, the high core loss, and particularly the high magnetizing components, represent a large part of the primary current, and the ratio therefore rises rapidly with increasing secondary impedance.

There is also an increase of ratio with decreasing primary current when the primary current is small (light line load) due to the fact that the magnetization curve at very low densities is the reverse in form of that at ordinary densities. That is to say, at low densities the permeability is less than at moderate densities. With primary current decreasing, the volts secondary, and hence the core flux, decrease proportionately; but since at this stage the iron is becoming less permeable, the magnetizing current does not decrease proportionately, and therefore represents an increasing proportion of the primary current. This feature limits the minimum desirable density, and calls for an iron of uniform permeability at low densities. This light load error should not be active above one-tenth load. Where the power involved is large and even a small percentage error means considerable, it is important that the ratio be accurate over the usual range of load, particularly at normal load and usual overloads.

The General Electric Company has standardized a secondary current of 5 amperes, with rated current flowing in the primary. This permits a standard line of secondary devices to be used with suitable transformers, on circuits of any capacity. A transformer is usually supplied having a current capacity equal to the momentary rating of the apparatus with which it is to be used. Under standard one or two hour overloads, such a transformer carries 3.75 amperes secondary; and if the transformer is rated 40 watts, the secondary impedance should be such as to require not more than 8 volts to circulate 5 amperes, or 6 volts to circulate 3.75 amperes; that is, the total secondary impedance should not exceed 1.6 ohms. In adding up the individual impedances of several pieces of apparatus constituting a secondary load, in order to get the total load on the transformer, the displacement between current and voltage in each device must be considered, and the vector sum of the voltages used.

To properly insulate the primary of the higher voltage transformers is a rather difficult problem, calling for the best of insulating materials and wide experience on the part of the designer. Between windings there is always the normal potential strain to ground, while during abnormally high frequency disturbances the primary, which acts as a choke coil, is very liable to break down between turns. To insure operator and secondary apparatus against a dangerous potential between low tension circuits and ground in case of failure of insulation between primary and secondary, the secondary winding should be permanently grounded. Even though well insulated, the secondary receives a charge, due to the static potential of the primary, which may be serious to the operator and apparatus unless relieved by a ground connection. On this account, also, the frame work of the transformer should be grounded.

Fig. 2. General Electric Current Transformer

It is interesting to note that the open circuit secondary voltage of a transformer is determined by the frequency, secondary turns, and flux; the flux used being that value corresponding to the product of primary turns and maximum instantaneous value of primary current for the particular brand of iron used, and is practically limited by saturation. This open circuit voltage for small transformers at ordinary frequencies may be less than 100 volts, and will scarcely exceed 1000 volts in the largest size. Apart from the building up of the secondary voltage, transformers should never be operated open circuited; since the iron losses, at the high density obtaining under this condition, cause serious heating, and the reactance of the primary in series with the line is objectionable.

PATENTS*

Part I

By Albert G. Davis

The following paper is designed to give some idea of the general object and nature of a patent. It is only a rough outline of general information, and is not to enable the reader to dispense with the services of a lawyer in any specific case.

I shall not consider copyrights, trade marks, labels, nor design patents; but patents for inventions—what we call mechanical patents.

The patent system is the outgrowth of a very odious system of monopolies, which were formally granted by the English Crown in the form of an open letter—from which comes our expression "Letters Patent." This was an open letter under the seal of the Crown, conferring the exclusive right to practice some business in the Realm. These monopolies became particularly objectionable during the reign of Queen Elizabeth, and not long after her reign they were abolished. A statute of James I contained a provision against monopolies being granted excepting to those who introduced new manufactures into the Realm, and this theory still survives in England in the patent of importation, or "communication."

In this country the patent law is based on a clause of the Constitution of the United States which gives Congress the right to grant to inventors, for limited periods of time, the exclusive right to enjoy the fruits of their inventions. A patent, therefore, is a Federal thing, that is, a thing of the Federal Government and not of the States. It is a grant of the exclusive right to make, use, and sell a certain invention for a certain period of time. An infringement consists in the making, using, or selling of the thing concerning which the grant was made, by some other person without authority. Patents are granted by the Government of the United States, under the seal of the Patent Office, and, of course, in accordance with the Statutes of the United States, and the Patent Law is a Statute Law. A patent is a creature of these statutes, and can only be considered with reference to them.

In this country a patent of the kind we are considering runs for seventeen years from the date of issue, not from the date of filing the application.

* Lecture delivered before the Schenectady Section A.I.E.E.

The following paragraph is Section 4886 of the Revised Statutes of the United States, as now amended. It is the fundamental basis of our patent law, and is worthy of careful reading, as every word means something.

> "Any person who has invented or discovered any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvements thereof, not known or used by others in this country, before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof, or more than two years prior to his application, and not in public use or on sale in this country for more than two years prior to his application, unless the same is proved to have been abandoned, may, upon payment of the fees required by law, and other due proceedings had, obtain a patent therefor."

As I have said, every word in this statute means something. Considering the separate phrases, we have, first: "*Any person who has invented or discovered.*" This means that the application must be made by the inventor; no one else can make it; otherwise it is void. If two persons jointly invent, and one files a sole application, or if two file a joint application on an invention made by one of them, no valid patent can issue on that application. So the person who furnishes the money, or a mere assignee, cannot make the application—it must be made by the inventor.

Next in the statute are the words:—"*Any new and useful.*" Of course a thing must be new, for this is the fundamental idea of a patent. (We will go a little more into detail regarding this later.)

If a thing is not "useful," no patent should be granted, but on the other hand, a small degree of utility will support a patent. If a thing is really harmful, the patent is void. For example, a device for perpetrating fraud on the public would be void. There was a case in Connecticut of a patent on a process for producing tobacco in imitation of certain high grade Cuban tobacco. It was found at one time, that in a certain district in Cuba, there was a parasite or fly, which, by biting the leaves of the tobacco plant, caused little white spots to appear; and the public got into the habit of looking for these spots and recognizing them as the mark of the tobacco of this particular district. This man in Connecticut conceived the idea of going out in his tobacco fields and spraying a certain solution on the leaves, and thus reproducing these white spots. He got a patent on this, though with considerable difficulty, as the Patent Office held that it was a fraudulent thing. He stated, however, that this invention made the cigars more free-burning, and on that ground a patent was granted. He prospered in this business for some time, until some other man decided that he would try it also. This brought up litigation, and the judge without hesitation held the patent invalid, resting his decision on the grounds of lack of utility. He said that there was no proof that the cigars really were more free-burning, though he seemed inclined to rest his decision on the broader ground of the essentially fraudulent nature of the business.

What constitutes novelty? "*Not known or used by others in this country before his invention or discovery.*" If used in a foreign country, it does not affect an American patent, unless it can be shown that it is an idea brought home by the inventor, in which case the patent is void. If a man goes abroad and seeing something over there that seems to him meritorious, comes home and patents it, obviously he has not invented it. If, however, a man in this country invents a thing in good faith, the fact that it was *used* abroad is no bar to the patent, provided the thing was not "*patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof.*" This relates to the date of his invention and not to the date of his patent. To grant to a man a patent on a thing that had been described in a printed publication before his discovery of it would be bad practice, because he might have read that publication; and in any event it would not be new, the world would be in possession of the invention. But if he had invented it in good faith before this publication was issued, he could file his application in this country within two years of that publication; otherwise it would be void.

Referring again to the statute we find the phrase:—"*Not in public use or on sale in this country for more than two years prior to his application.*" This means that a man cannot make an invention and allow his device to go into use or be sold to the public for an indefinite period, and then obtain a patent; he must file his application within two years from the time such public use begins. The question is, what constitutes public use, and this question is a very difficult one. For example, in the case where a pavement had been laid for six years on a toll road near Boston, it was held not to be in public use. The reason for this decision was that the pavement was held to be experimental, having been put down to determine whether it was serviceable. It was placed in front of a toll-gate, where the horses had to stop and start, and where the work on the pavement was the heaviest. Every few days the inventor would examine the pavement, would discuss it with the men, and find out every detail regarding it. He was held to have been experimenting, but that was an extreme case.

When a man has finished with his invention, when he is satisfied the thing is good, although capable of further improvements, then the use becomes public use under the statutes. Ordinarily, when he begins to derive profit, it constitutes public use.

Of course, an invention can be abandoned, as any other right and privilege can be abandoned. The right to own a piece of real estate can be abandoned; as is the case when a man allows the public to walk over a part of his land for a sufficient number of years; for there then accrues to the public the right of way over this particular lot of land, and thus to this extent it is an abandonment of the right of the proprietor. In the same way, a man who has made an invention and obtained thereby a right to apply for a patent, may abandon that right; either definitely and formally, by publishing a statement that he has made an invention and is not going to take a patent; or indefinitely and informally, by simply allowing it to run long enough to result in abandonment.

If we look at an American patent, we find that it usually contains a drawing, always a specification, and always certain short paragraphs which we call claims. The drawings are merely illustrations, the specification is the description, and the claim is the soul of the patent. The patent is in the nature of a contract—that is the modern view of it. The Government says to the individual: You have made an invention; you may, if you wish, keep that invention secret; you may use that invention as a secret process, and hand it down to your descendants if you can keep it secret; but if you come to us and tell us about this, explain it to us so that we can use it, then, as a reward for that, we will give you the exclusive privilege of the use of it for a term of seventeen years. The inventor must tell all he knows about it; if he deliberately holds back one thing vital, the patent is void.

In this matter of patents for inventions there is great diversity in the practice of the different countries. Obviously, a man ought to get the monopoly of whatever new patentable thing he has invented, but the practical question comes up as to just how to ascertain what that is. It should be well and sharply defined, but a careless or incompetent patent attorney should not be able to take any right from the inventor.

Latin nations follow the French system, which is exceedingly simple—a man files a description of an invention in the French patent office, and that is all there is to it. He can file the description of anything, and they will take it and grant a patent on it, and he can enforce that patent against anyone who uses any new or patentable thing found in the specification; but it is exceedingly difficult practically to find out what a French patent covers, on account of the absence of what we call the claims, and that is the difficulty with the French system.

The German system is something like the American; a man is required to claim what he has invented. He specifies in a form of words the particular thing he has invented; but the construction of the claim is so different, the phraseology is so different, that we Americans, as a rule, cannot understand the German practice.

The Japanese system is intermediate between the German and American—it is not yet settled which way they are going. As far as I can see, the tendency is toward the German practice.

In this country we have another system, which is a logical antithesis of that of the French. Here a man with an invention gives a description of some new thing, but he must do more than this; he must select and define certain things and say: "these are mine." We call these claims, and the claim as I have said, is the soul of a patent. In a sewing machine, for example, a claim reads: "The combination of a wheel, a treadle a shuttle," etc. Now this means that this man thinks he is the first that has ever put a wheel, a treadle and a shuttle in a sewing machine, and if this is the case, no one else can do this without infringing. Broadly and roughly speaking, a claim is a combination, and a thing does not infringe that claim unless it contains every one of those things, every "element" of the combination. The mere fact that it contains more things will not prevent it from being an infringement. We put as little into a claim as we can. For if a certain combination is new and is made up of three elements, and we put in four, anybody can use the three elements providing he does not put in the fourth one; so we have given away some of our clients' rights to the public. Obviously the patentee must sharply define his claim. He often does it badly; he is often advised by poor attorneys, and is often ignorant of the real invention. It is exceedingly rare in ordinary practice for a man to know just what he has invented. An ordinary man says, "here is my invention," and it is a matter for cross-examination to find out what really belongs to him. Even the best of attorneys frequently fail to see the real gist of the invention and claim it more narrowly than they should.

Many will remember when the Tesla patents were patents on detail improvements on electric motors; and ten years later they were foundation patents at the basis of a great art. That means, an art has grown up under those patents. So it is hard to say which patents are narrow and which are broad.

A man can obtain a patent on anything that is new, whether he has a right to use it or not, provided it fulfills the statutory requirements. If I invent a certain thing and patent it, and some one else makes an improvement tomorrow, he can patent his improvement, but cannot use my patent. The mere fact that the patent office has granted him a patent does not mean that he has a right to use that thing, but merely that he has the right to keep other people from using it. A patent grants the *exclusive* right to make, use and sell an invention; it *excludes* others from the use of a certain thing. It is on that point that some interesting State and Federal decisions have been made.

There are a number of cases where a man has made an invention the use of which was prosecuted as a criminal act in a state where it was against the law, the defendant maintaining that the patent was granted under the federal laws and statutes and therefore took precedence over state laws. Take as an example the case of a man in the state of Maine making and selling whiskey made by the use of a patent still, and defending himself by saying: "This is my patent, in which the Government granted me the right to make, use and sell this invention; and I do not care for your local laws which say that it is wrong to distill whiskey." The courts would hold that to be no defense, and the true reason for this is that the patent did not grant to this man a right to do anything, but simply the right to prevent others from doing something. It is no protection for him to say that he is working under the laws of the United States. The only thing he can do is to prevent other people from distilling whiskey with that particular still.

Take as an illustration the automobile tire or bicycle tire. There was once a time when somebody had the conception of running a wheel on air enclosed in a surrounding tube. That thing was or might have been patented, and there is no reason why the man should not have had a patent as broad as the idea of the pneumatic tire. Suppose he had taken out that patent, showing the old hose-pipe bicycle tire. Then suppose that in time it was found that it was difficult to repair a tire of that nature, and some one conceived the idea that the tube itself need not be circular and continuous, but could be locked into the rim at each side; and that it need not be air-tight provided there is an air-tight tube inside, thus making the double-tube tire. Now he could patent that, of course. Then perhaps somebody wanted a means for taking off the tire more quickly, and got the idea of a quickly detachable tire, and so on; a dozen or a hundred inventions, culminating in some good automobile tire. Now the second man cannot make his tire unless the first man lets him. The man who conceived the idea of the double tube tire must use the invention of the first man, and so on. Of course, the first man's patent will expire, and then the second will go ahead.

(To be continued)

THE COST OF COPPER

By George L. Walker

Author Walker's Copper Letters, Editor Boston Commercial

The cost of producing copper depends chiefly upon the richness of the ore and the size of the ore deposit; but much depends also on the character of the mineralization, and minerals which are associated with the copper. Copper ores which do not yield readily to known methods of reduction are called refractory. The most refractory ores are those in which the copper occurs as oxides and carbonates in a highly silicious gangue; and those ores in which the copper occurs in any of its various mineral forms associated with zinc, nickel, antimony or arsenic are also difficult to smelt and refine.

The theory that there are some considerable deposits of high grade ores which cannot be smelted or treated profitably, and the belief that large masses of native copper exist which cannot be cut up, are both unfounded. All of the large masses of copper ever found were cut up and marketed very profitably. Modern metallurgists can treat any ore in existence at a good profit, provided it is rich and exists in sufficient quantities to warrant the construction of large plants.

As a result of my personal inspection of practically all the producing copper mines in the United States and Canada and the largest one in Mexico, I have come to believe that necessity helps to develop an economical management and attain low production costs. The management of a mine in which there is an abundance of rich ore is always prone to overlook many of the small opportunities for economy of operation; but the manager who is forced to continue development work tirelessly in order to keep a mill running on a very poor grade of ore, and from it win profits, is pretty sure to give careful attention to every known method of economy and use every one of them to its best possible advantage. Human nature asserts itself in mining as in all other pursuits, and the traditional relationship between necessity and invention is never severed.

In copper mining the best results are practically always obtained from working very large bodies of low grade ore. To illustrate: in the Cobalt silver district it costs \$60.00 to \$150.00 per ton to mine ore from veins which average three or four inches wide;

while in the British Columbia copper camp ore is extracted from a lode 300 feet thick, trammed half a mile and loaded on railroad cars at a cost of $1.02 per ton.

Of course it is not practical to set up heavy modern mechanical equipment, hoists, electric tramways, etc., to mine a small ore body. The narrower the vein and the more "bunchy" the deposit, the greater relatively is the amount of dead work which must be done to mine a given tonnage of ore; hence the cost per ton increases with the narrowness of the vein.

Those who know little or nothing of copper mining will be interested in a brief summary of the methods by which the red metal is won from Mother Earth in different mining districts.

At Lake Superior native (pure) copper occurs disseminated, chiefly in small particles, throughout porous beds or lodes of hard trap rock, called amygdaloid. About 120,000,000 pounds is produced there annually from this rock which yields an average of about 18 pounds of fine copper to the ton, giving the rock a gross value of only $2.50 on a 13-cent copper market. The total average cost of handling this rock, however, is only about $1.80, which means a production cost of 10 cents per pound. This does not include the Calumet & Hecla which produces from 85,000,000 to 90,000,000 pounds annually from a conglomerate rock which yields about 40 pounds to the ton at a cost of about 9 cents per pound. The Tamarack and Franklin produce 15,000,000 to 20,000,000 pounds annually from lower grade conglomerate rock at a higher cost.

At a cost of 15 to 25 cents per ton, Lake Superior rock is milled and concentrated, 40 to 80 tons into one, and the mineral, or native copper, is refined by a simple smelting or melting process and put into the various shapes ready to be drawn into wire or rolled into sheets. It commands a higher price in the markets of the world than any other copper. Natural conditions are such that the simplest processes in use anywhere in the world can be employed.

At Butte, Montana, the leading copper producing district of the world, the copper ores, chiefly chalcocite and enargite, occur in big fissure veins in a granite formation. The disposition of the wall rock to cave, necessitating the use of a great deal of strong timber and the refilling of stopes, makes the mining cost high.

The ores are transported a considerable distance, the lower grade concentrated in big mills and the higher grade smelted direct. A portion of the ores have to be roasted to expel the excess sulphur before smelting. The arsenic is precipitated to prevent injury to vegetation and, incidentally, it is refined and sold, yielding a fair manufacturing profit.

The matte, the first smelter product, is converted into buillion, about 99 per cent. fine. Then the copper is shipped to the Atlantic seaboard and refined electrolytically, a combined process of chemical and electric treatment, the result of which is a chemically pure copper.

Butte ores yield an average of 65 pounds of copper to the ton; but operating expenses exceed $8.00 per ton. From $1.00 to $1.50 in silver and gold is recovered, however, which keeps the cost of copper down around 10 cents.

There are only a few copper concentrating mills at work in Arizona, two each at Clifton and Morenci, and one at Globe; but the greater portion of all the Arizona ores are smelted in bulk as they come from the mines.

Bisbee is the highest grade copper district in the world. All the ore mined and treated there yields an average of 7 or 8 per cent. copper. The managers of the Bisbee mines and smelters, as a result, do not watch the cents but the dollars, and even these are not looked after so carefully but what another one could be saved per ton of ore treated, provided such a saving was really necessary. It is not—the mines of Bisbee pour out a golden river of profits year after year.

In the boundary district of British Columbia what appears to have been originally a gigantic deposit of volcanic ash is being smelted direct and is yielding copper at as low a cost as 8½ cents per pound. It is self-fluxing, containing all the lime and iron necessary to carry the ore through the furnace and making possible a very low smelting cost. Only about 25 pounds of copper, or about 1¼ per cent. is recovered; but the ore also yields about $1.40 per ton in gold and silver. Mining is done at an exceedingly low cost, also, the total operating expenses figuring only about $3.00 per ton.

At Ducktown, Tenn., ores yielding 32 to 33 pounds of copper, and carrying no precious metal values, are being mined from very wide veins and handled so economically that the copper is produced at a cost of about 9 cents, the direct blast furnace smelting system being employed.

Of tremendous interest at the present time are the plans being worked out on a gigantic scale for the treatment of the large deposits of secondarily enriched porphyry at Bingham, Utah, and Ély, Nevada. At the first point one company is now treating over 5,000 tons of ore daily at a gross cost from the ground to the copper market of $2.10 per ton of ore. This ore contains less than 2 per cent. copper and the portion now being treated yields only 26 pounds to the ton. At this rate the cost is only 8 cents per pound of copper. There is reason to believe that these big porphyry deposits will be a tremendous factor in the copper metal market in the future.

In discussing copper costs I have included not only the expenses at the mine but those of management as well, so that my figures cover the cost of delivering refined copper to consumers, all expenses paid. Where ores contain gold and silver in addition to copper, the cost of the precious metals is not figured. It is assumed that they help pay the expenses of mining and treating the ores and thus reduce the cost of copper proportionately; copper, not gold and silver, being the metal sought.

The average cost of producing the world's output of refined copper during the past 25 years probably has been slightly less than 10 cents per pound. The average selling price has been about 13½ cents per pound, resulting in a very substantial profit for an industry of such magnitude. As the world's copper output in 1907 probably cost about 10½ cents, and has been sold at an average of about 17½ cents, there was a net profit of 7 cents per pound, or a total profit of over $100,000,000 on the product of the world's copper mines, which aggregated about 1,550,000,000 pounds. If the price of copper averages less than 14 cents per pound during the present year, production probably will not exceed 1,350,000,000 pounds, and the aggregate profit at 13½ cents will be about $50,000,000.

In view of the fact that there are a great many mines in which the copper costs from 11 to 13 cents per pound, there may be some authorities who will dispute my estimate of 10½ cents as the average production cost last year. With one or two exceptions, however, all of the world's largest copper mines make their product at a comparatively low cost. About 30 per cent. of the world's 1907 output was produced by nine mines; Anaconda, Boston & Montana, Copper Queen, Rio Tinto, Calumet & Hecla, Copper Range, Calumet & Arizona, North Butte and United Verde. All of these, with the exception of Anaconda, produced their copper for 9 cents per pound or less; Anaconda's cost was probably 10, but possibly 10½ cents. Rio Tinto's cost probably did not exceed 7½ cents, Calumet & Arizona's 7½ cents, and Boston & Montana's 8½ cents.

There are a few moderately large producers, among which may be mentioned Greene Consolidated, the Mansfield of Germany, Arizona Copper and the Old Dominion, whose copper costs from 11 to 15 cents per pound. But the aggregate production of these four companies is only equal to that of the Copper Queen and Calumet & Arizona combined, which are capable of making their copper at a cost of 7½ cents.

The cost of copper has very little to do with its market price. During the civil war, from 1861 until 1866, the price of copper did not decline below 17½ cents, and it rose in July, 1864, as high as 55 cents. At that time miners were scarce and wages high; and uncertainty as to the future of the country had prevented a continuation of expansion and progress along general business lines, and in the copper producing world particularly. When business began to revive there was a scarcity of copper, and a sharp advance in price naturally followed.

The lowest price ever recorded for copper was 9 cents per pound. This quotation was made in January, 1894, and was the result of the halt in general business, due to the Bryan silver panic. The lowest price the metal touched at the time of the failure of the Secretan Syndicate, in 1885, was 9¾ cents.

While there have been most remarkable strides in the application of mechanical contrivances and of steam and electric power to copper mining, milling and smelting within a quarter of a century, the economies thus achieved have been very nearly counterbalanced by the advance in the wages of labor. I mention labor alone, but I wish it understood that the mining companies pay for labor not only in wages at the works, but in the higher prices of steel, coal, machinery and practically all supplies and equipment.

The high development of mechanical, mining and concentrating devices has made it possible to treat a very much lower grade of ore than could be handled profitably 20 years ago. It therefore has been productive of the custom of mining the lean ore with the rich, thus greatly increasing the ore tonnage handled daily and reducing the general average grade of ore treated in each of the several districts and by every big mine.

The managements of the big established mines of Butte, Lake Superior and other districts are not striving to reduce the average cost per pound of the copper produced by their companies. They are interested rather in reducing operating costs in every department, that by so doing they may be able to increase the available tonnage of ore in the mines. To illustrate, suppose that only those portions of a company's ore deposits which assay 3 per cent. or more can be mined and treated so as to yield copper at a cost of 10 cents. If the manager succeeds in reducing the average cost of handling a ton of ore by from \$1.00 to \$3.00, he will then be able to mine and treat all the ore in the deposit which contains more than 2 per cent., and still produce it at a cost of 10 cents. By doing this the total amount of ore available may be increased 50 per cent., and thus may add millions of dollars to the value of the property. For instance, 3,000,000 tons of ore averaging 2½ per cent. unavailable when operating costs were \$6.00 per ton, on an operating cost of \$4.00 would yield up its copper at a cost of 10 cents, and would be worth, with copper at 13 cents, \$1.25 per ton net, or \$3,750,000, as the ore would return this amount in profits.

The assertion often heard that there is copper enough along Copper River in Alaska to supply the world for a thousand years, should not be taken too literally. There is enough copper in the Lake Superior district, at Butte and in Arizona to flood the markets and close down all the other copper mines in the world, provided this copper could all be produced immediately at a very low cost. It is probable that 75 per cent., and possibly 90 per cent. of all the copper in and adjacent to the districts named is so widely disseminated through the country rock as to make its recovery at a profit by any known method impossible. You must build mills or smelters or both before you can produce copper, and after they are finished there is a limit to their capacity.

Speaking of a thousand years, a considerable portion of this time will be required to develop, equip and man the copper deposits of Alaska and make them ready for production on any considerable scale. Alaska has the disadvantage of low grade ores and isolation from transportation and supply centers, and the only way to get labor there is to import it and then make living conditions sufficiently attractive to keep it there—by no means an easy undertaking.

It requires from three to ten years to develop and equip a large copper mining enterprise. Therefore, every time the world's consumptive demand has a sudden and unexpected increase, the price of copper must go soaring into the clouds. On the other hand, whenever there is a sudden contraction in the volume of the business of several countries at the same time, the price of copper has a severe decline.

It is not necessary to tell the readers of an electrical magazine that the future of the copper producing business is assured. The electrical age, upon which we are now entering, of course means an age of copper. As the development of the steam railroad was predicated upon a profitable iron and coal mining business, so must electrical progress make a market for a steadily growing production of copper.

The world's great copper deposits are in the United States. Though this country is young, its mines located far inland, and its wage scale higher than any other, it produces about 60 per cent. of the world's copper output. Copper has the advantage of a world-wide market, always selling on a given day at the same price in Tokio, London, New York and San Francisco. Copper can be shipped half way around the world for 6 per cent. of its value, while it would cost 150 to 200 per cent. of the value of pig iron to transport it a like distance. When the industries of one country are depressed, therefore, a market for copper can usually be found in others. During the past six months, for instance, much more than the normal proportion of the production of this country's mines has been sold in Europe, domestic consumption having declined 50 to 60 per cent.

THE ELEMENTS OF STEAM LOCOMOTIVE DESIGN*

By C. J. Mellin

The design of a locomotive is based on the conditions under which it is to work and the kind of service required. These factors govern the type and proportions of the engine if left to the builder for decision; the type, however, is in many instances a choice of the purchaser. In either case, the first consideration is the allowable wheel pressure on the rail, and by this is determined the weight on the driving wheels. The maximum curvature of the road limits the length of the rigid driving wheel base, and, in the best cases, it is not advisable to make this over 16 or 17 feet, and then only for slow-going freight engines. This generally limits the number of driving wheels to four pairs for freight and three pairs for passenger engines. It is better to couple as few wheels together as possible, and therefore three pairs of coupled drivers are often used for freight, and generally two for passenger service. So far as the driving wheel arrangement goes, this would only make four types of road engines; but as all road engines must, for the sake of safety, have a guiding truck, it is generally considered that a two-wheel or "pony" truck, is the most suitable for freight engines, partly because it can be held to the track with less dead weight, and partly because it adds the least to the already long total wheel base of the engine. The four-wheeled truck is mostly used in passenger service.

There are further to be considered fast freight, and mixed freight and passenger service, in which both types of trucks are used, and to meet these varying conditions, several types of engines are brought into existence.

These various types are distinguished from each other by names and figures, depending on the wheel arrangement. For the ordinary locomotives, these figures represent the grouping of the wheels, where the first figure signifies the number of wheels on the first truck; the second, the number of drivers; and the third, the number of wheels in the trailing truck.

We have thus the light passenger or eight-wheeled engine, with a four-wheel truck and four coupled drivers, which is classified as 4-4-0, the last figure indicating that there are no trailing wheels; medium sized passenger engines, or Atlantic type 4-4-2; heavy passenger engines, or Pacific type 4-6-2; and the ten-wheel type 4-6-0. The latter, as well as the Mogul engine 2-6-0, and the Prairie type 2-6-2, are also very suitable for mixed or fast freight service. For regular freight service, the Consolidation class 2-8-0 has practically become the standard, and for heavy freight the Articulated class 0-66-0 is rapidly looming up as another advance toward meeting the constantly growing demand for increased power units.

Fig. 1. Atlantic Type of Passenger Engine. Weight of Engine 200,000 lbs.; Weight of Tender 122,000 lbs. Tractive Effort, 23,500 lbs.

* Lecture delivered before Schenectady Section A.I.E.E.

For switching service, it is considered that no truck is needed for guiding purposes, and the slow and intermittent runs, and consequently the smaller weight of the boiler, favors the adoption of only coupled wheels and a short wheel base, which is of great advantage in view of the numerous and sharp curves in yards and around freight houses. The 0-6-0 type has practically obtained the entire possession of this field, and only in a few instances has it admitted the 0-8-0 type as a special assistant.

This comprises practically all of the general types of engines for ordinary railway service, and we shall find after careful investigation, that each of the above types meets conditions on the road where it is more suitable than any of the other types

The large demand of speed and power for passenger service brought into existence the Atlantic and Pacific types, superseding the eight and ten wheel engines with larger wheels, larger cylinders, and consequently larger boilers. These enlargements necessarily increased the weight of the engines beyond the allowable rail load, and the spread of the firebox for obtaining the required grate area necessitated the introduction of a pair of trailing wheels under the overhanging firebox.

As previously stated, the road and service conditions determine the size and type of the engine, which means, in the first case, the allowable weight per driving wheels on the rail; secondly, the required hauling capacity; and thirdly, the service speed (and maximum speed at a given weight of train if the engine is intended for passenger service). Maximum grade, condition of road bed, curves and bridges are all factors that must be considered in order to produce the most servicable engine. These conditions are often of so fluctuating a nature that only experience and good judgment can determine the most suitable type and the fundamental dimensions. Thus the type and the combined weight and diameter of the driving wheels are decided upon, and usually the total weight of the engine. Within these limitations the work of laying out the engine can be started. The required cylinder power is figured out on the basis of the tractive weight, which is only another designation for the weight of the driving wheels on the rail.

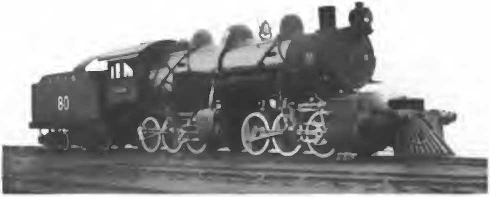


Fig. 2. Articulated Type of Freight Locomotive. Twelve Drivers. Weight of Engine 206,000 lbs.; Weight of Tender 90,000 lbs. Tractive Effort, 42,400 lbs.

The tractive power is usually figured out to be 22 to 23% of this weight, and is found by the following formula:

$$\frac{23W}{100} = \frac{CPd^2S}{D} = F \qquad (1)$$

where W = the weight exerted by the drivers on the rail;

C = a coefficient varying with the speed and cut off;

d = diameter of the cylinder,

S = stroke of the piston;

P = boiler pressure,

D = diameter of the drivers;

F = tractive power.

The boiler pressure is always predetermined, while the diameter of the drivers is in proportion to the required speed, and is made about equal, in inches, to the speed in miles per hour, at which the engine is expected to run. The stroke is selected so as to give the required maximum train speed with a moderate piston speed.

We have next to find the diameter of the cylinder, but this is dependent on the value of C at the maximum speed and cut-off. This value is expressed as a percentage of the boiler pressure, and when multiplied by the latter, gives the average cylinder pressure. The average pressure for a given cut-off may be found from formula 2 as follows:

$$P_1 = \frac{P\ (1 + log_e n)}{n} - 15 \qquad (2)$$

where P_1 = the average pressure in the cylinder with n number of expansions. Since the engine is non-condensing, the atmospheric pressure (15 lbs.) must be subtracted. This formula gives us the result of a constant product of volume times pressure, whereas steam expands adiabatically; that is, the temperature falls with the pressure and causes a slight fall in the expansion curve.

We have further a "wire drawing" of the steam at high speeds, and back pressure to take into consideration; these modify the expression for formula 2 and make it uncertain, because of the uncertainty of the actual loss in pressure due to the higher velocities of the steam through the passages, and to cylinder condensation. In the ordinary engine the number of expansions are seldom over three, and at the maximum power this is only an extremely small fraction of the admission volume. Therefore, the generally accepted value of C is 85% of the boiler pressure, for a piston speed not exceeding 250 feet per minute and with a cut-off at 87% of the stroke; this gives the maximum tractive power of the engine, and is the regular rule for simple freight engines.

For high speed the value of C falls gradually, and will be about 30% at 1000 feet per minute piston speed.

It remains now to find the diameter of the cylinders, which is done by transposing formula 1 as follows:

$$d^2 = \frac{DF}{CPS}, or\ d = \sqrt{\frac{DF}{CPS}} \qquad (3)$$

The train resistance must not, of course, exceed the pulling power of the engine, and the size of the train will be arranged accordingly. In many instances the weight of the train is put down as the fundamental requirement, and it is then necessary to find the resistance of the train, and from this side of the question determine the tractive power and number of driving wheels needed to handle this resistance.

It will be considered that for passenger service the weight of the train must always be limited to the tractive force obtained by employing three pairs of coupled wheels, because the long wheel base that an additional coupled pair of wheels necessitates is dangerous for high speed on curves. In freight service, however, a comparatively recent development has been introduced by subdividing the driving wheels into two groups

Fig. 3. "Hump" Type Freight Locomotive Special. Weight of Engine 270,000 lbs.; Weight of Tender 149,600 lbs. Tractive Effort, 55,362 lbs.

of engines in a so-called articulated system, whereby practically any desired size of train can be handled, limited only by the strength of the draft gears. It is not improbable that this type will find its way into passenger service also, to meet exceptionally heavy road conditions.

The train resistance per ton weight due to rolling, is found to be $= \frac{V}{4} + 2$, where V is the speed of the train in miles per hour.

Resistance due to grade = sin x, or sine of the angle of inclination, which is usually expressed in feet per mile. Calling the number of feet of inclination per mile M, we get the resistance per ton of train weight

$$= \frac{2000}{5280} M = 0.38M$$

The curve resistance is found to be about 0.5 lb. per degree of curvature per ton.

train and engine, which, when F is given, will be

$$T = \frac{F}{1.08(\frac{V}{4} + 2 + .38M + .5b + .0126V^2)} \quad (5)$$

The factor 1.08 represents the internal resistance in the engine.

For the resistance at uniform speed, the term $0.0126V^2$ representing the acceleration should be eliminated, since no further acceleration takes place, and consequently such resistance disappears.

The tractive power of compound engines is based on the low-pressure cylinder only, when working compound. In the following formula for compound working, d represents the diameter, of the low-pressure cylinder, while the coefficient C is a modification of formula 2, and for maximum power is equal

Fig. 4. The Latest Type of Articulated Freight Locomotive. Largest Engine Ever Built. Weight of Engine 410,000 lbs.; Weight of Tender 160,000 lbs. Tractive Effort 94,800 lbs.

The acceleration, including the revolving of wheels and axles with that of the weight of the train, figures up to be about $0.0126V^2$ per ton.

Adding to this the resistance of the engine, we get the following formula, which must be equal to F in formula 1, namely:

$$R = 1.08\left(\frac{V}{4} + 2 + .38M + .5b + .0126V^2\right) T = F \quad (4)$$

R being the resistance of the train, including the weight of the engine and tender; and being the opposite of the tractive power, it is also equal to F. The symbol b represents the number of degrees of the sharpest curve, and T the number of tons in total weight of

to 0.54 when the cylinder ratio is 1:2½, as is usual in two cylinder or cross-compound engines. Where the ratio increases, as is the case in some designs of three and four cylinder engines, the value of C decreases.

When working the compound engine simple, with independent exhaust for the high-pressure cylinder, at will, and with properly reduced pressure for the low-pressure cylinder, the high-pressure cylinder is the base for the tractive power, as per formula 1, or:

$$F = \frac{CPd^2S}{D} \quad \text{(working simple)} \quad (6)$$

where d = diameter of high-pressure cylinder and $C = 0.85$;

For working compound:

$$F=\frac{CPd^2S}{2D} \tag{7}$$

where d = diameter of low-pressure cylinder, and $C = 0.54$.

For three and four cylinder compounds, where the cylinder ratios are 1:3, and where two low-pressure cylinders are used, we get, when working compound:

$$F=\frac{CPd^2S}{D} \tag{8}$$

where d = diameter of low-pressure cylinder and = C 0.50. If provided with an intercepting valve for simple working, 20% increase in tractive power is obtainable.

For four-cylinder articulated engines, the same formula (7) holds good for working compound, but as the cylinder ratio is about 1:2½, the value of $C = 0.54$.

In working the articulated engine simple we get:

$$F=2\left(\frac{CPd^2S}{D}\right) \tag{9}$$

where d = diameter of high-pressure cylinder, and $C = 0.85$.

For triple expansion engine, with two low-pressure cylinders, formula 7 is used by substituting 0.40 as the value of C; but this takes us somewhat into the future, and we will leave off here for the present, merely pointing towards what we still have undeveloped ahead of us.

Since we have found the cylinder diameters and the stroke of the piston, we will proceed to determine the heating surface and grate area, which are two of the most important factors in a successful locomotive.

There are two different methods employed for determining these factors; one being based on the maximum horse-power that the engine must develop, while the other is to proportion them on the volume of the cylinders. A third method; namely, to base the amount of steam used on the cut-off pressure when the greatest horse-power is being developed, is probably as good as any, when the actual cut-off pressure can be obtained in advance; but as that usually has to be estimated, it would be difficult to arrive at any uniformity. As this is also to a great extent the case with the first method, the second is very generally adopted and found to give satisfactory results.

This method is to make the heating surface in square feet, not less than 450 times the volume of one of the cylinders in cubic feet, for passenger engines, and 400 times this volume for freight engines; it is desirable to make it greater when the weight of the engine and other circumstances will admit. The grate area should be about 1/[illegible] of this amount.

A selection of a graphic representation pertaining to the balancing of and the distribution of weights of Articulated engines is shown in Fig. 5, an explanation of which is as follows:

The Articulated type of engine consists of two systems, of lateral flexibility in their relation to each other, of which the front group of wheels, with frames, cross-ties and low-pressure cylinders, forms one system; and the rear group, with frames, cross-ties, high-pressure cylinders, boiler, cab and fittings, forms the other. The location of the small balls in the cut represent the longitudinal center of gravity of the respective systems, and the arrows under the wheel groups, the supporting centers.

It will be noticed that the center of gravity in both cases falls ahead of the supporting centers, and that the rear system with the boiler, etc., is considerably heavier than the front system. One-half of the difference of the weights must therefore be carried by the front engine in such a way that it balances the weight of the latter over its supporting point. The momentum curve of the front engine is transferred to the rear of its supporting center, and the momemtum curve of the rear system is extended until it intersects with the former. These curves are laid out with reference to the respective supporting centers, and the weight represented by their vertical height above a common base line.

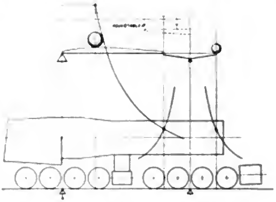


Fig. 5. Diagram Showing System of Weight Distribution of Locomotive shown in Fig. 4

We can now readily find the weight on the rail of each system, which, due to continuous equalization within itself, is concentrated in the middle of each wheel group, referred to above as supporting centers indicated by arrows. In order to obtain equal weight on both supporting centers or both groups of wheels, the center of gravity of each system must be thoroughly figured out and the various parts of the engine so placed that the desired location of the intersecting point is obtained. This intersecting point then becomes the vertical bearing point on the front engine where one-half the difference of the weights between the two systems must rest to bring the front engine in complete equilibrium over its own supporting center, and equal distribution throughout the entire engine takes place as illustrated by the lever system in the upper part of the figure.

This is the ideal condition, which, however, for ordinary service will produce too sensitive an engine. It is better to locate the actual bearing point in front of the virtual one and apply an adjustable hanger, or strut, as may be most convenient, in the rear of this, as indicated in the top of the figure, and thereby establish the desirable stability without disturbing its equalization.

INFLUENCE OF WAVE FORM OF E.M.F. ON CORE LOSS AND EXCITING CURRENT IN TRANSFORMERS

Part II

By L. T. Robinson and O. Holz

General Electric Standardizing Laboratory

The exciting current, which we will call I_t, is composed of two components, the energy current I_e, and the magnetizing current I_m.

The energy current is that component of the total exciting current which is in phase with the impressed electromotive force E, and is equal to the watts supplied to the core divided by the e.m.f. impressed; the $I\ R$ drop of voltage due to the exciting current being negligible

$$I_e = \frac{W}{E} \qquad (6)$$

The magnetizing current is that component of the total exciting current which is at right angles to the impressed e.m.f. E, and is therefore equal to

$$I_m = \sqrt{I_t^2 - I_e^2} \qquad (7)$$

The relation between the two currents I_e and I_m and the total current I_t can also be expressed as

$$I_e = \cos\theta \times I_t, \text{ and} \qquad (8)$$

$$I_m = \sin\theta \times I_t \qquad (9)$$

The currents are given in effective values, and θ is the equivalent angle of lag corresponding to sine waves.

It has already been shown that the hysteresis component of the core loss is inversely proportional to the 1.6 power of the form-factor of the e.m.f. wave; therefore the energy current is influenced by the form-factor of the wave, because the quantity W is made up of hysteresis and eddy components. Hence, the effect of the e.m.f. wave on I_e may be determined by separating I_e into its eddy and hysteresis components and correcting the hysteresis component alone for the form-factor of the wave; or we may write

$$I_e = \frac{W_h + W_e}{E} = \frac{W_h}{E} + \frac{W_e}{E}$$

where W_e is power consumed by eddy currents and W_h is the hysteresis loss on any wave b, differing from a sine wave a, and equal to W_h observed multiplied by

$$\left(\frac{1.11}{\text{form-factor of } b}\right)^{1.6}$$

Let us now consider in what way the correction for wave shape may be applied to the magnetizing current I_m.

The maximum magnetization caused by I_m depends not on the effective value of I_m but on its maximum value, and also upon the permeability of the core at the maximum magnetization.

Different magnetizing currents are computed from I_t by (7) or (9), which will give the effective values, as I_t will be observed on an ammeter, and hence its effective value only is known. The maximum value of I_m must be that which will give a density corresponding to the form-factor of the wave b on which the observations are made. The density is found from equation:

$$B_b = \frac{E \times 10^8}{4 \times A \times N \times \text{cycles} \times \text{form-factor}} \quad (10)$$

where A is the cross section of the iron core and N is the number of convolutions in the winding used

$$\text{or} \qquad B_b = \frac{K}{\text{form-factor } b}$$

$$\text{and} \qquad B_a = \frac{K}{\text{form-factor } a} \quad (11)$$

$$\therefore \qquad \frac{B_a}{B_b} = \frac{\text{form-factor } b}{\text{form-factor } a}$$

$$\text{and} \qquad B_a = \frac{\text{form-factor } b}{\text{form-factor } a} \times B_b$$

The form-factor a of sine wave is

$$\frac{\frac{1}{\sqrt{2}}}{\frac{2}{\pi}} = \frac{\pi}{2\sqrt{2}} = 1.11$$

from which we find B_a at sine wave.

Now, knowing both densities, that of test and that corresponding to sine wave, we find from the saturation curve of the transformer H_b corresponding to test wave b, and H_a corresponding to sine wave a.

$$\text{As} \qquad H = \frac{4\pi}{10} \times N \times I_m \text{ max., we have}$$

$$\frac{H_a}{H_b} = \frac{I_m \text{ max. with e.m.f. wave } a}{I_m \text{ max. with e.m.f. } b} \quad (12)$$

To simplify notation, it will be understood that I_{ma} is the magnetizing current with impressed e.m.f. of wave shape a, and the same with respect to I_{mb}.

Now, $\frac{I_m \text{ max.}}{I_m \text{ effective}}$ is called the amplitude factor, or I_m max. $= I_m$ effective $\times$ amplitude factor.

$$\therefore \frac{H_a}{H_b} = \frac{I_{ma} \text{ effective} \times \text{amplitude factor of } a}{I_{mb} \text{ effective} \times \text{amplitude factor of } b}$$

$$\text{and } I_{ma} \text{ effective} = \frac{\text{amplitude factor of } b}{\text{amplitude factor of } a} \times \frac{H_a}{H_b} \times I_{mb} \text{ effective.} \quad (13)$$

Now assume, for the sake of simplicity, that a and b have the same amplitude factor; we have then

$$I_m \text{, at sine wave of e.m.f.} = \frac{H_a}{H_b} \times I_m \text{ of test.} \quad (14)$$

To find the magnetizing force at densities below the knee of the saturation curve, it is preferable, due to the steepness of the B and H curve, to divide B by μ, instead of reading H directly from the B and H curve, in which case

$$I_m \text{, at sine wave} = \frac{B_a \times \mu_b}{B_b \times \mu_a} \times I_m \text{ at test.} \quad (15)$$

Therefore, the process of finding the magnetizing current corresponding to a sine wave e.m.f. a, consists in finding B existing at test by means of the form-factor (equation 10) of the impressed e.m.f. wave b, and multiplying this B by the ratio of the form-factor of test wave to that of sine wave (1.11). We thus find B for the sine wave. From the B and H, or B and μ curve, we find the corresponding H's, and we multiply I_m, as found by (7), by the ratio of H corresponding to B at sine wave e.m.f. a, to H corresponding to B of test wave b.

The two components of the exciting current on sine wave of e.m.f. a are now known, and are added at right angles to give the total exciting current I_t; *i. e.*:

$$\sqrt{I_m^2 + I_e^2} = I_t$$

Now assume that the wave of e.m.f. b, on which the exciting current I_t was determined, has the same form-factor as that mentioned on page 237 (April REVIEW); namely, 1.25.

In a transformer of 20% eddy loss and 80% hysteresis loss, we found that the core loss on a sine wave would be 1.23 times that found by testing on wave b. Assume now that we found on this wave b, that

$$I_t = 2.5$$
$$E = 100$$
$$\text{watts} = 100$$
$$\text{power factor} = 0.4$$

Now from (6) we find e.m.f. current

$$I_e = \frac{100\ (W)}{100\ (E)} = 1, \text{ and from (7) we find} \quad (7)$$

magnetizing current $I_m = \sqrt{2.5^2 - 1^2} = 2.29$. W becoming 23% greater on sine wave Therefore, from (6) we get $I_e = 1.23$.

To correct I_m, assume that we had a density of 11100 B on the test wave b; then the density on sine wave will become

$$11100 \times \frac{1.25}{1.11} = 12500.$$

Again referring to the saturation curve, we find that

$$H \text{ at } 11100\ B = 4.3$$
$$H \text{ at } 12500\ B = 6.5$$

The magnetizing current found above; namely 2.29, is now multiplied by $\frac{6.5}{4.3}$ to obtain the new magnetizing current on sine wave a, and is equal to 3.46, and the total exciting current $= \sqrt{3.46^2 + 1.23^2} = 3.68$.

That is, the total exciting current has been increased 47%, and the power factor of the core loss has become 0.334.

As before stated, this approximate correction of exciting current is based on the assumption that the ratio of I_m max. to I_m effective, is the same with e.m.f. wave a as with wave b. Actually, this ratio, or amplitude factor, which is on a sine wave $\sqrt{2}$ or 1.414, increases with the density, which fact makes the results calculated as above only approximately correct. The amplitude factor of the exciting current can be found from an oscillogram of the test wave, and this factor corrected for eddy currents would give the amplitude factor of I_{mb}. But the amplitude factor of I_{ma} would still be unknown. This latter may be determined by plotting the current wave from the hysteresis loop of the iron, but accuracy of this degree will rarely be required.

The correction computed as above applies to cores of perfectly closed magnetic circuits. In open circuits, that is, in cores with an air gap, the combined permeability of iron and air is more constant, and the magnetizing current will be subject to less variation; but it will be difficult to make comparison for different wave shapes, as core loss and magnetizing current will be influenced by the leakage which will vary at different densities.

In transformers with very high tension primaries or secondaries, say 100,000 or more volts, the exciting current contains another component of appreciable magnitude; *viz.*, the condenser or capacity current which flows through the dielectric, solid and liquid. This capacity current is very sensitive to wave shape, and its effect must be considered in dealing with the subject. This can only be dealt with by analyzing the wave shape of e.m.f. into the fundamental and its harmonics, and from this analysis computing the capacity currents and their effects.

While the wave a was assumed to be a sine wave, and the wave b was taken as a pointed one, and therefore producing smaller maximum B at a given voltage, the same method and formulæ may be employed when dealing with a wave b having form-factor less than 1.11. In this case, the correction to sine wave values will produce smaller values instead of larger, as shown in the examples taken.

It is also evident that observations on any wave b may be corrected to any wave a not a sine wave in the same manner, and the results which will be obtained on any known wave may be predicted.

The examples given are not taken from tests, but were chosen arbitrarily, simply to illustrate the use of the formulæ. The results of some actual tests in which the corrections have been applied in the manner outlined will next be considered.

(To be continued)

TUNGSTEN ECONOMY DIFFUSER

By W. D'A. Ryan

The tungsten economy diffuser fills the demand for a large lighting unit, having approximately the same power as the enclosed

Fig. 1. 26 in. Tungsten Economy Diffuser for Store Lighting

arc lamp, and provides, in addition, a light of variable intensity, with a wide range of wattage adjustment without mechanical change.

By using various combinations of 40, 60 and 100 watt lamps, the cluster can be made to operate at 120, 180, 240, 300, 360, 420 and 480 watts, in the following combinations:

Double Circuit Triple Watt Combinations

3– 40 watt	120 watts	300 watts
3- 60 watt	180 watts	

Fig. 2. 26 in. Tungsten Economy Diffuser for Mill Lighting

Single Circuit Combinations

3– 40 watt	120 watts
3– 60 watt	180 watts
3–100 watt	300 watts

3– 40 watt	120 watts	420 watts
3–100 watt	300 watts	
3– 60 watt	180 watts	480 watts
3–100 watt	300 watts	

Fig. 3. 39 in. Tungsten Economy Diffuser for Mill Lighting

Double Circuit Combinations

2 circuits of 3–40 watt lamps each, 120 and 240 watts

2 circuits of 3–60 watt lamps each, 180 and 360 watts

The triple combinations, such for example as the three 60 and the three 100 watt lamps, giving 180, 300 or 480 watts at will from a single switch, are of exceptional utilitarian and economical value.

Mechanical Construction

The diffuser is designed primarily to carry six tungsten lamps suspended in a vertical position. Very good results, however, can be obtained by the use of either tantalum or carbon filament incandescents. When the latter are used, the platform carrying the lamps can be readily lowered without taking the fixture apart. This adjustable feature makes the fixture universal for all types of incandescent lamps.

For store lighting, the 26 in. diffuser is recommended, and for mill and factory work the 39 in. will be found more satisfactory, as it gives somewhat better distribution and diffusion, although it is not so attractive in appearance. We have found from experience that the 39 in. tungsten economy diffuser gives excellent results for mill lighting when equipped with three 100-watt tungsten lamps. This permits, for the same energy, somewhat closer spacing than arc lamps, which arrangement is particularly desirable on low-studded floors with over-head belting.

Fig. 4. Exploded View of 26 in. Diffuser

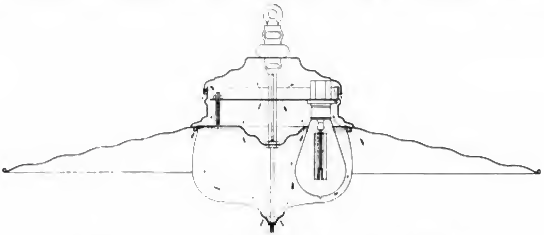


Fig. 5. Sectional Diagram Showing Passage of Air through Diffuser

Finish

Fig. 1 shows the standard 26 in. cluster.

The diffuser is made of steel, coated with white porcelain enamel on the under side and black on the top. The supporting reflector is made of brass with nickel finish, and carries springs to compensate for expansion or variation in the size of the globes.

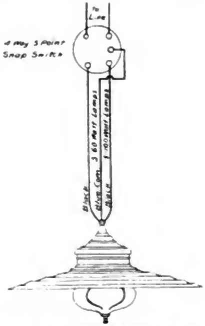


Fig. 6. Connections for Economy Diffuser

The casing is finished in streaked oxidized copper. When specially ordered, streaked oxidized silver or verde-antique can be supplied. The chain suspension and canopies are finished to correspond with the casing, and will be shipped only when called for in the requisition.

The 39 in. or mill type tungsten diffuser is identically the same as the 26 in., except that the diffuser is larger, and in place of being finished in porcelain enamel, it is coated with white zinc enamel. The 39 in. diffuser is shown in Fig. 3.

Shade

The shade is made of clear glass frosted on the inside, and is curved so as to take the general shape of the lamps. Placing the frosting on the inside of the shade gives a lower intrinsic brilliancy than is obtained by the same grade of frosting placed on the lamps, and does not reduce the life of the lamp.

The six-lobe shade is standard for all lamp combinations, and the curvature of the shade minimizes the spotted effect so apparent when part of the lamps are extinguished in a fixture having a spherical globe.

Ventilation

In order to prevent an excessive rise of temperature, the air is drawn into the bottom part of the reflector, passes around the bulbs of the lamps, and mixes with an upper ingress of air passing between the top of the shade and the reflector. This stream of air rises through the star-shaped openings in the central reflector and passes out through the ventilating ring in the casing.

Wiring

All fixtures are shipped wired for two circuits of three lamps each, one of the leads, which is common to both circuits, being blue, while the other two are black. When the customer does not wish to use the double or triple wattage combinations, the two black leads may be joined together, thereby making a single circuit.

When the double and triple combinations are required, we recommend the use of a five-point switch placed in one side of the line, as shown in Fig. 6.

When the diffuser is equipped with three 60 and three 100-watt lamps, the first point on the switch will turn on the three 60-watt lamps (180 watts); the second point will extinguish the "sixties" and turn on three 100-watt lamps (300 watts); and the third point will combine both groups, taking 480 watts. In all cases the fixture should be operated with either three or six lamps, as any other number will cause a distortion in the distribution of the light, and will destroy the symmetrical appearance of the fixture when lighted.

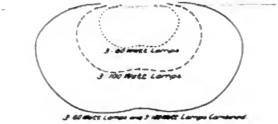


Fig. 7. Economy Photometric Curves, Showing Relative Illumination for the Different Combinations

TUNGSTEN LAMPS

By A. D. Page
Manager Incandescent Lamp Sales, General Electric Company

The General Electric Company has met with very gratifying success in the introduction of the tungsten lamp, particularly the 100-watt multiple type. To date these lamps have been placed on illuminating circuits in 630 cities and towns in not less than standard package quantities. In 295 cities and towns additional orders have been received from customers who less than three months ago placed orders for their first trial packages. There is no record of any place where the lamps are not giving satisfactory results. In one city over 2500 100-watt tungsten lamps have been ordered by one customer, and 11 other cities have each placed orders for over 500 lamps.

Very accurate reports have been received as to the breakage of lamps in transit; and this has averaged, on shipments to all parts of the United States, less than one and one-half per cent. The customer above referred to, who, as stated, has ordered more than 2500 lamps, reports that he has carefully examined those received and found that the breakage in transportation was less than 1 per cent. On over 1200 lamps sold and delivered to customers, including all lamps which burned out inside of 25 hours, the accidental breakage in handling was less than 1½ per cent., making the total breakage and early burnouts up to the time the lamp had lived 25 hours, a total of less than 2½ per cent.

The Company has just commenced to solicit orders for and make shipment of 60 and 40 watt lamps, and during the last ten days the orders for these types have amounted to over 22,000 lamps. The Company's total orders to date for the three types (100, 60 and 40 watts) have amounted to over 85,000 lamps, of which amount over one-half was sold during the month of March.

The tungsten lamp gives a light of high brilliancy and of agreeable color and quality closely resembling daylight, with the remarkable efficiency of from 1 to 1¼ watts per candle. Compared with the ordinary carbon filament lamp of equal life (3½ w.p.c.), for the same power consumption the tungsten lamp produces a superior quality of light of practically three times the volume of the former. The actual saving is 2.25 watts for every candle of light, giving a saving of 2.25 kilowatts hours for every 1000 candle hours.

The low resistance of tungsten necessitates a considerable length of filament for a 100-120 volt lamp; the filament is therefore made up of four or five hairpin loops connected in series, as shown in the accompanying illustration.

(Illustration ⅔ actual size)
GE Regular Tungsten Lamp—100 to 125 Volts—100 Watt—80 C.P. (Mean Horizontal)

The Tungsten lamp is serviceable on both alternating and direct current, and gives equal life—approximating 800 hours—on both. Tests conducted show a remarkably slow and small decline in candle-power during life; so small that well-made lamps can be satisfactorily used until they burn out.

HORIZONTAL TYPE OF CURTIS STEAM TURBINE

By Richard H. Rice

The phantom illustration of a small direct current Curtis turbine set on page 246 shows the simplicity of the unit. The principal rotating element, so far as operating conditions are concerned, is practically a single piece, made up as it is of a shaft carrying armature, commutator and two turbine wheels. As this shaft is carried in only two bearings, which number would be required for the armature alone in the case of an ordinary generator or motor, the addition of the turbine driver has obviously not complicated the rotor from an operating standpoint. As a matter of fact, the presence of the turbine wheels has simplified the bearing problem, by reason of the fact that the center of gravity of the rotating system has been brought within the main bearing; and, therefore, since it is the only bearing carrying any weight, it is the only one requiring any special means of lubrication.

The special means of lubrication provided consists of a small gear pump located on the lower end of the vertical shaft driving the governor and valve gear. This vertical shaft receives motion from the main turbine shaft through a worm and gear, the worm being placed adjacent to the main bearing. In addition to the very slight amount of power required to operate the pump, the vertical shaft has only to rotate the inertia governor and supply an occasional momentary impulse to open or close one of the number of small governing valves which admit or shut off steam from the nozzles of the turbine. The light load on the worm gears, and the ample lubrication provided are responsible for the ascertained fact that the wear on these parts is imperceptible. Measurement on a set after two years of operation failed to reveal any appreciable wear; the teeth of the worm and gear were both within the original limits. Altogether, some hundreds of worm drives of this character are in operation throughout the country, and not one has ever had to be replaced.

The main bearings are similarly long-lived. The high speed of the shaft, when ample lubrication is supplied, is a positive advantage, since the shaft forcibly draws into the bearing a substantial quantity of oil, and therefore always runs on oil, and never touches the bearing. There is consequently no wear of the bearing.

The steam using elements of these turbines should be compared with those involved in the operation of reciprocating engines, if the chief advantages of the turbine are to be realized. In the case of the reciprocating engine, a definite quantity of steam is measured off for each stroke; this quantity of steam is then confined in the cylinder behind the piston and allowed to expand as the latter moves onward to the end of the stroke. Exhaust then takes place, and a new quantity of steam is admitted to the opposite side of the piston for the next stroke. It will be seen that, for the proper performance of this cycle, tight valves and tight pistons are essential. This prime essential is, however, difficult to secure; in fact, it is impossible to secure this condition permanently where any form of valve is used sliding on metal surfaces. As soon as motion begins, wear begins also, and experience shows that this wear is very rapid at first, gradually decreasing to some minimum rate if reasonable lubrication is secured. As a result, the steam consumption of single-cylinder engines increases rapidly from the time they are first put into operation; this increase varying from 10 to 40% in amount, depending on accidental conditions of lubrication, quality of metal, etc. Another cause of leakage often difficult to deal with is that occasioned by the warping of the valves and seats. This warping is caused by the temperature and pressure of the steam, and naturally is a variable quantity, depending upon the character of the design, and to some extent upon the foundry operations.

The admission valves for the steam turbine, on the other hand, are simple poppet valves which do not require lubrication, and which wear very slightly, always remain tight, and are not affected by warping. Once past these valves, the steam acts on buckets which never touch any other part of the mechanism. It has been demonstrated, that the running clearance between the revolving buckets and the nozzles and intermediates, can be made so great, without loss of efficiency, that destructive contact will never occur, and all these machines are now made in this manner.

Some small loss might be anticipated from leakage past the diaphragm packing from the first to the second stage. On small turbines this packing is made of carbon rings which wear for a long period without leakage, and which are easily renewed when necessary. The condition of this packing as regards tightness is always revealed by a simple inspection of the stage pressure corresponding to a given number of first stage valves open.

The only remaining source of possible loss is that which would result from direct wear of the buckets themselves. A few cases of bucket wear have been noted in turbines equipped with steel buckets, due to excessive quantities of moisture in the steam. It has, however, been demonstrated that considerable wear of these edges may take place without a perceptible loss of efficiency.

This wear is apparently due to the rusting of the steel forming a coating which is blown off by the moist steam, and as often renewed. Probably this rusting only takes place when the turbine is standing still. At any rate, the use of bronze buckets, now standard and universal on all Curtis turbines, entirely eliminates it.

The condensing Curtis turbine, size for size, is more economical than the best reciprocating engine. Non-condensing, with steam pressure best suited for it, the Curtis turbine is equal to the average high-grade non-condensing engine when the latter is new, and is superior to the latter in economy after a comparatively short period of service, even under conditions best suited to the reciprocating engine; while from the standpoints of durability, simplicity, ease of operation, attendance, cost of supplies, good governing, and all-around availability, the turbine is the superior.

THE MERCURY ARC RECTIFIER AND ITS USE WITH SMALL DIRECT CURRENT MOTORS

By W. F. Sneed

The mercury arc rectifier has been before the public now for about four years, and during that time it has been adapted to many cases where it was found necessary to rectify alternating current into direct current; in every case it has given satisfaction and has gained for itself quite a favorable reputation, and to-day is about as well known as any other piece of electrical apparatus.

Fig. 1. Monotype Keyboard Operated by Motor Driven Air Compressor

There are two distinct types of mercury arc rectifiers—the high potential or constant current type, and the constant potential variable current type. The former is used for rectifying constant alternating current into constant direct current for operating direct current series arc lamps, while the constant potential type is used for rectifying power from a constant potential alternating source into constant potential direct current. This latter type has been used for charging automobile storage batteries, telephone batteries, signal batteries, ignition batteries, and batteries used for many other purposes. It has also been used for operating direct current multiple arc lamps, induction coils, small power motors, and dental motors.

At the Norwood Press, Norwood, Mass., a mercury arc rectifier was recently installed for operating a number of 230 volt direct current motors. These motors, nine in number, are of rather small capacity, the largest being a ½ h.p. GE motor used for driving a ventilating fan. The other eight are ¼ h.p. GE motors, and are used for driving casting machines of monotype composing sets. The

Fig. 2. Mercury Arc Rectifier and Motor Driven Monotype Machine, Norwood Press, Norwood, Mass.

Fig. 3. Group of Monotype Machines Operated By Motors Driven from Mercury Arc Rectifier

rectifier is operated from a 525 volt 60 cycle alternating current supply source, and delivers direct current to the motors at 230 volts. The motors were originally supplied with direct current at the proper voltage from the Electric Power Company, but as the power system was recently changed from direct to alternating current, it became necessary to make some arrangement for driving the casting machines, either by changing the motors or by furnishing some kind of rectifier, and as the latter was the cheaper, as well as the better arrangement, it was adopted. The rectifier installed at the Norwood Press is the

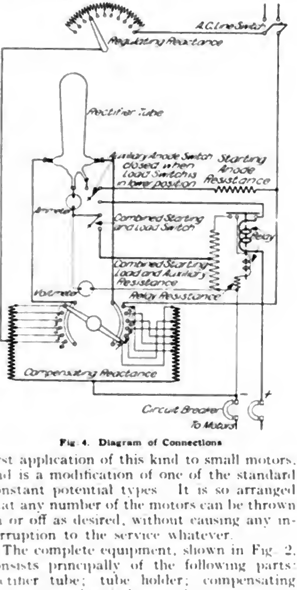


Fig. 4. Diagram of Connections

first application of this kind to small motors, and is a modification of one of the standard constant potential types. It is so arranged that any number of the motors can be thrown on or off as desired, without causing any interruption to the service whatever.

The complete equipment, shown in Fig. 2, consists principally of the following parts: rectifier tube; tube holder; compensating reactance and switch; regulating reactance and switch; starting load resistance, starting anode resistance; auxiliary load resistance, opening circuit relay; alternating current line switch; combined starting and load switch with auxiliary anode switch; panel and panel supports, etc. The connections for the outfit are given in Fig. 4, which shows clearly the function of each part of the apparatus.

The method of operation is simple, and follows in general the method used for the standard rectifier outfit; *i. e.*, close the circuit breaker and the alternating current line switch; hold the starting switch in the lower position and rock the tube gently until the mercury in the cathode makes and breaks contact with the starting anode, causing a flash which will start the tube on the starting load resistance. When the hand is removed from the starting load switch it will fly into the upper or load position, and thus transfer the rectified current to the auxiliary load resistance, and at the same time energize the motor buses. The motors can then be started when desired. The relay is so adjusted that it will open the auxiliary load circuit, as well as the shunt winding of the relay, when the current taken from the rectifier reaches the stable current of the latter, thus reducing the auxiliary losses to a minimum. It was found that the load taken by the fan motor was sufficient in itself to maintain the arc in the tube and to hold the relay open, and as it is necessary to always have the fan running while the casting machines are in operation, the attendant makes it a practice to start the fan motor first and the other motors as they are needed. If for any reason the fan motor and a sufficient number of the other motors are shut down to reduce the current taken from the rectifier to a value near the stability current of the tube, the relay will close the auxiliary load circuit, and the latter will take enough current from the tube to maintain the arc. All the motors may then be shut down for any length of time, and started up again without having to restart the rectifier. Of course, if the motors are to be off for any length of time, such as at noon hour, the rectifier should be shut down and restarted when needed, as it is much cheaper to restart the rectifier than it is to let it run on a dead resistance load for any but short intervals of time.

As the auxiliary load is used only as stated above, *i. e.*, at starting, and in cases of emergency, it is safe to state that the efficiency of this outfit is practically the same as the standard outfit when run at 230 volts direct current, which is about 82 per cent.

AN ELECTRICALLY-DRIVEN PORTABLE ELEVATOR

By J. S. Baker

In a large majority of the factories, warehouses and shipping depots engaged directly or indirectly in handling and storing commodities, loading and unloading steamboats, barges, cars, drays, etc., the work of moving the wares and produce is done mostly by hand.

In the Northwest, the speedy and economical stacking and handling of vast quantities of wheat, the principal product of that section, often assumes a serious aspect; and in the South, owing to the steady increase of wages, the same problem exists with regard to rough rice.

Recognizing the demand for a machine that would accomplish this sort of work at a reduced cost and at a more rapid rate than the existing method, with less work on the part of employees, the Brown Portable Elevator Co., of Portland, Oregon, invented and placed on the market a few years ago a portable elevator that is well adapted for transferring and elevating boxes, barrels, bales and sacks of a weight not exceeding 300 pounds.

The original portable elevator was designed for piling wheat in sacks, to a depth of 25 sacks, each sack containing from 100 to 150 pounds of wheat. The successful performance of this machine induced owners of warehouses and others interested in handling products other than wheat, to make requests for elevators for handling various shapes and weights, with the result that to-day the Brown Portable Elevator is found stacking barrels filled with flour, sugar, feed, bran, etc., bales of hay and fodder, and boxes containing articles of almost every description. Only minor changes were necessary in the original design to render the elevator suitable for handling the different shapes and weights.

In some of the larger grain handling firms on the Pacific Coast, as many as 25 of these elevators are to be found in use.

Fig. 1. Brown Portable Elevator Stacking Rough Rice in Sacks

Fig. 1 shows a Brown Portable Elevator, driven by a General Electric direct current motor, in the process of piling rough rice in sacks weighing 150 pounds. Fig. 2 shows a like machine designed for handling bales of hay, fodder, etc. The latter machine is shown driven by a General Electric alternating current motor.

The machines are usually supplied with 2 or 3 h.p. motors, and have a capacity for piling of about one ton per minute. Only two men are required to operate the elevator

—one to load, the other to pile—the man trucking ordinarily doing the loading. The same work if done by manual labor alone would require six men; it is therefore seen that the machine saves for its owner the wages of four men, which amount to from $6.00 to $10.00 per day, depending upon the scale of wages in different sections of the country.

As may be seen from the illustrations, a wooden platform or frame, on which are mounted the motor, starting apparatus, and driving axle, forms the base of the machine. This base is fitted with roller casters at or near each corner, by virtue of which the machine may be readily moved from place to place. To the front or receiving end of this frame is pivoted the lower end of the conveyor platform, or runway. This runway is supported at its upper end by two grooved wheels which bear on the under rails of the steel lattice work forming the sides of the runway. These wheels are mounted on an axle which is part of a steel rod brace, the lower end of this brace being pivoted to the rear of the base. To the ends of this axle are attached steel cables, which pass back parallel to and on each side of the conveyor platform, and are wound on small winch heads, located on the sides of the runway at a distance from its lower end equal to about one-third the length of the platform. By winding or unwinding these cables, which operation may be done by means of a ratchet device, the height of the delivery platform may be varied at will. Passing around the runway are two endless link belts, and attached to these at regular intervals are the carriers, which are supported on wheels running in steel guides.

The Brown Portable Elevators, as originally built, were fitted with gasoline engines, and even now, in certain sections of the extreme Northwest where electricity is not available, these engines are employed for driving the machines. Where electric power is readily obtainable, however, the makers warmly recommend the electric motor, as much for its reliability of service as for the reduced fire risk ensured by its use. Owners of large warehouses are averse to the fire hazard occasioned by the use of gasoline engines in the vicinity of dry and dusty materials, where the liability of fire, due to the cigarettes and pipes of the workmen, is already great.

Fig. 2. Portable Elevator for Elevating Bales of Hay, Fodder, etc.

The electric motor is the safest, most serviceable and satisfactory source of motive power available at the present day, and is especially desirable for service such as the above.

The leads are flexible and can be readily connected to the power circuits that are almost always to be found in or near large industrial centers.

TYPE DP PORTABLE INSTRUMENTS

By D. P. Burleigh

Type DP direct current portable instruments have been designed by the General Electric Company for laboratory and general testing purposes. They are constructed on the D'Arsonval principle, in which a coil of wire carrying the current to be measured or a shunted portion of it, is wound on a rectangular aluminum frame which is so mounted in jewelled bearings that it is free to rotate in the annular space between the pole pieces of a powerful permanent magnet and a soft iron core.

The entire mechanism is enclosed in a soft iron case which protects the instrument from the influence of magnetic fields, which are always present in the neighborhood of electric currents. The indications are rendered perfectly dead-beat by Foucault currents set up in the aluminum frame upon which the moving coil is wound. Errors due to paralax are eliminated by the use of a mirror situated under the scale.

Fig. 1. Type DP Milli-Voltmeter and Shunt

The magnets are made from the best grade of magnet steel obtainable, and are subjected to various processes of ageing and hardening which insure their permanency. A liberal amount of iron is used in the magnets, providing a strong field and a high torque with a generous air gap, the latter feature reducing to a minimum frictional errors which might otherwise assume large proportions due to dust or other foreign particles lodging between the pole pieces and the coil.

A complete line of DP instruments will be manufactured, consisting of ammeters, voltmeters, milli-ammeters and milli-voltmeters. The ammeters are made self-contained up to and including 30 amperes. For higher ranges a milli-voltmeter with portable shunt will be furnished, the scales being marked directly in amperes.

These shunts are designed to give a uniform drop of 200 milli-volts at full load current. They are made of a metal having practically a zero temperature coefficient, and are free from errors due to thermo-electric currents. Thus, the instruments used with these shunts are practically free from errors due to changes in temperature.

The portable shunts are mounted on a base made of an aluminum alloy combining lightness with durability, and are protected by a perforated sheet metal casing. If desired, shunts can be furnished with two or more capacities combined in one case, thus adapting the instruments for a wide range of current. For use with these shunts, the milli-voltmeter is provided with a scale marked to agree with one of the capacities, and when connected to taps of different rating, the indications of the pointer are multiplied by the proper constant.

When instruments are desired for a class of work which does not require extreme accuracy, the milli-voltmeters may be provided with an extra binding post, so that they can be used in connection with ordinary station shunts, giving full scale deflection when subjected to a drop of 60 milli-volts.

ROTARY CONVERTERS

Part V

By Ernst J. Berg

Effective Resistance and Reactance of the Armature

In connection with the discussion of the heating of the armature conductors it was found that the effective resistance, depending upon the number of phases used, was different from the resistance for direct current. The true copper loss, with non-inductive load, is equal to the square of the direct current multiplied by the effective resistance. This gives the following values for the copper losses in the different rotaries:

Single-phase rotary,	1.414 ×	ohmic resistance
Three- " "	0.55 ×	" "
Four- " "	0.377 ×	" "
Six- " "	0.266 ×	" "

The armature self-induction can be calculated in the same manner as the self-induction of an alternator. For a distributed winding such as is used with rotary converters the self-induction is very small, usually in the neighborhood of 2 per cent., and can for most purposes be neglected.

Control of Voltage of Rotary Converter

Unlike the alternating or direct current generator, where the voltage changes almost in proportion to the change of field excitation, the direct current voltage of the rotary converter is only very slightly affected by a change in field strength, assuming, of course, that the rotary is supplied with alternating current at constant voltage.

The slight change in ratio between the alternating and direct current voltages is due to the internal drop in the armature, which depends upon the effective resistance and the armature self-induction. With a weak field, the rotary takes a lagging alternating current which causes a drop of voltage in the armature, whereby the direct current voltage is made less than it would be if the field excitation were such as to correspond to non-inductive or leading current.

Thus, for a constant direct current voltage, a higher impressed alternating current voltage is required with weak field than with strong field excitation.

A considerable change in the direct current voltage can, however, be obtained by placing a reactance, consisting usually of ordinary reactance coils, in series with the alternating current lines to the rotary. The amount of change in this case also depends upon the excitation, which controls the amount of wattless current.

Voltage Characteristic

The general equation showing the relation between currents and electromotive forces is given below:

e_0 representing the generator voltage;
e the alternating current voltage which corresponds in value to the direct current voltage;
i the alternating energy current;
i_1 the wattless lagging current;
$I = \sqrt{i^2 + i_1^2}$
r the total resistance between the two electromotive forces, e_0 and e;
x the total reactance between the two electromotive forces, e_0 and e;
$z = \sqrt{r^2 + x^2}$

We have then:

$$E_0 = e+(i+ji_1)(r-jx) = e+ir+i_1x-j(ix-i_1r)$$

$$\text{and } e_0 = \sqrt{(e+ir+i_1x)^2 + (ix-i_1r)^2} \qquad (9)$$

This equation enables us to determine what the generator voltage should be for any value of e; that is, for any direct current voltage; or, solving the equation for e, we get:

$$e = -(ir+i_1x) + \sqrt{(ir+i_1x)^2 + e_0^2 - I^2z^2}$$
$$= -(ir+i_1x) + \sqrt{e_0^2 + 2ii_1rx - i^2x^2 - i_1^2r^2}$$

(Equation 10)

To study the range in voltage that can be obtained on the direct current side at no load, without external reactance, we will consider the following practical case.

Let the effective resistance of the armature be 2 per cent. and its reactance 2 per cent. We have then

$e_0 = 1$
$r = 0.02$
$x = 0.02$
$i = 0$ (since no load is considered)

Referring to equation 10 we have:

$$e = -0.02i_1 + \sqrt{1 - .0004\, i_1^2}$$

thus for $i_1 = 1$ we get $e = 0.98$
$i_1 = 0.5$ $e = 0.99$
$i_1 = 0$ $e = 1$
$i_1 = -0.5$ $e = 1.01$
$i_1 = -1$ $e = 1.02$

A range of 4 per cent. can, as a maximum, be expected, and with a reasonable amount of wattless current—say ½ of the full load value—a range of only 2 per cent.

As a second example, find the change in ratio with load; that is, with energy current only.

We then have: $e = -.02i + \sqrt{1-.0004\,i^2}$
at no load $e = 1$
and for $i = 0.5 = \frac{1}{2}$ load $e = 0.99$
$i = 1$ = full load $e = 0.98$

Thus the ratio changes 2 per cent. with load; or, in other words, for constant alternating current voltage the direct current voltage drops 2 per cent. between no load and full load.

The change in voltage will be much greater if considerable reactance exists between the generator and rotary converter. To illustrate this, assume that the rotary is supplied with power over a line of 8 per cent. resistance and 18 per cent. reactance, in which case, due to its own resistance and reactance, the total resistance is 10 per cent. and reactance 20 per cent. Find the change in direct current voltage, with constant generator voltage, with a change of wattless current from the full load lagging to the full load leading value, for the following conditions:

1st. With no load on the direct current side.

2d. With full load on the direct current side.

In the first case the equation becomes:

$$e = -i_1x + \sqrt{e_0^2 - i_1^2r^2} = -.2i_1 + \sqrt{1-.01i_1^2}$$

In the second case:

$$e = -(.1+.2i_1) + \sqrt{1 + .04i_1 - .04 - .01i_1^2}$$

The results obtained are tabulated below:

At No Load	At Full Load
For $i_1 = 1$, $e=0.795$	$i_1 = 1$, $e=0.695$
$= 0.5$, $e=0.898$	$= 0.5$, $e=0.789$
$= 0$, $e=1.000$	$= 0$, $e=0.879$
$= -0.5$, $e=1.098$	$= -0.5$, $e=0.968$
$= -1$, $e=1.195$	$= -1$, $e=1.054$

It is thus seen that in this case the voltage can be varied 20 per cent. either way, and that in general (subject to small error only) the change in voltage is governed by the product of the reactance and the wattless current.

Thus, if it is desired to raise the voltage 10 per cent., it may be done with full load leading current and 10 per cent. reactance, or with one-half of the full load leading current and 20 per cent. reactance.

Too much wattless current is undesirable on account of the increase in armature heating (especially near the taps to the collector rings), and too much reactance on account of the stability of the converter.

As a reasonable reactance, 15 or 20 per cent. may be assumed, which can be made up of the line reactance proper, the reactance of transformers, choke coils, etc.

Phase Characteristic

One of the most interesting and important features of synchronous apparatus, such as synchronous motors and rotary converters, is its ability to take current of various power factors, depending upon the excitation.

There is a certain excitation at which the alternating current is a minimum, and corresponds to the actual load. Increasing the excitation beyond this value causes a leading current to flow; decreasing it, a lagging current.

The magnitude of the wattless current can be obtained directly from the synchronous motor equations by inserting the "effective" resistance and reactance previously discussed.

Since, however, the effect of the resistance is slight, a very close approximation can be obtained by a relatively simple calculation.

Armature Reaction

If there were no magnetic leakage between the field poles, and if, therefore, the whole magnetomotive force of the field was available at the armature surface, the effectiveness of the armature reaction (which is to say the armature magnetomotive force), would be the same as that of the field poles for the same number of ampere turns. As it is, the effectiveness of the field magnetomotive force is from 10 to 20 per cent. less than that of the armature magnetomotive force, and therefore, with a field excitation of F ampere turns, the effective value can be assumed as only $0.85\,F$.

Let F_0 denote the resultant magnetomotive force of field and armature.
F the field excitation.
R the armature reaction, or armature excitation with full load current.

We then have: $F_0 = 0.85\,F + R$.

To illustrate these characteristics, a 300 kw., 600 volt, three-phase rotary converter will be used. This machine has an armature reaction of 3820 ampere turns and a no-load excitation of 6300 ampere turns with 600 volts at the commutator.

Fig. 18 gives not only the calculated, but the actual test results, the former being shown in dotted and the latter in full lines. Since in the test the direct current voltage was kept constant, the equation

$$e_0 = \sqrt{(e + ir + i_1x)^2 + (ix - i_1r)^2}$$

has been used.

The voltage characteristic is calculated on the basis of 2 per cent. resistance and 2 per cent. reactance; and the phase characteristic on the basis of the armature reaction and no-load excitation given above, with a magnetic leakage coefficient of 15 per cent.; in other words the effectiveness of the field magnetization is assumed as 85 per cent. of that of the armature.

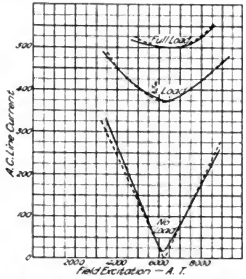


Fig. 18. Phase-Characteristic of 300 Kw. Rotary Converter

Since in the test the phase characteristics are plotted with the actual field excitation as abscissas, and the armature current as ordinates, it is convenient to consider the armature reaction as 15 per cent. more effective than the same number of ampere turns on the field, instead of the field excitation as 85 per cent. of its actual value.

Therefore we may write: $F_0 = F + 1.15\,R$.

In this particular case $F_0 = 6300$, and the full load alternating line current is

$$\frac{300{,}000}{\sqrt{3} \times .615 \times 600} = 470 \text{ amp. at } 100\% \text{ eff.}$$

The armature reaction can be expressed as the product of a constant k (which depends upon the winding), and the wattless alternating current. Thus at full load current:

$$1.15 \times 3820 = 470\,k, \text{ and } k = 9.35.$$

The general equation for any wattless current becomes: $6300 = F + 9.35 i_1$

Thus for F	= 2000	i_1 =	460
	= 4000	=	246
	= 6000	=	32
	= 6300	=	0
	= 8000	=	−182
	= 10000	=	−395

The full load and fractional load phase characteristics are obtained by vectorially combining the wattless current with the energy current. So, for instance, at full load we get

$$\text{energy current } i = \frac{470}{0.94} = 500 \text{ amp.}$$ (assuming 94 per cent. efficiency).

Thus for

F = 2000	total	cur.	$I = \sqrt{i^2 + i_1^2}$	= 680 amp.
4000	"	"	"	= 557 "
6000	"	"	"	= 500 "
6300	"	"	"	= 500 "
8000	"	"	"	= 532 "
10000	"	"	"	= 640 "

Fig. 18 shows the close agreement between the calculated and observed value.

(To be continued)

A SIMPLE AND EFFECTIVE LAMP BRACKET

By G. H. Stickney

The accompanying illustration (Fig. 1) shows a convenient form of lamp bracket for suspending lamps from walls or poles. It is common practice to suspend arc lamps on brackets so that they hang four or five feet from the bracket support, but with this arrangement it is often quite difficult to reach the lamps for trimming. The special feature of this bracket is that it permits the lamp to be swung up close to the support, where it can easily be reached from a ladder leaning against the latter. When hung from a wall it is sometimes convenient to trim a lamp from a window; and it is likewise often desirable to trim a lamp from a pole. The construction of the bracket and its operation are so convenient that the device is sure to appeal to a practical man.

The bracket consists merely of a piece of gas pipe bent and mounted as shown in the sketch. The lamp is suspended by means of a pulley arranged to run on the pipe. When the lamp is in its regular position, the pulley rests in a shallow loop formed in the pipe, this being sufficient to keep the pulley firmly in place. A stop can be provided to prevent the lamp from striking the support.

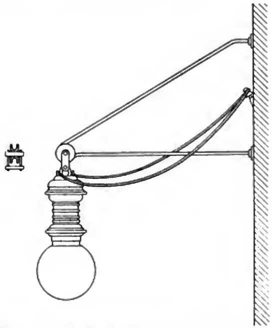


Fig. 1. Arc Lamp Bracket in Regular Use by The Detroit Edison Illuminating Co.

From the above, it will be seen that the device can readily be made in any pipe shop without special tools.

It is in regular use by the Detroit Edison Illuminating Company, having been described to the writer by Mr. W. B. Thompson of that Company.

NINTH MEETING PITTSFIELD SECTION A. I. E. E.

On March 27, the Pittsfield Section of the A. I. E. E. held its first annual banquet. One hundred and nine members of the local section were present and enjoyed a very pleasant evening. An excellent dinner was served, after which Mr. Joseph Insull called upon Mr. R. W. Pope, the speaker for the evening, who responded in his usual happy manner, mingling many laughable stories and anecdotes with his reminiscences of the growth of the Institute and his connection with the work.

Mr. Pope began his electrical career in Berkshire County, and was quite at home in a Pittsfield audience. He described a number of the advantages to be gained by joining the Institute, and stated that no electrical engineer could afford not to join.

Mr. C. C. Chesney told of pioneer local developments in alternating-current generators and transformer design dating back to 1883—one of these generators having been in regular service ever since.

Mr. W. S. Moody spoke of the electrical engineer as a business man, and told several stories illustrating his point that the successful engineer of the day is generally a shrewd man in business matters.

Mr. W. S. Andrews of Schenectady described some of his varied experiences with Edison at Menlo Park in the early days of electric lighting. His witty remarks elicited much laughter and applause.

Mr. H. W. Tobey made a few remarks urging the local members to join the National body, and to take active part in the meetings.

In addition to the speeches, entertainment was furnished by Mr. A. V. Thompson of Schenectady, and Mr. Boland of Pittsfield, who gave several songs and responded willingly to vigorous encores.

BOOK REVIEW

STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS

McGraw Publishing Co. 1300 Pages Price $4.00

This is by far the best book of the kind that has yet appeared, the only one comparable to it being Hütte's Ingeniers Taschenbuch.

The subject matter is divided into twenty sections, each section being treated as a separate unit, and in many cases these have been specially written by recognized authorities. The sections are further subdivided into numbered articles.

A casual examination of the ordinary handbook is apt to create the impression that it must contain all data that can ever be required; but when, subsequently, the engineer has occasion to consult it for some specific information, he finds, too often, that the particular item wanted has been omitted, or if not omitted, is next to impossible to locate.

The new handbook, however, is particularly satisfactory in this respect. The information is very complete, and the division by sections and articles, together with the excellent typographical arrangement, makes it possible to locate quickly any desired fact. An exceptionally full index still further facilitates rapid reference. The index references are given by section and article number instead of by page—a system which is in a measure less convenient but which lends itself well to frequent revision, as does the sectional arrangement of the book as a whole.

The diagrams and curves seem to be the weakest feature of the book; the former are in many cases, unworkmanlike and crude, while the latter would have been greatly improved had they been shown on a larger scale.

On the whole the book is one that is likely to become its owner's *vade-mecum* and to find a place on his desk rather than on his book shelves. It is certainly well worth the price that is asked for it.

TWO DOLLARS A YEAR TWENTY CENTS A COPY

GENERAL ELECTRIC REVIEW

VOL. X, No. 7
PUBLISHED MONTHLY BY
GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU
SCHENECTADY, NEW YORK
JUNE, 1908

LIGHTNING FLASHES

(See Page 299)

Mill Motors

For Direct or Alternating Current

From 25 to 150 H.P., 110, 220 and 500 Volts D.C., 220, 440, 550 Volts A.C.

Always ready to start
Always ready for heavy overloads
Always ready for duty—however severe

Where absolute certainty of service is desired these motors are invaluable

They drive from either end of the shaft and run in either direction, in any place, under any conditions, at any time

Motors supplied either with or without axle bearings for back gearing. Gears and pinions furnished too if desired

Simple in construction

Four big rough bolts hold motor frame together
Four big rough bolts hold motor to foundation

Every part easily removed and all parts interchangeable

1744

GENERAL ELECTRIC REVIEW

VOL. X, No. 7 | JUNE, 1908

CONTENTS

Trial of Curtis Turbine Driven Pumps on New York City Fire Boats

(See page 339)

GENERAL ELECTRIC REVIEW

LIGHTNING PHENOMENA AND LIGHTNING ARRESTERS

By E. E. F. Creighton

Power and Mining Department, General Electric Company

It is the object of this paper to give a general review of the more important results of the study of lightning phenomena that have been obtained during the past year; to describe the usual lightning troubles that occur on most transmission systems, and to show briefly how lightning arrester design has been made to meet the requirements of protection. In a paper written for the annual meeting of the A.I.E.E., June 1908 the forms of apparatus used for studying lightning in Colorado during last summer are described. It is not the object of this paper to show how these measurements were made, but simply to give a review of the results obtained and refer the engineer who is further interested to the more detailed description in the institute paper.

Since the Colorado tests show many of the conditions which have to be met, they will be reviewed first. The five principal factors studied are:

1st. Duration of the surge of lightning.
2d. Potential values of the lightning.
3d. Maximum current discharge rate.
4th. Natural frequency of the lightning.
5th. Quantity of electricity in the lightning stroke.

The Duration of Lightning

The duration of lightning on the transmission line was measured by means of a spark gap in front of a rapidly revolving photographic film. Out of three dozen discharges, the usual duration of a single stroke was in the neighborhood of one one-thousandth of a second. The longest single stroke of induced cloud lightning recorded was 0.04 second. The principal factors which control the duration of discharge of induced cloud lightning are as follows:

(a) The actual duration of the discharge of the cloud.

(b) The nearness of the cloud to the line.

(c) The initial induced potential on the line.

(d) The earth resistance between the point of cloud discharge and the point of the discharge through the arrester. In other words, the value of resistance which controls the logarithmetic decrement of potential of the discharge.

(e) The value of the gap setting of the arrester or measuring apparatus.

(a) The actual duration of the usual stroke of cloud lightning we know from many observations is comparatively short. A fairly authentic record of one stroke of the order of a half second has been made. Such a length of duration, however, is rare, and careful measurements seem to indicate that such a duration is only the effect of multiple strokes, or successive discharges from the clouds. So long as the oscillations take place between the cloud and the earth, the potential will be impressed upon the transmission line in the form of forced oscillations. If the stroke of lightning is between clouds in a horizontal direction parallel to the line, then the induced potential on the line must necessarily die away with the cloud lightning discharge. This is a case of electro-magnetic induction. If, on the other hand, there is a quantity of static electricity induced on the line by the cloud and freed when the cloud discharges, it is possible for this freed charge to oscillate after the surges from the cloud have entirely disappeared. The duration of the line discharge will then depend upon the initial voltage and the damping in the path of the surge of lightning current.

(*b*) and (*c*) Factor b may in reality be considered under factor c, in that the voltage of the oscillation will depend upon the nearness and the intensity of the discharge. It is evident that a cloud of a given dimension will induce a higher voltage if it is near the line than if is it far away. With the same damping of the surge on the line the discharge at the higher potential will have a longer duration. Storm clouds differ enormously in size and in capacity. A single cloud was observed which was a small patch in a clear sky. This cloud discharged to earth with a stroke of small volume. Larger clouds were observed from which heavy strokes took place, which in turn caused other clouds to discharge to them, giving multiple strokes to earth. It is evident from this that the quantity of electricity induced on the line will vary greatly with the form of the cloud, as well as the distance from the line.

(*d*) If the charge of lightning is freed at some distance from the station, this charge on the line has a complimentary charge on the surface of the earth which is held by static attraction. As this charge on the line moves along the line toward the station, it drags its complimentary charge along the ground through the comparatively high resistance of the surface of the earth. How much the charge on the earth will penetrate as it moves along under the line is an unknown factor, but it is evident that this resistance is far greater than the resistance usually found in the earth connection of the lightning arrester. The subject will be further treated under "Potential." This surface resistance of the earth is the factor damping the discharge on its way to the arrester. On the other hand, if the cloud should happen to be directly over the station or lightning arrester, this damping factor will evidently be very much less, due to the fact that the resistance of the surface of the earth is reduced to a proportionally less value.

(*e*) In the measurements made on the line the gap setting was about 10,000 volts. It is evident that when the potential on the line reduces to 10,000 volts, the line will cease to discharge across the gap, whereas if the gap had been short circuited, the surge would continue until zero potential was reached. Assuming the damping factor constant, the duration of the discharge from the line is determined by the ratio of the initial to the final potential.

So far, we have considered the duration of a single stroke. It is found, however, from measurement that the usual conditions in a large storm produce many multiple strokes. As many as eight successive strokes were recorded in an interval of less than a second. There were several cases where four strokes were distributed over one second. So far as the lightning arrester is concerned these multiple strokes give the effect of long duration of discharge. In the discharge of the multigap arrester, a successive stroke which follows at any time later than half cycle and less than the time necessary to cool the cylinders, will have somewhat the same effect as a discharge which continues over the length of time between the successive strokes. This factor of multiple strokes must be considered in the design of arresters and a corresponding endurance obtained. There seems to be no doubt that an occasional failure of an arrester has been due to some severe condition of successive strokes. In certain classes of storms these successive strokes take place slowly enough to be observed visually. They seem to be due to the readjustment of potential between clouds. For example, a cloud discharges and releases the potential strain in its neighborhood. The static electricity which, up to this time, had been distributed over the face of the adjacent cloud next to the earth or other oppositely charged clouds, now is drawn through the high internal resistance of the cloud toward the one which has just discharged and has been reduced to earth potential. It seems that this readjustment in the non-discharged clouds requires an appreciable time. Finally the static strains between this cloud and the one discharged is sufficient to cause a cloud to cloud discharge, which readjusts temporarily the potential in this locality but causes another stroke to earth. This process is repeated indefinitely until all the clouds in the neighborhood have readjusted their potentials with the original discharging cloud.

There is a third consideration of duration of lightning which comes under the head of continual lightning. Continual lightning usually occurs from an internal source. The usual cause is a grounded phase through an arc. The duration of this kind of discharge depends entirely upon the circumstances. So long as the arc to ground takes place there will be lightning more or less severe according to the local conditions, and this lightning will continue until the trouble is removed from the line. During the measurements last summer aluminum lightning arresters were in operation continuously for periods ranging from forty seconds to a half hour.

Potential Values of the Lightning

The maximum potential value that a lightning charge can have on the line will result from a direct stroke. The usual effects of a *heavy* direct stroke are well-known. The lightning jumps over the insulators and down the poles to the earth. If the stroke is not heavy enough to jump over the insulators to the earth, then it will spread over the line and the lightning arrester has an opportunity to carry the discharge to earth. These induced potentials may have all values ranging from the spark voltage from line to ground through the insulation and poles, down to insignificant values. The observations of last summer show conclusively that the potential on the line nearest to the clouds is the peak value, and when the charge is freed it spreads gradually over the line, giving at every other point a lower potential. If there were no resistance in the path of the complimentary charge on the surface of the earth, this high peak of potential would travel undiminished in a wave along the line to the end. If the storm occurs over the station the lightning arrester in the station must take care of this excessive peak potential. The difference in the requirements to discharge under these two conditions of nearness or distance of the lightning storm really comes under the consideration of the maximum current discharge rate (the 3d heading).

From the measurements of quantity of electricity, estimates were made of the maximum potential which might occur for a given stroke. A value was estimated at 600,000 volts. It occurred on a wooden pole line insulated for 50,000 volts. The question whether this high potential will jump over the insulators to ground is not solved by impressing a test voltage of 600,000 on the line, because the conditions would be entirely different. The potential from a lightning stroke is due to the quantity of freed electricity, which initially may not cover over a mile or so of line. This quantity of electricity is connected directly with the total capacity of the line and its natural tendency is to spread out over the line. If the inductance of a straight line is sufficient to hold the potential at the insulators at this spark value, for a time equal to the dielectric-spark-lag, then the insulator will spark over, otherwise it will not. In other words the danger of sparking at the insulators is a matter of the relative time constant of the line to the dielectric-spark-lag of the insulator.

In connection with this subject of the arcing at the insulators, a digression in this discussion is made to describe some tests which gave concrete figures on the value of a wooden cross-arm relative to a metal cross-arm as an extra protection against lightning. A wooden cross-arm was arranged as shown in Fig. 1: two porcelain tubes held wires 1.7 in. above the surface of the wood and ten inches apart. On the upper surface of the wood either tin-foil or a wet towel was placed in imitation of line conditions. The first test on this cross-arm was made on a 60 cycle circuit with a needle gap in parallel with the cross-arm.

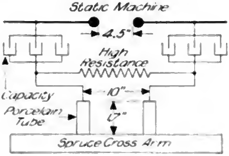


Fig. 1. Connections for Disruptive Tests of Insulators on Wooden or Metal Cross-Arm

The spark voltage was the same whether the wet cloth or the metal was used. By transformation the voltage was 46,900, and by needle gap it was 3.5 ins., (52,000 volts by interpolation from the curve). This high indicated potential by the needle gap is due to local oscillations set up by corona discharges over the porcelain tube. The disruptive discharge circuit was then made up as shown in Fig. 1. The natural frequency of discharge was 2.25 million cycles per second. The applied potential was a 4.5 in. gap between spheres 1.25 in. in diameter. When the cloth was used very wet the equivalent-needle-gap was 5.6 in. (68,000 volts). When the metal plate was used between the porcelains, the equivalent-needle-gap was only 2.5 in. (45,000 volts). Summarizing this we have the following:

VOLTAGE

	60 Cy.	E.N.G.	2.25 Million Cy.	E.N.G.
Metal cross-arm	46,900 52,000	3.5″	42,000	2.5″
Wet wood arm	46,900 52,000	3.5″	68,000	5.6″

It will be noticed that the spark potential of the metal cross-arm is actually less at high frequency than it is at normal line frequency. This phenomenon is due to the double gap between line and line and no connection of the metal plate to earth. The metal cross-arm has a static capacity which takes an appreciable charging current across the gaps. The action is similar to the action in the multigap arrester. In regard to the interpretation of the test it is well to note that 5.6 in. was the limiting potential at which the needles would spark over, the actual conditions would have been even more favorable to the wet wood if the applied potential had been greater. Taking it as it was, the wet wood cross-arm was 160 per cent better than the metal as a protection against high frequency lightning, and the metal cross-arm was only 80 to 90 per cent. as good for lightning as it was for dynamic potential. If the wooden cross-arm were not saturated with water, there would be of course greater protection than shown by these experiments.

Although these figures will no doubt be somewhat modified by changing the relative conditions of the test, it is safe to conclude that the wooden cross-arm is always to be recommended, and would be a most desirable and economical feature even on iron towers. It is usually cheaper to add insulation with wooden cross-arms, than it is to obtain it with added porcelain in the insulator. These tests have a bearing on the use of insulator horn-gap protectors that will be apparent to the engineer.

Fig. 2. Record Taken from a Revolving Film Duration Apparatus

Impressions having the same radius are due to multiple strokes occurring in a fraction of a second. The duration of each stroke can be calculated from the velocity of rotation

Maximum Current Discharge Rate

In this discussion the subject of direct strokes from a cloud will not be considered. The rate of discharge of an induced current on the line is nearly always definitely fixed. Since it is the maximum value of the current passing through the resistance of the lightning arrester causing the menace, the following equation is given for the maximum rate, on the assumption that the resistance is negligible.

I max. $= v\sqrt{\frac{C}{L}}$, where C is either the capacity per unit length of the line, or the total capacity of a condenser; and L is correspondingly the inductance of a unit length of line, or the concentrated inductance in a coil. In the high frequency circuit in the laboratory the maximum current is 0.03 ampere per volt impressed; consequently, at the value of 100,000 volts impressed, the maximum possible rate of discharge is 3000 amperes. The value of current is actually somewhat less than this on account of the resistance of the circuit and the spark. On transmission lines the maximum possible current of a discharge coming from a distance out on the line is of the order of 0.002 ampere per volt impressed. Therefore, in order to produce a current of ten amperes the impressed potential would have to be 5000 volts. Ten amperes is the current limitation at double normal voltage of some of the old types of arresters. In order to get a current discharge of 1000 amperes, the applied potential must be at least 500,000 volts. This is the value of current discharge of the aluminum arrester at double normal voltage.

If, however, the lightning cloud is over the station or arrester, then the maximum possible rate of discharge may be somewhat greater than the value given above, on account of the fact that the average inductance of the line wire in the path of the discharge is less than in the previous case considered. Furthermore, it has already been noted in the paragraph on potentials that the maximum potential of the lightning is invariably greatest under the discharging cloud; consequently the rate of discharge of the arrester must be greater on account of the higher induced potential.

The Natural Frequency of Lightning

The frequency of lightning may be considered under four heads.

1st. The frequency of recurrence of the lightning stroke. For example, lightning strokes often come into a station during a storm at an average rate ranging from two per minute to one in five minutes. Since lightning arresters are, without question, designed to take lightning discharges as frequently as given, this condition will not receive further attention here.

2d. Each of the flashes that appear to the eye as a single flash is often several distinct strokes distributed over a fraction of a second (Fig. 2). The bearing that these multiple strokes have on lightning arrester design has already been discussed under the heading of duration.

3d. Each individual stroke may be analyzed into frequencies of the order of the natural frequency of the line. This was done in the Colorado tests by means of a rapidly revolving film in front of a spark gap, as described under the heading of duration. Fig. 3 shows a record from one of these machines. The impression on the photographic film is in the form of a broken line. The parts of this broken line represent the half cycles of discharge of lightning over the line through a single gap to ground. This line was not connected to generators. The accuracy of measurement is not high, so the frequencies recorded are divided into seven groups. One stroke at 840 cycles per second, eight strokes at about 1400, six strokes at about 2000, two strokes at about 2500, twenty strokes at about 3000, and one stroke at about 4000

Fig. 3. Enlarged View of One Discharge Taken from the Record Shown in Fig. 2

Since the spark is extinguished every half cycle, no impression is made on the film at this time; this makes the record of discharge a broken line cycles per second. The natural frequency of the line was in the neighborhood of 1800 cycles. All of these records were taken from discharges that were generated by clouds located five miles or more from the station.

4th. At the point underneath the cloud, it is very probable that a frequency as high as one million cycles per second was impressed on the line, due to the induction from the cloud. The potential of such a high frequency would be greatly diminished as it travels along the line. However, it has been mathematically demonstrated in the study of telephonic transmissions, that high frequencies travel along the line faster than low frequencies. Therefore, such a high frequency would reach the lightning arrester before the main body of the charge and would consequently be effective in starting the discharge over the multigap arrester.

In order to prove out that this high frequency exists on the line, a special form of high frequency meter was designed, working on the principle of interference of traveling waves, or in other words, stationary waves. This instrument had a number of coils resembling the pipes of a church organ, each one responding to its individual frequency and over tones. Due to the initial experimental difficulties with this apparatus and the natural condition of discharge on a long line, only two of the many records taken were of value. Both of these records show frequencies of the order of a million cycles per second.

Quantity of Electricity in the Lightning Stroke

By means of fuses and the duration meter, the quantity of electricity to blow a fuse can be found. Its value $Q=\sqrt{\frac{Jt}{R}}$, where J is equal to the energy in joules necessary to raise one centimeter length of fuse metal to its melting point, t is the duration of discharge, and R is the resistance in ohms per centimeter length of fuse metal. The joules of energy necessary to melt the fuse can be found by calculation of the metal used, or by actual calibration by the use of an oscillograph. The average effective quantity of lightning (q) passing through a fuse is equal to Q divided by the number of oscillations shown by the revolving film. If the number of oscillations are few, this calculated value is approximately equal to the original quantity on the line freed by the cloud discharge.

Using the data taken from a number of tests, and making approximate calculations, it is found that the ordinary induced charge of lightning may initially have surprisingly high voltage. In one calculation of a fairly heavy discharge, the estimated initial voltage was of the order of a half-million volts.

Summarizing some of the essential parts of the foregoing discussion we have: that the strain on the lightning arrester will depend on the size of the storm cloud, the nearness of the cloud to the line, the distance of the storm away from the arrester, the resistance of the surface of the earth, the condition of the multiple stroke and the time elapsing between them, and the condition of continual lightning. The effects of these factors may all be grouped under three heads:

1st. The spark potential of the arrester.

2d. The factors which relate to the rate of discharge of the arrester.

3d. The factors which relate to the duration of the discharge of the arrester.

1st. The arrester must be capable of sparking over at a voltage which is within the safe value of the insulation.

2d. It must have a resistance low enough to discharge the maximum rate of current that could flow to that point.

3d. It should have a duration sufficient to discharge so long as the potential is dangerously high.

For many years the presence of continual lightning on a transmission line was not fully understood. Lightning arresters were designed *par force* for transitory lightning. The multigap arrester is distinctly a transitory lightning arrester. It can not be expected to carry the discharges which occur on a system from continual lightning. With the graded shunt resistance on the multigap arrester, light discharges may be taken through the high resistance for an appreciable time reckoned in seconds, but through the low resistance the amount of energy dissipated is large, and consequently the duration of the discharge must be correspondingly small. The question may pertinently be asked. "Why not design the multigap arrester to carry continual lightning?" The multigap arrester is intrinsically not suited for such a condition. While it might be possible to design the arrester with sufficient metal in the cylinders which form the gaps, and sufficient radiating surface of the resistance to carry the current for a considerable time.

it would make the cost of the arrester prohibitively high. The arc extinguishing quality of the multigap arrester depends, to a considerable extent, on keeping the cylinders cool and limiting the amount of molten metal in the gaps where the arcs take place. It is evident that no arc can play across the gap for any considerable time without producing a disadvantageous amount of molten zinc. Furthermore, the cost of the resistance alone designed to radiate the necesssarily large amount of dynamic energy would make the arrester too expensive. Attention was turned to the type of arrester which was intrinsically suited to discharge continual lightning, and has resulted in the development of the aluminum arrester.

Before describing the aluminum arrester, a partial review will be made of the usual demand of protection on a system in a territory where lightning is fairly frequent. Since by the law of chance only a small percentage of the lightning storms will pass directly over the station, it is safe to assume that the lightning arrester will usually be called on to discharge only about 0.002 ampere per volt of lightning potential. Incidentally, this may explain why the resistance type of arresters have given such good results. Since the peak of lightning potential occurs immediately under the cloud, the arrester at one station cannot be expected to give protection to any other station at some distance away. It is necessary to install an arrester at every point where apparatus is to be protected.

Occasionally, through a broken insulator, a transformer bushing, or a switch bushing, one phase of a non-grounded neutral system will become grounded through an arc. This arcing ground will send a series of surges throughout the entire system. It is necessary to have a lightning arrester on the circuit which will discharge the abnormal voltage for a long enough time to permit the operator to locate and isolate the trouble. It is estimated that, in general, a half hour should be sufficient to do this. If the trouble occurs at some sub-station the information can usually be received immediately. If there should be an auxiliary transmission line, the damaged line can be switched out within a half hour. If, however, the trouble should occur on a single transmission line, a half hour will usually allow a patrolman to travel out toward the trouble. In such a case it is desirable to have the duration of the arrester longer than a half hour to give the patrolman more time. These factors have been kept steadily in view in the design of the aluminum arrester. Since the conditions to be met are so variable, this fact has resulted in the design of several types of aluminum arresters. In all of these arresters, the aluminum cell is the basis of design, and consequently they have certain common characteristics. The characteristics of the aluminum cell will be described, and subsequently some of the variations in the design of the arrester to meet the demand of practice.

The useful characteristic of the aluminum cell is its critical voltage. This critical voltage depends upon the formation of a hydroxide film of aluminum on the surface of the aluminum plates. The plates are put through chemical and electro-chemical treatments until this film is formed. After this, the plate, dipped in a suitable electrolyte, has a characteristic of taking exceedingly low currents up to its critical voltage, but above this critical voltage the current is limited only by the internal resistance of the elctrolyte. The closest analogy to this action is found in the well-known safety valve of the steam boiler, in which the steam is held back until the pressure rises to a given value, and is then released for all pressures above. On the aluminum plate there are myriads of these safety valves, so that if the electric pressure rises above the critical voltage, the discharge takes place equally over the entire surface. This phenomenon is visible to the naked eye. It is important to distinguish between the valve action of this hydroxide film and the failure of any dielectric substance like mica for example, which resembles somewhat the hydroxide film in chemical composition. If a thin sheet of mica has impressed upon it a voltage just sufficient to puncture it, say 20,000 volts, the failure will take place at a single point and the pressure will suddenly drop from 20,000 volts down to 20 or 30, which is the voltage necessary to maintain the arc between electrodes. On the other hand, if the pressure is gradually raised on the film of the aluminum cell, there is no single puncture point, and no decrease in potential when the film allows a heavy dynamic current to flow through.

The volt-ampere-characteristic curve of the aluminum cell will vary somewhat according to whether direct currents or alternating currents are used. If direct current is used there will be no current passing through the circuit except the tiny leakage current through the film; whereas, if alternating current is used the aluminum cell acts as a fairly good condenser, and there is not only the leakage through the film, but also a heavy capacity current flowing into the cell. The phase of this current, then, is nearly 90° ahead of the potential and represents a very low energy factor. A volt-ampere-characteristic-curve of the aluminum cell on direct current is shown in Fig. 4. The permanent critical voltage is shown as 420. This voltage will vary considerably with the nature of the electrolyte. A curve is shown of the current discharging above the critical voltage in Fig. 5. The data for this curve were taken with an oscillograph. Since the arrester will discharge high dynamic current for a brief interval, there is no doubt that it will take lightning discharges which are of less duration. In all of the designs, the number of cells for the circuit are chosen so that the average dynamic voltage per cell is always less than 420 volts, the permanent critical voltage.

Another characteristic of the aluminum cell is the dissolution of a part of this film when the plates stand in the electrolyte and the cell is disconnected from the circuit. The film is composed of two parts; one part is hard and insoluble and apparently acts as a skeleton to hold the more soluble part. The facts connected with the action of the cell seems to indicate that the soluble part of the film is composed of gases in the liquid form. The dissolution of the film varies greatly with the nature of the electrolyte. When a cell, which has stood for some time disconnected, is reconnected to the circuit, there is a momentary rush of current which replaces the part of the film which is dissolved. In suitable electrolytes the duration of this current rush will be less than .01 of a second, even after the cell has stood over a week. This current rush will have increasing values as the interval of rest of the cell is made greater. Dozens of electrolytes have been studied, and there has been no electrolyte found which does not show this dissolution effect to a greater or less extent. The disadvantageous conditions produced by these current rushes are usually negligible. If the cell has stood disconnected from the circuit for several weeks, there is a possibility that the initial current rush will trip an instantaneous relay of a circuit breaker. This current rush also raises the temperature of the cell.

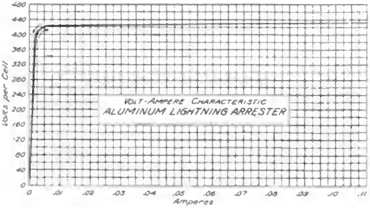


Fig. 4. Volt-Ampere Characteristic Curve of a 600 Volt D.C. Aluminum Arrester Drawn to a Large Scale

When a cell is connected permanently to the circuit, there are two conditions, which may be distinguished as *temporary critical voltage*, and *permanent critical voltage*. For example, if the cell has 300 volts, applied to it constantly, and the voltage is suddenly increased to, say 325 volts, there will be momentarily a considerable current rush, until the film thickness has been increased to withstand the extra 25 volts. This will take place at all voltages up to the permanent critical voltage which is about 420 volts. Above 420 volts the film cannot thicken appreciably. If the voltage is again reduced to 300, this excess thickness of film will be gradually re-dissolved. If the voltage is varying periodically between two values, each of which is less than the permanent critical value, the temporary critical voltage will be the upper value. This is a valuable characteristic of the cell. It provides a means of discharging abnormal surges the instant that the pressure rises above the normal impressed value. In comparison, other arresters usually require 100 per cent. or more rise in potential before the current begins to discharge.

Life of the Arrester

If the arrester is connected to the circuit continually there is a constant wear on the surface of the aluminum, and it is necessary to replace the aluminum plates from time to time. If, however, a gap is used in series, and the arrester brought into operation only at times of high abnormal voltages, there is no appreciable wear on the plates.

To meet the usual conditions of transmission circuits, three main types of aluminum arresters have been designed. Each type will give different results by slight mechanical changes in its installation. The variations will be pointed out in the consideration of each. For the protection of over-head constant potential alternating current systems of all voltages from 2300 to 110,000 volts, the gap aluminum arresters have been designed. This arrester consists of inverted concentric cones slightly separated and partially filled with a suitable electrolyte. This stack of cones is then immersed in oil contained in an iron tank; the lowest cone is connected to the iron tank, and the upper cone is connected through a horn gap to one phase of the transmission line (Fig. 6). The connections of this lightning arrester for a delta circuit are shown in Fig. 7.

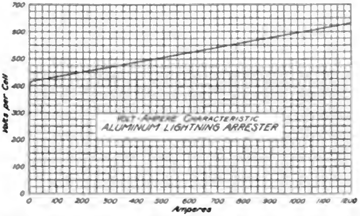


Fig. 5. Volt-Ampere Characteristic Curve of a 600 Volt D.C. Aluminum Arrester Drawn to a Small Scale, Showing the Rate of Discharge above the Critical Film Voltage

Choice of Design

The aluminum arrester, according to the design, will carry the current continuously for either a half hour or more, or six months or more. The financial investment here enters to determine which design shall be used. An aluminum arrester which is designed to carry the current continuously must be large to radiate the internal heat, and consequently relatively expensive. In certain locations it is of questionable value to install a costly arrester requiring some expense for the up-keep, in order to take care of discharges that probably occur not more frequently than once or twice during a year. It is better economy in this case to design an arrester which is connected to the line through a single series gap and comes into operation only at the time it is needed. In this case it need have only sufficient heat storage capacity to carry the discharge until the trouble can be removed.

The two variable factors which can be adjusted by an operator to meet the local conditions are first, the gap setting, and second, the nature and quantity of the electrolyte. This arrester is designed primarily to discharge continual lightning for one-half hour or more. The total duration of discharge will depend on the initial temperature of the arrester, since the limitation is set by the final temperature. To obtain these conditions, it happens that the electrolyte chosen has an appreciable dissolving effect on the film, and therefore it is recommended that the arrester be connected to the circuit for a moment from time to time. Since, when continual lightning comes on to the circuit, it is advisable to start the arrester at a low temperature, it is well to keep the film in perfect condition so as to avoid the unnecessary heating of it due to a large initial current rush; therefore it seems advisable in most cases to make the test once each day. Incidentally, this has the advantage of forming a fixed habit, and of making the operator accustomed to the discharge condition of the arrester. Since the aluminum arrester is the only one designed for continual lightning, its series horn gaps should be set at values less then the spark value of the other arrester on the circuit designed for transitory lightning, so that it will protect the transitory arresters from destruction. For this kind of a disturbance, then, the aluminum arrester becomes a protector for the other arresters, and completes the protection of the system. How many aluminum arresters are necessary to do this depends on the size of the system, the voltage, the tendency to resonance on the circuit, and the severity of the arcing ground. The minimum number may be one.

Fig. 6. One Phase Leg of a Gap Aluminum Arrester, Showing the Form of the Cones, Method of Holding them Apart, and the Position of the Electrolyte, Oil, and Tank

As a further consideration, since the time of discharge of the arrester is limited, it is necessary that an attendant shall be advised as soon as the arrester commences to discharge, so that he can take precaution to remove the trouble. Where the arrester is installed in plain view and in hearing of the attendant, its operation will make itself known to him immediately; if, however, the arrester is installed out doors or in an adjacent room, it is essential to use a lightning alarm in connection with the arrester. This lightning alarm consists essentially of two parts; an extra aluminum cell installed in the arrester circuit next to the earth, from which leads are run to an alarm bell, placed at any convenient place in the office or station.

The endurance of arresters to continuous discharge is somewhat indefinite since, as already stated, it depends on the initial condition of the arrester and the initial room temperature. Some idea of this endurance may be formed from life tests that were made on a 13,000 volt cone type arrester. The gap on this arrester was set below the spark potential of the circuit, and the arrester allowed to discharge in relays of *two* and *three* hours twice a day until the total length of discharge was 80 hours. At the end of that time the arrester was still operating normally. The cones were disassembled, and were all found to be somewhat worn by the passage of the current, but still in useable condition. It is estimated, however, that it would require many years to sum up a total of 80 hours of continual lightning on any circuit under normal operating condition. There is one feature of these tests that the operators should be acquainted with, namely: that after the cell has operated for a long time and heated up, the dissolution effect of the electrolyte on the film is abnormally great; so that subsequently, when the arrester has cooled down and is reconnected to the circuit for its diurnal test, there will be an abnormal current rush similar to that which would take place if the arrester had been left off the circuit for many days. This abnormal current rush can be entirely avoided, if the operator should feel it necessary, by taking the precaution of placing a resistance in series with the cells during the few moments of the first subsequent test. This brings up the question of what will take place if the arrester is left continuously on the circuit. It is recommended that the arrester may be allowed to discharge for half an hour without causing any serious trouble. If the operator should care to run the risk of allowing his arrester to discharge for a longer time, he may do so under certain circumstances; the action of the arrester will then be as follows:

The continuous passage of the current will continue to heat the electrolyte and oil, but the current will increase only slightly until a certain critical temperature is reached; then the current will increase quickly from about 1 ampere, normal discharge rate to the destructive value. If a fuse is placed in series, of a size large enough to take all known forms of induced lightning and recurrent surges, but small enough to disconnect the lightning arrester from the circuit in time to prevent permanent damage to the arrester, an interruption of service from a failure will be avoided, and the arrester may be put into serviceable condition again after it cools off. In order to overcome the natural prejudice against a fuse, it should be noted that the use of the fuse with this lightning arrester is under different conditions from its use with any type of resistance arrester.

In a resistance type of arrester of any value, there must be possible a large discharge rate of dynamic current, whereas in the aluminum arrester the dynamic current is limited to a very small value by the film, and it is only the lightning current of brief duration which assumes large values. A fuse will take high current for a brief interval without melting. It is then possible, at a slight risk, to operate the gap aluminum lightning arrester up to its limit of endurance without destruction of the arrester. While this recommendation cannot go out to operators in general, it may be used if necessary under conditions of peak load, where continuity of service is of great value.

The discharge rate of this arrester at double normal voltage is of the order of 1000 ampere, and the leakage current at normal voltage is less than one ampere.

Line or Unattended Arresters

When an aluminum arrester is located either on the line, or in the station where there are no attendants, it is evidently undesirable to have the arresters discharge continual lightning unbeknown to any one. If the arrester does this it will discharge until it is disconnected from the circuit by its series fuse. The first condition, then, in the installation of the arresters in this location is to increase the length of the horn gap to such a value that if continual surges occur on the line it will not discharge except for very abnormal peak values, and the lesser surges will be carried to the station arresters, where the discharge will be observed and precautions taken to remove the trouble. Since the arrester is to be used more or less in an intermittent capacity, and may not be inspected conveniently every day, the electrolyte is changed. An electrolyte is chosen which gives less dissolution of the film, so that it may be allowed to stand for a long interval without connection to the circuit and still not cause an inconveniently large initial current rush. In making this change, the discharge rate of the arrester is not diminished, in fact, it may even be increased if desired; the endurance to long discharge, however, is lessened. In all situations inspection is normally made at least once a week; consequently it is recommended that this line arrester be connected to the circuit once every week.

The value of oil in the arrester as an absorber of heat may be judged by the following test.

Two 2300 volt arresters, having equal internal resistance, were set up. One was filled by allowing the electrolyte to over-flow from the upper cone to the lower one, and a small amount of oil was then placed on top; the other was partially filled and immersed in a tank of oil. The arrester that was not immersed in oil operated fifteen minutes and then blew its fuse. The other arrester immersed in oil operated two days continuously, and did not blow its fuse at the end of that time. In other words, for this low voltage the surface of radiation was sufficient to keep the arrester within reasonable temperature limits. Since for higher voltages it is impossible to proportionally increase the radiating surface with the potential, this condition of radiation will not hold, and it is necessary to depend more and more on the heat capacity of the oil. While an aluminum arrester not immersed in oil answers very well for transitory lightning, it is not at all suited to taking care of continual lightning.

Horn Gap Switches

On account of the desirability of connecting arresters to the line from time to time, the horn gaps take new forms. The horn gap is arranged to fulfill three functions:

1st. As a horn gap, to prevent line voltage from reaching the arrester.

2d. A short circuiting switch, so that the operator may safely and easily connect the arrester to the line when desired.

3d. A disconnecting switch to isolate the arrester from the line when desired.

Two types of combination horn gap switches are shown in Figs. 7 and 8. For high voltages the revolving horn is used as shown in Fig. 8. For voltages up to 25,000, a tilting insulator is used to short circuit the gap, and the horn is arranged to act as a switch blade and to open in the vertical plane (Fig. 9).

On delta connected systems, or on systems with a neutral grounded through a high resistance, it is necessary to use an arrester leg connected between the multiplex and ground, in order to give the proper distribution of voltage in the cells during the condition of an accidental grounded phase. In the first arresters installed this grounded leg on the arrester was kept in condition by short circuiting each one of the phase gaps separately. In the later types auxiliary switches are inserted which exchange the ground leg with one of the phase legs during the interval of the test. One of these devices, the tilting insulator switch which accomplished this exchange, is shown in Fig. 9.

Fig. 7. A Skew Sketch Showing the Relative Connection of the Aluminum Arrester for a Non-Grounded Neutral Circuit, or a Circuit with the Neutral Grounded Through a Resistance

Aluminum Arresters for D.C. (the Second General Type)

The arresters for direct current have to meet more favorable conditions of internal loss, but more difficult conditions of delicate insulation to be protected.

The usual direct current circuit has a potential of 600 volts, and the insulation is usually double cotton covered wire; yet the motors carrying this delicate insulation are run out in the suburban districts where the induction from thunder clouds is as severe as found on a high tension circuit. To meet this condition the series gap of the arrester is abandoned, and the aluminum cells are connected directly between line and ground. A value of plate area is chosen which will discharge over 1000 amperes of current at double voltage (1200 volts). This effect is shown in the curve of Fig. 4. Some idea of the comparative value of this arrester is obtained from the current discharge rate relative to the arresters in present use. One of these arresters discharges 17 amperes and the other about 0.3 ampere of dynamic current, at double normal voltage. The leakage current through the aluminum arrester is never over a few milli-amperes, and is usually only one milli-ampere. Thus the increase of current from normal potential to double normal potential is a million fold. The equivalent-needle-gap of this arrester is 0" as compared to 0.25" for the older types of 600 volt arresters. The internal resistance is so low, and the inductive circuit so short, that the hands can be held across this arrester while a discharge of 100,000 volts at a frequency of about a million cycles from leyden jars is being discharged through it. In this type of arrester the effect of the temporary critical film voltage is prominent; it may be said that the arrester begins to discharge the instant the voltage rises one volt above normal. The capacity of this arrester as measured by the ordinary methods is equal to the electro-static capacity of 400 miles of trolley. The capacity is a combination of the electro-chemical and electro-static.

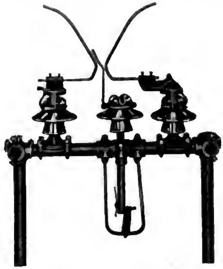


Fig. 8. Insulator Carrying a Horn Which Revolves Horizontally Around its Axis

When the horns are in line the gap length is less than the spark potential of the line, and in this position the arrester can be tested The normal position for the horn is at an angle to the opposite horn, so that the gap setting is greater than the normal line potential When used as a disconnecting switch the horn is swung around at right angles.

Induction of Connecting Leads of 600 V. Direct Current Arrester

While this arrester will discharge at a high rate of current and limit the voltage at its terminals to a very small value, it cannot, however, prevent a drop of potential in its connecting leads. At ordinary frequency, the drop in potential along even a small wire is of negligible value, but at high frequencies the voltage drop for even a foot of wire may become dangerous to cotton insulation. Some idea of what might take place may be obtained from the discharge of a leyden jar. With a circuit giving a frequency of 2.25

ERRATA Pages 310 and 311.

Title under	*Fig. 7*	*should be*	*under*	*Fig.*	*9*
"	"	*Fig. 8*	"	"	"	*7*
"	"	*Fig. 9*	"	"	"	*8*

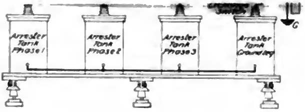


Fig. 9. Tilted Insulator Horn Gap

In this switch the horns are set in the same plane with the gap, at a setting somewhat above the line potential, so that the current will not flow into the arrester continuously. For the purpose of testing, an intermediate insulator is supplied which revolves around the horizontal axis, and by tilting carries a metal wire between the horns, and thus places the aluminum cell in contact with the line. For disconnecting, one horn is fulcrumed at the top of the supporting insulator and may be turned over backwards in a vertical plane.

length of wire which will puncture four thicknesses of cotton covering. In other words, it will short circuit two adjacent wires, each of which is double cotton covered. While this condition evidently happens infrequently on the trolley circuit, it shows the advisability of taking the precaution to make the distance from the lightning arrester tap to ground as short as possible, as compared to the length of connection to the other apparatus. The ideal condition would be to install the arrester as near the motor frame and truck frame as possible, and bring the trolley lead down to the arrester and then back to the controller apparatus. Exactly how far it is necessary to reduce the inductance or length of the ground connection of the arrester, has not yet been determined. Unless the lightning conditions are unusually severe, no

resent practise seems neces-
ny case extra precautions
to lessen the inductance
ey will be found in one or
wing: (*a*) Flat strip used as
rth; or (*b*), connections to
frame, and wheel, as well as
ne.

he potential drop in a flat
hat in a round wire is shown
values of equivalent-needle-
leyden jar circuit having a
y of 2.25 million cycles per second.

5 ft. strip $2\frac{1}{2}$ ins. wide and very thin, $\frac{3}{16}$ in.
5 ft. round No. 10 wire, $\frac{7}{16}$ in.

When certain foreign substances are placed in the electrolyte, the aluminum cells fail by allowing a heavy current to flow through them. This brings the electrolyte up to the boiling point, and the cells boil themselves dry and finally open up the circuit.

Surge Protector

The third general type of aluminum arrester is the surge protector. The surge protector, like the direct current arrester, is connected directly to the circuit. The principal problem relates to the wear of the aluminum plates under the continuous scouring action of the alternating currents. The cone type of the arresters has been tested in service during several years, but the surge protector is more recent, and is now being tried out in service. The necessity for the surge protector is found principally on cable systems where the ratio of the capacity to the inductance is large, and consequently, where the surge current on the line will be correspondingly large for every volt of lightning potential.

Choice, Condition, and Location of Arresters

In the preceding discussion, an attempt is made to show briefly the variable demands on an arrester. Although no invariable rules can be made to include all cases, it is possible to cover most of them with the following directions.

On overhead systems use enough gap aluminum arresters to protect the entire system from an accidental grounded phase. Use these aluminum arresters in stations where there is an attendant, or where an auxiliary small wire may connect to an alarm in a house or office from which word can be sent to the nearest station that trouble exists on the line. In all such locations use normal electrolyte and a horn-gap setting of 125 to 175 per cent. of normal potential, according to the local conditions. In general, use the aluminum arrester where there is expensive apparatus. Move other types of arresters from important stations to places of less importance to give room for the aluminum arresters. Keep the aluminum arrester as cool as possible. Except in very sunny, hot countries, no unusual precautions need be taken.

In unattended stations or isolated installations, use modified electrolyte if tests cannot be made more frequently than once per week, and make the horn gap setting 175 to 225 per cent. of normal voltage. Use this type of installation, or the multigap arrester where overhead lines join cables.

For direct current railway circuits, the aluminum arrester becomes essential in suburban districts where lightning is frequent. On every direct current feeder circuit, use aluminum arresters in the stations, at least. Use aluminum arresters in any location where the resistance type is not giving complete protection. For complete protection, the established rule should be followed of placing one arrester on each car, and two per mile on the line.

On 110 volt direct current circuits use the no-gap 100-300 volt aluminum arrester to protect recording meters and other delicate apparatus.

THE LUMINOUS ARC LIGHTING OF TOLEDO

By C. R. McKay

A ten years' contract for the street lighting of Toledo became effective on January 1, 1907, between the City of Toledo and the Toledo Railway & Light Co.

This contract required the furnishing of 1375 arc lights of 2000 candle-power equivalent, to be burned nightly, from one-half hour after sunset to one-half hour before sunrise.

Fig. 1. Summit Street, Toledo. Showing Ornamental Poles Supporting Luminous Arc Lamps

The low remuneration and character of service required demanded the adoption of the most efficient system of illumination, in order to avoid financial loss to the contractor.

The luminous arc system, with mercury rectifiers and constant current transformers, was selected, and there are at present 1637 General Electric 4 ampere magnetite arc lamps in operation, with 129 additional lights in process of erection.

Thus, the results of one year's trial justified the City of Toledo in adding within that period nearly 400 lights to the number originally specified.

Station Equipment

The required energy is generated in 3-phase Curtis turbo-generators wound for 4000 volts, Y connected.

Thirty-seven constant current 25 cycle 50 light transformers, wound for 2200 volts primary were installed, together with a corresponding number of mercury arc rectifiers and switchboard panels.

Thirty-four of these rectifiers are of the air-cooled type, the blast being supplied by either of two fans, driven by 12 h.p., 25 cycle induction motors, each of which has ample capacity for the entire 34 sets.

Recently, three sets with oil-cooled rectifiers have been added to the original installation.

Each circuit panel supports one rectifier, with adjustable blast gate, ammeter, excitation switch, primary, secondary, short circuiting plugs, bus transfer plugs, and tube tilting handle.

A totalizing panel located in the center of the arc switchboard supports three indicating wattmeters, three recording wattmeters, and two triple pole, double throw fused switches, each of these switches controlling a blower motor.

A three phase 4-wire 4000 volt bus, controlled by a motor operated oil switch, traverses the entire length of the arc switchboard behind the sub-bases. The transformers are so connected between the neutral and outer buses as to closely balance the system.

The transformers stand in two parallel rows on the engine room floor directly below the switchboard gallery, and their primary and secondary leads rise directly from the transformer terminals to the rear of the panels overhead.

In case of necessity, it is possible to supply power for the luminous arc lights by inverting either of the two 1000 kw. 25 cycle rotary converters, normally used to convert alternating current into direct current for operating the street railway.

Lines

All lines leave the power house in multiple conductor lead covered cables with $\frac{7}{32}$ in. paper insulation on each conductor. After traversing the underground district in vitrified tile, or cement lined iron duct, the circuits continue overhead on ordinary construction with double petticoat glass insulators.

Fig. 2. Lighting of Summit Street, Toledo by Luminous Arc Lamps

No unusual line troubles have occurred, either on the aerial, underground, or submarine lines, although surges coincident with tube flashings have occasionally punctured temporary wiring between transformer secondaries and rectifiers.

Lamps

The lamps are distributed throughout the city at an average distance of 600 feet apart, and are generally hung over the center of street intersections, at a height of approximately 25 ft., by means of suspension wires, and are lowered for trimming.

The first lamps were started during stormy winter weather, and some difficulties were encountered due to high winds rupturing the arcs. Upper electrodes of ¾ in. diameter were in use, but these tended to oxidize, thus reducing the diameter, and resulting in sticking or welding of electrodes.

line losses, as measured at the direct current circuit terminals. The watts at the circuit terminals for the alternating current 7½ ampere lamp averaged 525, showing an approximate reduction of 38 per cent. in energy per light supplied to the circuit.

The satisfaction afforded by the illumination from the new light is well illustrated by a recent incident, when it became necessary to substitute without notice the original 7½ ampere enclosed alternating current lamps

Fig. 3. Interior of Power Station of the Toledo Railway and Light Company (Daylight View)

These difficulties have been satisfactorily remedied in the later type of lamps by securing wind proof contact between globes and canopies, and by the use of upper electrodes of large diameter.

The life of the lower electrode has been increased from approximately 110 hours to over 160 hours, and it is expected that the upper electrode will last fully a year.

The luminous arc lamps in operation average from 320 to 324 watts per lamp, including

in place of the luminous arc lamps, owing to the breakage, by a falling bridge span, of six arc circuits supplying some 300 lamps in East Toledo. Vigorous protests to the City Council from residents and merchants of East Toledo clearly expressed the public opinion as to which type of lamp gives the best illumination.

Gazing directly at the luminous arc, there is discernible to the trained eye a slight frequency flicker, which is imperceptible in the general illumination.

Mercury Rectifiers

The doubtful element of this system has generally been considered to be the rectifier tube life, and many inquiries regarding the luminous arc system have been aimed at the rectifier. The following data is therefore given in order to show the results in a specific case.

The manufacturer's guaranteed average life for the air cooled 50 light tubes was 400 hours operation.

Total number of tubes tried . . 93
Tubes failing to start 6
Tubes failing under 400 hours life 33
Tubes exceeding 400 hours life . . 49
Average life of these 49 to Mar. 1, 1908, ... 1445 hrs.
Tubes operating Mar. 1, and exceeding guaranteed life 25
Average life of these 25 . . 1594 hrs.
Tubes exceeding 400 hrs. life and failing prior to Mar. 1, 1908 . . 24
Average life of these tubes . . 1290 hrs.
Average life of 93 tubes, including failures to Mar. 1, 1908 . . 793 hrs.
Maximum life observed to March 1, 2697 hrs.

The above record includes both oil cooled and air cooled tubes, but sufficient time has not elapsed since installing the oil cooled type to definitely establish a preference. There are, however, reasons for expecting still greater life.

Efficiency and Power Factor

In response to numerous inquiries, tests have been made of the efficiency, the power factor, and the power required to supply the air blast. These tests closely confirm the makers' guarantees. The results follow:

Fig. 4. Interior of Power Station by Night

Transformer on 100% Tap

	LOAD		A.C. INPUT—25 CYCLE				%-P.F.	D.C. OUTPUT			% Effic'y.
	Lamps	%-full load	Amp.	Volts	K.V.A.	Kw.		Amp.	Volts	Kw.	
a.	50	100	13.74	2308	31.70	17.55	55.4	4.04	3899	15.75	89.8
b.	37	74	13.70	2303	31.55	14.17	45.0	4.13	2892	11.94	84.3

Transformer on 80% Tap

	LOAD		A.C. INPUT—25 CYCLE				%-P.F.	D.C. OUTPUT			% Effic'y
	Lamps	%-full load	Amp.	Volts	K.V.A.	Kw.		Amp.	Volts	Kw.	
c.	37	92.5	10.01	2294	22.96	13.59	59.3	4.17	2877	12.00	88.4
d.	25	62.5	9.29	2305	21.43	10.09	47.1	4.12	1952	8.04	79.7

	a	b	c	d
Volts per lamp D.C. (line losses included)	80.0	78.2	77.8	78.1
Watts per lamp D.C. (line losses included)	315.0	323.0	324.0	321.0
Watts per lamp A.C. (line losses included)	351.0	383.0	367.0	403.0

The efficiency indicated above is the ratio of the D.C. output to the circuit to the A.C. input to the constant current transformer, and includes all losses in the transformers, reactances, rectifier, and switchboard wiring and connections. All instruments were calibrated before and after the tests.

The efficiency and power factor readings are in each case averages of ten separate tests, which showed practically no variation from each other.

The primary A.C. voltage during the tests was about 5 per cent. above rated transformer voltage, which fact accounts for the low power factor.

During each test the circuits were patrolled to insure that the full number of lamps specified were actually burning.

The values of the A.C. input to the transformer under test were closely confirmed by both the indicating and the recording wattmeters on the totalizing panel, which gave averages for the entire installation; therefore these values are not open to criticism as representing special conditions unattainable in normal operation.

Power for Air Blast

The following figures show the input to the blower motor with various numbers of blast gates opened.

Power for Air Blast. (Blower Motor Input)

No. Blast Ports Open	Kw. Input	Average Kw. per Blast
0 (Fan running light)	3.37	0.
10 (Fan running light)	4.65	0.47
20 (Fan running light)	6.08	0.30
33 (Fan running light)	6.98	0.21

An important factor in the life and operation of mercury rectifier tubes is the temperature range to which they are subjected, and unsatisfactory results from tubes of moderate voltage could perhaps frequently be attributed to improper temperature conditions. The blast temperature can not readily be regulated in all seasons and localities, and therein may lie a strong inherent advantage of the oil cooled type over the air blast type.

Display Street Lighting

The satisfactory results obtained in general from the introduction of the luminous arc lamp system in Toledo, early led to a demand for special illumination of Summit Street, one of the principal business throughfares, which includes much of the shopping district.

On each side of this street, for approximately one and one-quarter miles, ornamental iron poles, each supporting two luminous arc lamps, were erected at intervals of 80 feet. The result is perhaps the best illuminated street in America, according to the opinions of various illuminating experts.

One-half of the cost of this display lighting is borne by the City, and the other half by the merchants and property owners.

The effect of this lighting in attracting business from adjacent streets, which lack the brilliancy of Summit Street, has aroused other merchants and property owners to activity, and an installation duplicating that of Summit Street is now in process of erection on Superior Street.

Other business streets are planning similar extensions, and it may be predicted that at an early date the entire business district of Toledo will be brilliantly illuminated with an economical and harmonious system, free from the circus effects which so often offend good taste.

MILL TYPE MOTORS

By M. A. Whiting

Power and Mining Department, General Electric Company

Operating Conditions

The power required in a steel plant is much greater than that required in the largest manufacturing plant of any other industry. In addition to the main rolls, there is required a large number of auxiliary machines for handling the raw materials and the product at various stages in the train of operations. In most cases, several of these machines are handled simultaneously by one operator located at a considerable distance. For this reason, and because the distribution of electric current through a large plant is much simpler than the distribution of steam, the tendency is to use motor drive throughout.

With the exception of bloom shears and manipulators, which are generally hydraulically operated, the various classes of auxiliary machinery can be electrically driven with considerable advantage. The more important of these auxiliaries are: ore unloaders (including car dumpers), ore bridges, furnace hoists, charging machines for open hearth and reheating furnaces, cranes, screw downs for adjusting the main rolls, tilting tables, transfer tables, cambering rolls, and pull-ups for handling the rolled product to and from the hot beds. Plate bending rolls, and very small main rolls for rods and small bars may also be classed with the machines just enumerated.

These applications constitute the severest service for which the electric motor has ever been used. Motors in this class of service must meet the conditions of intermittent service with very large momentary overloads, abnormally rapid acceleration, and reversal at full speed with consequent heavy shocks.

As a rule, motors in mill service must be totally enclosed as a protection against dirt and scale, and must operate with very high surrounding temperatures. In general, the mills will run twenty-four hours a day, six or seven days a week, thus allowing very scant time at infrequent intervals in which to make repairs and replacements. In almost every case continuity of operation is of prime importance; for example, the disabling of a 50 or 75 h.p. motor on a tilting table may shut down a blooming mill, rail mill, or structural mill, interrupting the entire production. A motor which shows signs of trouble will invariably be kept in service until it is entirely disabled, or until the mill is shut down for other reasons. Motors in this service must therefore be as simple and as conveniently arranged as possible in order that they may be taken out and replaced, or opened up and defective parts replaced in the shortest possible time. In addition, the motors should require a minimum amount of inspection and should be as nearly fool proof as possible. The workmen, accustomed to handling heavy masses of steel, and working under pressure, so to speak, become very reckless in handling apparatus of any sort; thus, the motors are

Fig. 1. MD or MI-107, 75 H.P. Motor, Back Geared

subject to a great deal of unnecessary abuse, in addition to the severe handling which is made inevitable by the requirements of the service.

The severe electrical and mechaneal requirements, as outlined above, render the ordinary types of motors, including railway motors, entirely unsuitable for this work. Railway motors have been used to some extent in steel mills in spite of various disadvantages. Their shafts and bearings are not heavy enough, however, and in the larger sizes the frames are not split. The motors are entirely too compact, and commutators cannot be made large enough for satisfactory operation at 220 volts.

General Characteristics of Design

To meet the severe conditions of steel mill service, the General Electric Co. has developed the mill type motors for both direct current and alternating current. In the design of these motors the chief consideration has been a simple and extremely strong mechanical construction. The direct current machines, known as MD motors, are of the series type and are standard for 220 volts, but can be furnished for 550 volts. The alternating current machines, known as MI motors, are form M induction motors built for 25 cycles, and for 220 and 440 volts. The MD and MI motors are built in corresponding sizes which have the same horse-power ratings, ranging from 3 to 150 h.p. The corresponding sizes of the two lines of motors have the same outline and foundation dimensions. Shafts, bearing linings, frames, countershafts and various minor parts of these two lines of motors are similar, and in some cases identical. The frames are octagonal in shape and are split horizontally, the two halves of a frame being held in alignment by dowel pins, and bolted together by four heavy rough bolts with square heads, lock washers and hexagonal nuts. The corners of the bolt heads do not swing clear of the frame, this construction making it unnecessary to use two wrenches. Four heavy feet are provided at the corners of the frame, each foot being drilled for one large holding down bolt.

The armatures have been made small in diameter so that when reversing rapidly they will not require excessive power for acceleration.

Large openings are provided at the commutator or collector end to allow easy access to the brush rigging. The covers are of malleable iron and are held in place by a hinged lock bolt. The housings for the armature bearings are part of the frame and are liberally designed, no effort being made to crowd them inside the frame. Bearing linings are cast iron, babbitted, and offer a long bearing surface. A shoulder at the end

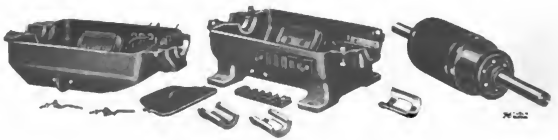


Fig. 2. Exploded View of MD-106, 50 H.P. Motor

of the lining nearer the armature bears against a machined vertical surface on the lower housing, the armature end thrust being thus transmitted from a shoulder on the shaft, directly through the shoulder of the bearing lining to the lower half of the frame. The bearing linings are split, the two halves being bolted together, thus permitting the use of solid oil rings. A forged bail is cast in the upper half of each lining by means of which the armature may be handled. The lower lining is provided with a projection on each side, which rests against the upper bearing housing and prevents the lining from rotating, the use of dowel pins being thus avoided.

The armature bearings are supplied for waste lubrication, or for oil ring lubrication with two rings per bearing. To change from ring to waste lubrication, it is simply necessary to change the linings. Oil grooves and deflectors are provided to prevent leakage of oil at any point.

Countershaft bearing brackets are a part of the lower half of the frame, while the caps for these bearing brackets are held down by two rough bolts at diagonal corners, and are lined up by a tongue and groove. The linings are split, and of the same general design as the armature bearing linings, with the exception that the two halves are not bolted together, and the bails are omitted. Countershaft bearings are designed for waste lubrication.

The shafts are extra heavy, being designed for an ample factor of safety against maximum combined stresses at 100 per cent. overload. The pinions are made of the best grade of hammered steel, and the gears of cast steel, the width of face being considerably greater than for standard railway practice. Tooth stresses are computed on a basis of 100 per cent. overload. Split or solid gears are furnished.

MD Motors

The pole pieces are laminated, according to standard practice. Each pole piece is held in place by two square headed bolts, which prevent improper alignment of the pole piece. The field coils are wound with flat strip copper, are insulated between turns with asbestos, and covered with sheet mica and asbestos tape, well filled with insulating varnish.

The armature core is built up of soft steel laminations keyed to a spider according to standard practice. A bar winding is used in open slots, the bars being held in place by binding wires recessed below the core surface.

The commutator shell is carried on an extension of the armature spider, allowing the shaft to be removed without disturbing the connections. The segments have solid ears, the ends of the armature bars extending directly into the slots in these ears, thus eliminating the commutator leads.

The brush rigging is of a simple and substantial construction, the body being of cast iron and the brush boxes of brass. A heavy coiled spring of phosphor bronze is used, which has no adjusting lever or other small parts to get out of order. Brush holder studs are screwed into the frame, no provision being made for shifting the brushes, as the motors, being reversible, are designed to operate with brushes at the neutral point. The largest motor, which is a six pole machine, has four studs, one of which is in the lower half of the frame, the lead for this stud being brought to the outside. Each of the other motors has only two studs, both in the upper half, thus simplifying the connections and rendering inspection a very easy matter. All connections between the two halves of the motor are brought to the outside. No connection board

Fig. 3. Exploded View of MI-107, 75 H.P. Motor

is used, as the leads are provided with a simple form of coupling over which an insulating sleeve is slipped.

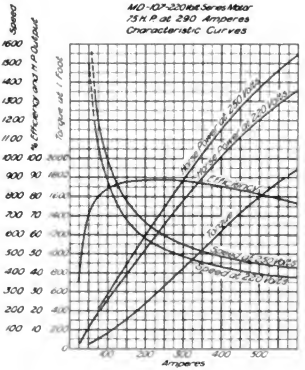


Fig. 4. Characteristic Curves of MD-107, 75 H.P. Series Motor

The MD motors are standard for 220 volts, with series field. Compound windings are usually 20 to 25 per cent. shunt, limiting the free running speed to about twice full load speed. Commutating poles are used on the four largest sizes, insuring black commutation at excessive overloads.

The efficiencies of these motors are important, not with respect to power consumption, but with respect to heating, and the efficiencies have, therefore, been made as high as is consistent with the severe mechanical requirements. The MD motors have efficiencies about three per cent. higher than those of the corresponding sizes of railway motors, the value for the larger sizes being about 90 per cent. at full load.

These motors will operate totally enclosed at rated load for one hour, with temperature rises of 65 to 75° C. by thermometer. The limit of commutation has never been reached on any of these machines, commutation being black at 100 per cent. overload, and only very slight sparking occurring at 200 to 300 per cent. overload.

MI Motors

As mentioned above, the MI motors have the same outline and foundation dimensions as the MD motors of corresponding sizes; the two types are, therefore, interchangeable. The MI motor has a split box frame from which the stator can be removed, this feature involving a radical departure from standard practice with respect to mechanical design of induction motors.

The stator is made up as a complete and separate unit. The punchings are assembled on twelve steel studs passing through ears on the outer circumference. By means of these studs the punchings are clamped rigidly between cast iron end flanges. Open slots are used, and liberal air ducts are provided for ventilation.

Coils are form wound and moulded to exact size before assembling on the stator, this arrangement rendering the coils interchangeable, and facilitating repairs. The principal insulation is placed on the coil, although ample slot armor is also provided. The coils are held in place by heavy wedges, and supporting rings bolted to the end flanges protect the coil ends. The completed stator is therefore proof against careless handling.

When the stator is let down into the frame, the ear at the bottom of the stator fits closely between two machined ribs on the frame, thus preventing the torque of the motor from revolving the stator. Each half of the frame contains several such ribs, bored out to the exact diameter of the outer surface of the stator, and when the two halves of the frame are bolted together the stator is brought into alignment and held rigidly in place.

The rotor spider is extra heavy, the punchings being held in place by double dovetails, and, in addition, by steel pins driven through reamed holes near the inner circumference. The end flanges are pressed on the spider and held by lengthwise and crosswise keys. The rotor is of the form M type, polar wound, a bar winding being used in partially closed slots.

In view of the severe service for which these motors are designed, the air gap has been made much larger than standard practice, being two and one-half to three times that of the usual type of induction motor with the same diameter of rotor.

The collector rings are of the open form, large in diameter, and of a heavy, rigid construction. They have fans cast on them, which help to maintain a circulation of air inside the motor. The collector rings are mounted on a shell which fits on an extension of the rotor spider, making it possible to remove the shaft without disturbing the collector. The well-known clock spring type of brush holder is used with heavy cast brass brush boxes and carbon brushes. Each of the three brush holders is supported at both ends, four studs in all being used, which are carried by a yoke bolted to the upper half of the frame. The arrangement of the brush rigging, and the large size of the upper hand hole cover make the brush holders easily accessible for inspection or for replacement of brushes. The rotor leads are brought out through the upper half of the frame, and the stator leads through the lower half. In taking the motor apart it is therefore unnecessary to break any connections inside of the motor.

The MI motors are wound for 220 or 440 volts, and as previously mentioned, they are form M, the control being accomplished by means of resistance in the rotor or secondary

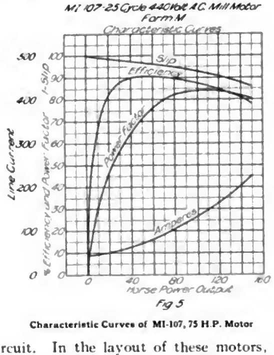


Fig 5

Characteristic Curves of MI-107, 75 H.P. Motor

circuit. In the layout of these motors, the chief considerations were superior mechanical construction and ease of repairs and replacement. Notwithstanding the severe mechanical requirements of the design, high efficiencies have been obtained, equal in most cases to those of the usual type of form M motors, the average in the larger sizes being about 90 per cent. The power factors of the MI motors are lower than those for standard motors; this is a necessary result of the increased air gap, and need not be considered a disadvantage in this type of machine. In cases where a high power factor is essential, the operating conditions are not, as a rule, so severe as to require machines of the extremely rigid design of the MI motors, and motors of the usual type can therefore be used. It should be noted that the power factors are highest between full load and 100 per cent. overload. As these motors will ordinarily operate at large momentary overloads, the average power factors will be better than is apparent from the first glance at the curves. These motors have a maximum torque, ranging in the various sizes between 240 and 267 per cent. of full load torque.

The current and torque during acceleration depend to a large extent upon the control equipment used; this point will therefore be taken up in the discussion of control.

When totally enclosed, the MI motors will operate at rated load for one hour with temperature rises, by thermometer, of 65 to 75 degrees C.

Control

Either drum or type M control may be used with the mill type motors. For the smaller sizes, drum control will in many cases prove satisfactory, while for the large motors, drum controllers should not be used except for infrequent service. For heavy duty the type M control system should be used, as it is more reliable, will handle heavier currents, and involves much less repairs and depreciation. Since the master controllers are small, several can be installed within easy reach of one operator; also, several motors can be operated as a unit from one master controller.

Type M systems in general may be divided into three classes; namely, hand, time limit, and current limit control. In a hand control system the successive resistances can be cut out either at intervals or simultaneously, at the will of the operator. With a time limit system, although the operator may throw the controller handle instantly to the full running position, each resistance step must remain in circuit a predetermined time before being cut out. With a current limit system, the current on each point must fall to a certain value, irrespective of the elapsed time, before the motor can be notched up to the next point. With either a time limit or current limit system, the master controller can be thrown instantly to the full running position, in which case the motor will accelerate at a rate subject only to the predetermined limit; or the controller may, be

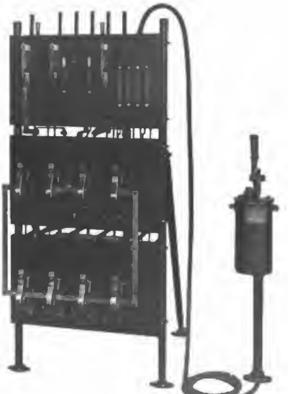


Fig. 6. Type M Control Equipment for Mill Motors

moved up one notch at a time, thus obtaining a slower acceleration. This arrangement is usually spoken of as a combined hand and automatic control.

Most of the apparatus is similar for the three systems, the connections and the limit device being the principal points of difference. As current limit equipments are preferred almost without exception for steel mill work, the discussion will be confined to this system. The motor circuit is closed and the resistances cut out by electrically operated switches known as contactors, operated by a circuit which is energized by the power supply and controlled by a small master controller. The control circuit passes through electrical interlocks on the contactors, and through a current limit relay in the main circuit. The interlocks consist of make and break contacts in the control circuit, and are attached to and operated by their respective contactors.

The connections through the relay and interlocks are arranged so as to accomplish several results. First, the line contactors are interlocked so that it is impossible for both pairs of contactors to be closed at the same time, which operation would short circuit the line. Second, the contactors which cut out the resistance are interlocked with the relay in such a manner that a contactor cannot be closed (cutting out a section of resistance) until the load current falls to a certain predetermined value. But when closed these contactors will remain so, independently of the operation of the relay. Third, adjacent contactors are interlocked with one another so that they must close in succession and not simultaneously.

The master controller commonly used has several segments, corresponding to the various

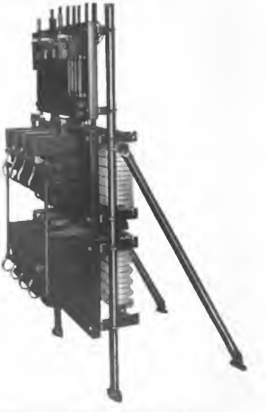


Fig. 7. Type M Control Equipment, Side View

steps, enabling the operator to start up slowly, notching up by hand. Or, if desired, the controller may be thrown instantly to the full running position, allowing the motor to accelerate automatically at a rate limited only by the current limit relay. With this form of master controller the motor can be operated at reduced speeds, either by notching up to the required point from stand still, or by notching down from full speed.

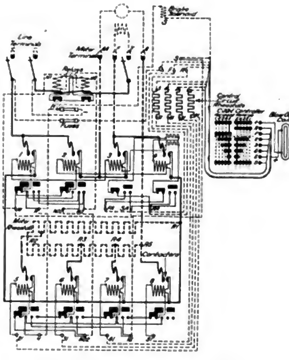


Fig. 8. Connections of Type M Control for MD Motors

Fig. 8 shows the connections of a direct current equipment with five points forward and reverse, used for operating a series motor. For a motor with a small shunt winding the control is similar, the shunt field being carried through the master controller. In this way the shunt field is opened, discharging into a resistance, every time the controller is thrown to the off position. It is thus impossible for a careless operator to leave the shunt field on, when the motor is shut down. When conditions render it necessary, a shunt field relay may be used, its function being to prevent the operation of the motor if the shunt field is broken.

Fig. 9 shows the connections of an alternating current equipment—seven points forward and reverse. The wiring of contactor coils, interlocks and relays is practically the same for the direct current and alternating current equipments.

The proper number of points in a control equipment depends upon several considerations. To obtain considerable refinement with respect to uniformity of acceleration and reduction of current peaks and motor losses, a larger number of points should be used than would otherwise be required. In the case of the type M equipments, however, a large number of points means a very expensive and complicated equipment, with a consequent increase in repairs and depreciation. Furthermore, in service requiring an extremely rapid acceleration, if a large number of points is used the contactors will not close rapidly enough. In mill service, therefore, the tendency is always toward a very few points. With the MD motors in heavy reversing service, five points with current limit are sufficient. With the MI motors the control should, as a rule, have seven points, which, in connection with a current limit, will give a satisfactory acceleration over a wide range of operating conditions.

In installations of MI motors for heavy service there is an additional reason, not mentioned in the foregoing, for using type M control. If an induction motor operated by a drum controller is started by throwing the controller handle instantly to the full running position, the motor will be thrown on the last, or full running point, before it has time to speed up, and a very low torque will therefore be obtained, with an excessive

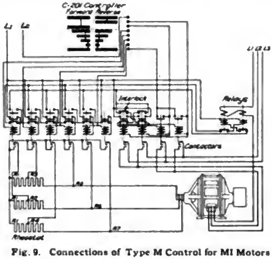


Fig. 9. Connections of Type M Control for MI Motors

current input. A still worse condition will be obtained if the motor is suddenly reversed at full speed. A time limit device offers only a partial remedy, as it notches the motor up to full running position in a certain number of seconds, independently of the load. A time limit, therefore, will not positively prevent the motor from reaching the last control point at too low a speed. In order to make it impossible to stall the motor by improper acceleration, and in order to secure the required torque with a minimum current input, it is necessary to use a type M equipment with current limit.

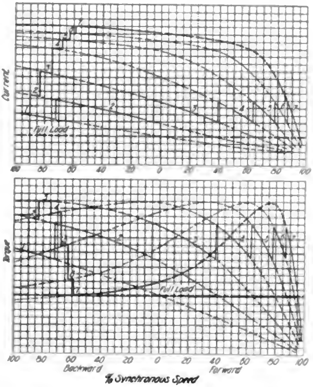


Fig. 10. Curves Showing Disadvantage of Drum Control with Induction Motors in Reversing Service

Fig. 10 illustrates, in a general way, the difference between a current limit acceleration and the acceleration obtained under unfavorable conditions with a drum controller. The heavy lines represent torque and current obtained by suddenly reversing a 75 h.p. MI motor at full speed by means of a drum controller, and the light solid lines represent the current and torque obtained by a type M current limit acceleration, the controller handle in each case being thrown instantly from full forward position to full reverse. With the drum controller the torque increases to a maximum on the third point and decreases on the following points, coming down approximately to full load torque on the full running position. Although the torque beyond the third point decreases, the current increases at every step, reaching a maximum of 400 per cent. of full load current. If the friction load is not too great, the motor, after coming to rest, will accelerate slowly (the torque being low, as shown by the heavy dotted curve), until the speed approaches the value corresponding to the peak of the torque curve. In the meantime a tremendous current will be taken. If the friction load is very large, however, the motor will not have sufficient torque on the last point to come up to speed, and will therefore be stalled.

In contrast to this cycle of operation which may be obtained with a drum controller, that obtained with a current limit acceleration is shown by the light solid lines in the same set of curves (Fig. 10). The torque varies between uniform maximum and minimum values throughout the reversal, a high average being maintained. The current also varies between uniform maximum and minimum values, the maximum current being less than half that obtained in the sudden reversal with the drum controller.

Fig. 11 gives a typical set of torque and current curves for an MI-107-75 h.p. motor with a seven point current limit control. These curves are laid out to cover the entire range from full speed reverse to full speed forward. The torque and current curves shown represent the proportioning of control resistance, which is suitable over the widest range of service conditions. The curves in Fig. 11 represent the most suitable control for reversing service, with average torque ranging from 150 to 225 per cent. full load torque; or for non-reversing service, with average torque ranging from 80 to 150 per cent. full load torque. If for reversing or non-reversing service, a greater torque is desired than the values given above, the same equipment will still prove satisfactory. If the acceleration is very rapid, however, the maximum torque of the motor will not be reached until the motor has slowed down considerably. If less torque is desired than that given above, the torque and current on the first point will be much higher than on the following points. However, unless considerable refinement is desired, it will be unnecessary, even in extreme cases, to depart from the standard equipment. Adjustment for a high or low torque is made by setting the current limit relay for a high or low current limit, the relay being adjustable over a wide range.

In Fig. 11 the light solid lines represent current and torque, with a current limit of

150 amperes. On the first step the torque and current are low; on the second and following steps the current varies between 225 and 150 amperes, and the torque varies between 1800 and 1320. The mean square current over the entire acceleration is 28,700, and the mean torque is 1550. If the current limit is raised to 200 amperes, the acceleration will be as shown by the heavy lines, the maximum current and torque being reached on the third and succeeding points. The current then varies between 285 and 200 amperes, and the torque between 1670 and 2050; the mean square current over the entire acceleration being 53,500, and the mean torque 1800. The maximum current therefore increases 26 per cent. for a 16 per cent. increase in torque. Making allowance for the less time to reverse at the higher torque, the heating due to copper losses increases 60 per cent. for a 16 per cent. increase in torque. If the current limit is raised to a still higher value, the copper losses and maximum current will, as before,

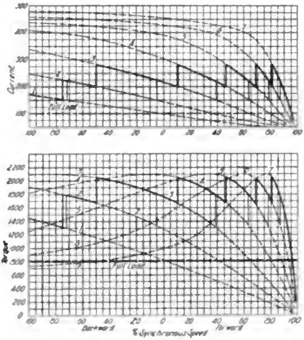


Fig. 11. Torque and Current Curves

increase more rapidly than the torque. As a rule, therefore, it will be found inadvisable to adjust the current limit to accelerate the motor at maximum torque. If the maximum torque is required, it can be obtained by setting the current limit at 275 amperes (not shown in Fig. 11), at which adjustment the motor will accelerate entirely on the peaks of the torque curves. If the motor is reversing a very heavy load, it will be notched up rapidly to the third point, where maximum torque is obtained. From the third point to the full running point, the mean torque is 2075, which is only 1 per cent. below the maximum torque of the motor. This value of mean torque represents the extreme limit of performance of the motor, and can be closely approached only when the acceleration is slow compared with the time required for the control equipment to operate.

The torque and current curves of the other MI motors are similar to those of the MI-107 shown in Fig. 11. In applying current limit control to these motors, the limiting conditions and operating characteristics are the same as those briefly outlined in the foregoing discussion.

Applications

The large majority of applications of the mill type motors will always be in and about steel mills, where the tendency is to use mill type motors throughout. It should be borne in mind that these motors were developed primarily to meet steel mill conditions, and therefore do not offer any particular advantage in general applications. In classes of work where any of the common types of motors have proved entirely satisfactory, the introduction of mill type motors is unwarranted. With the exception of bending and straightening rolls, and possibly some forms of shears, there is probably no class of ordinary machine tools to which the mill motors can be advantageously applied.

There are, however, certain other classes of work in which severe service conditions may make it advisable to use mill type motors. Gas plant charging machines and coke oven larries involve much the same conditions of heat, dust and rapid reversals which are met with in steel mills. In hoist work requiring an exceptionally high rate of acceleration, an ordinary type of motor will consume too much power in its own acceleration. In this respect the mill motors, with their small armature diameters, offer a marked advantage. These motors are also particularly well adapted to the operation of dredges, shovels, and other excavating machinery, where rapid acceleration, reversals, shocks, and general abuse of equipments render the service extremely severe.

SOME SUGGESTIONS ON THE CONSTRUCTION AND ARRANGEMENT OF SMALL TRANSFORMER SUBSTATIONS

By C. M. Hackett

Power and Mining Department, General Electric Co.

At present there are few, if any, small transforming stations that may be termed representative, the tendency being, as is the case in most new applications of electric power, to utilize available space in existing buildings, or to put up temporary buildings at small cost and install the apparatus in such a manner as, in the purchaser's opinion, will answer present requirements.

The fact that these installations can be effected cheaply makes a strong appeal to the prospective customer, and this feature is, of necessity, bound to be emphasized in making the sale of apparatus. There is no reason, however, why the advantages of a good arrangement cannot be had at as low an initial cost as a poor one, and the subsequent costs of operation, repairs and changes be carried on much more economically thereby.

It may be considered a good method of procedure to let the conditions to be met determine the location of the station, if possible, as the arbitrary placing of the source of power for a plant at some place which has for its chief advantage the fact that it can be made ready with the least amount of present trouble and expense, is likely to prove annoying and costly.

The next point for consideration is naturally that of the transmission line capacity and voltage. If conditions are such that a sufficient number of power consumers can be found within a reasonable radius to warrant the power company in establishing a transforming station and building a branch line to operate at a reduced voltage, the problem for the individual consumer is much simplified and cheapened. If, however, it is necessary to tap directly to the main transmission line, which may carry many thousands of horsepower at a potential of 33,000 volts or more, the question of providing suitable controlling devices, such as lightning arresters, and oil switches of suitable rupturing capacity, becomes of so serious a nature that a transformer installation of small capacity, 500 h.p. or less, is impracticable. This is true both from the consumer's standpoint of initial cost and subsequent operation, and from that of the power company, as the latter would be unwilling to take the additional chances of interruption of service introduced by the taps to their lines, unless the amount of power consumed should be a reasonably large percentage of their output.

Transforming stations may be divided into two general classes:

1st. Those which have the control of the power distribution in the station, with the possible addition of rotating auxiliaries, such as converters or motor generator sets, and which have a diversity of service of both alternating and direct current. (Fig. 1).

2nd. Those which have control in part at the point where power is consumed, no rotating units in station, and only alternating current of one voltage in use. (Fig. 2).

Under the first class will come the stations for supplying power for manufacturing establishments, these establishments requiring various types and capacities of motor drive, with lighting and possibly electric furnace service. The consumption of power for such a plant will possibly amount to 5000 kw.

For a station of this capacity, a building should be especially constructed, as only by so doing will it be possible to meet the requirements of the installation in a practicable manner.

If possible, there should be duplicate feeders to the station, with tie buses and switches between them, and also a complete complement of lightning arresters, disconnecting switches, choke coils and oil switches, and all reasonable precautions should be taken to minimize the chances of interruption of service. For convenience in installing machinery, the station should be so located, if possible, that a spur track may be run along both sides of it, and the main floor should be about four feet above the top of these rails. It will generally be found unnecessary to provide working space, crane, etc., in the station for removing windings from transformers, as the transformers themselves can be easily taken to some convenient point in the plant where proper appliances for this work are available, thus materially reducing the size and cost of the building, besides making it possible to isolate the transformers from all other apparatus, and from each other, if desired. As the transformers are accessible only through doors opening to the outside air, this isolation is especially complete, and possesses all the advantages to be had in this method of transformer installation.

Only a small part of the build ng need be carried up two stories, and in this part are

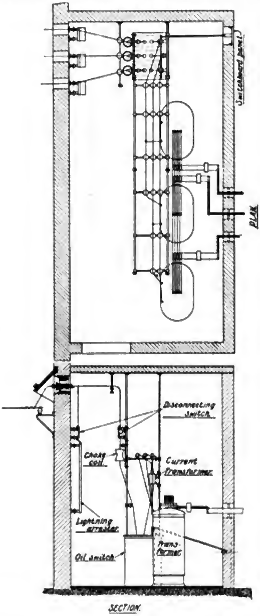


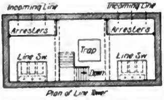
Fig. 1

arranged the lightning arresters, choke coils, transfer bus and oil switches. The bus and switch arrangement may be made very simple, with open wiring and knife switches in the transfer bus; or the arrangement may be elaborated upon by enclosing the buses, and employing oil switches for sectionalizing and for connecting lines and between transformers and buses. The conditions governing each proposition should determine the extent to which this elaboration should be carried.

The space required for lightning arresters, as well as the most practical location for them, which should provide adequate means for inspection and operation, is largely dependent on the line voltage. For low voltages (2300 to 13,000), the lightning arresters, if of the multi-gap type, may be easily placed in the same room with the switch and bus equipment. For higher voltages (33,000 and above), some special arrangement will generally be found necessary, and this will vary with the type of arrester used, and with the conditions of climate. In the warmer climates where little or no snow falls, the arresters, if of the electrolytic type, may be frequently installed on the roof of the station to good advantage, but in colder climates they should preferably be inside of the station, or under some form of shelter. It will generally be found advisable to have the horn gaps in the open air, so located as to be safe and convenient for operation and accessible for inspection. Only in cases where the available space is large, fire proof, and so arranged that it is occupied exclusively by the lightning arrester equipment, should horn gaps be placed inside of the building. If ground space is available, one of the most economical ways of installing an electrolytic type of arrester is to construct a small building near the station in which the cells can be placed, while horn gaps may be arranged upon the roof. These horn gaps may be located directly under the transmission line if the wires are of sufficient height above the ground, say forty feet or more for voltages not exceeding 60,000. If it is impracticable to have transmission lines at such an elevation, the arrester house should be placed to one side so as to give a safe clearance between horn-gaps and wires.

The shelter house for the arresters need not be more than 16 ft. in height; this should give a minimum distance of about 20 ft. between the horn gaps and the wires, if the house is built beneath the transmission lines. While not absolutely necessary, it will be preferable to have this house non-inflammable.

The operating room of the station, which contains the switchboard and such rotating auxiliaries as are required, should be well lighted by both natural and artificial light, and should have doors properly arranged for bringing in machinery, in addition to the small doors for the use of operators. The height of the room will be dependent on whether or not it is necessary to have a traveling crane, and this in turn will depend on the size and number of machines installed.



above grade, the advantages of the basement will frequently offset the small extra expense of the steel floor supports and excavation. In case it is decided to fill in and place the floor on the fill, great care must be exercised in tamping in the filling material, or the floor will soon settle out of level, crack, and break up. In all cases, machine foundations must have their footings well below the original surface of the ground.

A cable pit should be provided below the switchboard for the proper arrangement and distribution of wires, as, in an installation of this type, the number and size of wires to be disposed of will be large enough to make it difficult to properly handle them in any other way. From this cable pit, a conduit system

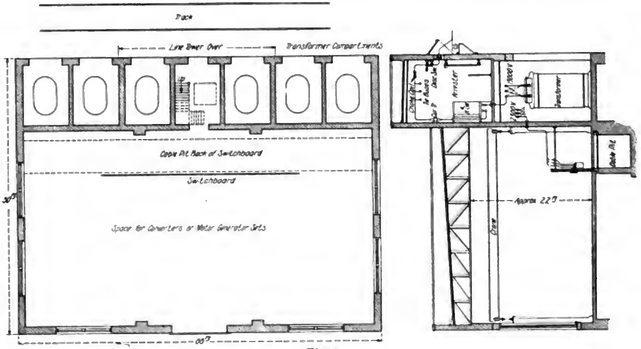


Fig. 2

If these aggregate 1000 kw. output, or more, it may be considered good economy to install a hand-power crane of sufficient capacity to handle the heaviest piece.

In the matter of the basement, the amount of cable to be installed must be considered; and in addition, the cost of foundations under the machines; the cost of floor construction, when supported by structural steel; and the necessary excavation. The expense and advantages of this arrangement must be contrasted with those of simply filling in and placing the floor directly on the ground. Assuming that the floor of the station is 4 ft.

may be run to convenient points about the plant, thus permitting apparatus to be connected up with a minimum amount of open wiring.

Material to be used in the construction of the building should, without question, be fire-proof in every respect. That portion of the building which contains transformers, high tension switches, buses, lightning arresters, etc., should preferably be built of brick and concrete, omitting as far as possible all structural steel that might be exposed to the action of fire. It will generally be found possible to so arrange the main walls and partitions that some standard form of reinforced concrete can be used, thus eliminating all necessity for having any exposed steel construction.

A roof with a single slope, if less than 50 ft. span, is to be recommended, as nearly any type of tile or concrete construction can be used, and if the slope is not more than one foot in 20 ft., no trouble will be found from washing by storms. If the span is short, that is, not more than 25 ft., ordinary I-beams can be used to good advantage to support the roof; but if the span is longer than this, a truss construction will be found more economical. The flat roof also permits the forming of drainage slopes to leaders at the most convenient points. In cold climates, leaders should be carried down inside of the building and run to the drainage system. If suitable drainage is not available, parapet walls should be omitted and a regular eave construction used, allowing the water to drip to the ground.

In warmer climates, where other ventilation than that afforded by windows is necessary, monitors may be placed in the roof with a pivoted sash; but if a cheaper system of ventilation is needed, iron ventilators similar to the star type will give very good results.

In a station where transformers are water-cooled, the extensiveness of the piping system will depend upon whether the water supply can be had under sufficient head to operate the system without the use of pumps, and upon whether a sufficient quantity can be obtained at a cost which is not prohibitive. The ideal system is one which eliminates all pumps and cooling apparatus, and consists in simply connecting the supply header to the transformer cooling coils, and thence to the drainage system. If, however, this is not practicable, and water must be purchased at considerable expense, it will be found advisable to arrange a system with pumps and a cooling tank so that the water can be used repeatedly, supplying only enough additional water to offset the loss by evaporation. In the latter case, a tank of a size proportionate to the amount of water required in the system should be so placed as to give a natural head, forcing the water through the transformers to the drain, thence to the receiving tank, whence it can be raised by a pump to the cooling apparatus. This latter may be of simple character, the climate determining whether it can be placed in the open air, or whether it must be enclosed to prevent freezing. Unless the amount of water to be cooled is large, an ordinary pipe header, with branches from which small outlet nozzles spray water into the receiving tank, will be adequate without a tower.

In case it is impracticable to have a cooler and a tank in the upper part of the building, a sufficient amount of basement room should be provided for them, and the circulating pump may then operate directly on the header for the transformer cooling coils.

In piping for the cooling system, supply headers should be of sufficient size to permit a slow flow movement when all transformers are under normal load. Arrangements should also be made for forcing a sufficiently rapid flow through the cooling coils to flush out any sediment which may be deposited there. The system as outlined here is of the open type; that is, with a break arranged in the pipe on the discharge side of the cooling coil to enable the rate of flow and the temperature of the water to be ascertained, as well as for the convenient attaching of a hose for carrying away the sediment when the coils are flushed out. With the exception of the devices for indicating the flow and the temperature, which devices are connected in the piping circuit, the closed system may be arranged in the same manner as outlined for the open.

For the air-cooled type of transformers, a ventilating system should be arranged which will provide a volume of air sufficient to carry off the heat generated at maximum load. If conditions are such that this ventilation cannot be produced satisfactorily with natural draught, a blower should be provided, with necessary passages to the transformer compartments.

All stations that have oil insulated transformers should have some provision for filling and emptying the tanks. As this has to be done only at long periods of time, a comparatively simple outfit will suffice.

A vacuum pump, power operated if possible, that can be used to exhaust air from transformer tanks while oil is being pumped in, gives the most nearly perfect results. Owing to the difficulty of getting a sufficiently good vacuum to draw oil into the transformer to the required height, a force pump should be provided for use in conjunction with the vacuum pump. Excellent results can be obtained in this manner, only a small amount of trouble being necessary to make the connections tight on the transformer. When filling transformers for high voltage, should the weather be damp, it is good policy to pass all air which enters the barrels from which the oil is being taken, through calcium chloride to prevent the introduction of water.

To empty oil from the transformer tanks is a simple matter if the station is built with the floor well above the grade, or if a basement is provided. Pipes can then be connected to the bottom of each transformer outlet, and through these the oil can be run to barrels or a tank as desired. If, however, the transformers are not in a proper position for being emptied directly by gravity, a force pump with a short length of hose may be attached to the transformer outlet, and the oil pumped to the storage. When three or more transformers are installed in the same room where the floor is on the ground at grade, they can be piped to a common header buried beneath the floor, and through this header oil can be run to a pit large enough to hold a barrel of the size commonly used in shipping transil oil. Above this pit, supports for a fall should be arranged for handling the barrels.

For the second class of transformer substations, the remarks concerning the power line, arresters and high tension switching system of the first class will apply with some modifications, these modifications being along the lines suggested by the smaller capacity of the station. This second class of substations naturally includes those which must be operated from a line of small capacity, whether it be from a small generating plant or from a branch of a line of large capacity, thus making the controlling features of the arrangement much more simple and direct.

The same care should be used in regard to all wiring and connections as in the case of the more complicated installations, such as the spacing of high tension leads, distance to ground, insulators and insulating, line entrances and anchorages, and the location of lightning arresters.

The station may consist of a small building erected expressly for the purpose, or of a room partitioned off in an existing building. If the latter is the case, or if the whole of an existing building is to be used, the manner of bringing in feeders will be likely to have some influence on the arrangement of the apparatus. Where the walls are of a sufficient height to permit the lines being brought through so that it is possible to locate disconnecting switches, lightning arresters choke coils, etc., high enough to be clear of other apparatus, the arrangement should be simple, straightforward and compact; but if the building is low, so that a tower or dormer must be used in order to get the entering lines far enough above the ground to be safe, there will generally be complications in wiring which will make it necessary to occupy considerably more floor space in order to render the installation safe and convenient. Since a single line will probably be considered sufficient for an equipment of this capacity, a hand-operated oil switch, with automatic trip for opening the circuit in case of emergency, will be satisfactory. From this, connections may be made directly to the transformers, all wiring being open and supported by porcelain insulators mounted on the walls or pipe framework. In case there are two or more banks of transformers, the introduction of additional oil switches and buses may be found necessary.

If the entire output of the transformer station is required for a single service, such as an electric furnace, the secondary connection from the transformers should be run directly to the carbon holders of the furnace, as this method requires only the simplest arrangements in the way of supports, and for control.

On the other hand, if power must be distributed to a number of points, and if it is important that the chances of interruption be reduced to a minimum, a low tension bus should be conveniently located, from which power may be taken, through oil switches, to supply the various feeders. If feasible to do so, the wiring between the transformers, buses, oil switches, and the out-going feeders should be open, as it can be much more economically installed, and is less liable to give trouble than if carried a portion of the way through conduit.

The method of leaving the building with the low voltage feeders will be largely dependent on the type of service, while lightning protection must be provided to suit each individual case. If the voltage is fairly high, say 2,300 to 6,600, with the lines overhead and long distances to feed, arresters should be used; while if the lines are in conduit, static dischargers should be installed. In either case, the protective devices should be mounted with good air spaces all around them, and should have knife switches for disconnecting them from the line. With lower voltages and short feed, the mounting of arresters is a simple matter, and they can generally be well placed with switchboard apparatus.

A few general principles may be added, which, if consistently followed, will largely aid in producing good results.

1st. So arrange your station as to get free operating space and maximum safety to operators, and progress always in one general direction from the point where power enters the station to where it leaves.

2d. Every piece of apparatus should be easily accessible, and so placed that it can be removed without serious interference from the other machinery and fixtures. The wiring should be done so that when one piece of apparatus is removed only those wires which are actually connected to it need be disturbed.

3d. Piping for oil and water to transformers should be placed where it will be clear of apparatus, and so arranged that any transformer may be cut off and removed without interfering with the operation of the others.

4th. Lastly, make all line entrances so that they are good mechanically, and safe electrically.

THE TANTALUM LAMP

By F. W. Willcox

The tantalum lamp was the first metal filament lamp to dispute the supremacy of the ordinary carbon lamp. With the excellent efficiency of 2 watts per candle, it is a material improvement over the ordinary carbon lamp, which requires 3.5 watts per candle for the same length of life as the tantalum, when the latter is operated on direct current. This gives a saving of power with the tantalum lamp of over 40 per cent. for the same illumination, or as the tantalum is not made in sizes less than 20 candle power, a saving of about 35 per cent. over the ordinary 16 candlepower lamp of same life (800 to 1000 hours). This material gain in economy has given the lamp a good start in commercial lighting, and over 600,000 of them have been sold in this country. The lamp would have had a wider use but for certain limiting conditions.

In the first place, the tantalum lamp reached its development a little late, coming as it did at the time of the introduction of the GEM, or metallized filament lamp, which gave an efficiency of about 2.5 watts per candle at a cost of but 25 per cent. more than the ordinary carbon lamp, while the tantalum costs three times as much.

Secondly, the reduced life of the tantalum lamp on alternating current (about half that on direct current at ordinary frequencies, 60 cycles or less) practically limits it to direct current service, and this seriously restricts its field of application on central station lines where alternating current is used for the most part. Out of 4000 central stations in this country less than 300 have direct current service, and in number of lamps used, about 40 to 50 per cent. only are on direct current circuits.

Further, the relatively high cost of the tantalum lamp makes it impossible for central stations to supply free renewals as is customary with carbon lamps. This naturally restricts its use among central station consumers, many of whom hesitate to adopt a lamp for which they have to pay when they can get free lamps, even though a clear saving of 20 to 30 per cent. in current, and an increase of 25 per cent. in illumination can be secured. This has necessitated a great deal of advertising and soliciting work to introduce the tantalum lamp.

In spite of these limiting conditions, the tantalum lamp has been quite extensively employed in this country since its introduction a year and a half ago. Most of the lamps have been of the 50 watt (25 candle power) and 40 watt (20 candle power) sizes. An 80 watt size is also made, which is used as an incandescent unit with the No. 2 size holophanes. The 40 watt and 80 watt lamps are supplied in the Meridian bulbs, also. The complete line is illustrated in Fig. 1.

The lamp has been received best in central station service where the central station does not supply free renewals of carbon lamps, as customers of such stations, accustomed to buying their lamps, will more readily purchase and try the tantalum. There are, however, relatively few of the direct current central stations that charge for renewals of carbon lamps.

The early difficulties in the manufacture of tantalum lamps have now been entirely overcome, and the present lamps are giving excellent life and very satisfactory service.

The average life on direct current service runs well beyond the guaranteed figure of 800 hours, with many lamps lasting for 1200 hours and more. The life on alternating current service, as is well known, is below that on the direct current. The alternating current life varies with the frequency in about the following ratio:

Frequency	Per Cent. of D.C. Life
25 Cycles	58%
37 Cycles	46%
60 Cycles	31%
133 Cycles	7%

ordinary socket installations. It will therefore probably share in the increased demand for high efficiency lamps created by the tungsten, and be used as a supplement to the latter in locations where it would not be desirable or practical to employ the tungsten.

A large part of tantalum lamp installations has been made on isolated plants. Its most successful service has been given on such plants in relieving overloaded apparatus, and in giving additional illumination without any increase of plant.

40-Watt Regular 80-Watt Regular 80-Watt Meridian 40-Watt Meridian

Fig. 1. Tantalum Lamps. 2/5 Actual Size

The 40-watt tantalum lamp is naturally the most popular one, since it saves 10 watts (1 kw. hour for every 100 hours of service) over the ordinary 50-watt carbon lamp, and thus pays for its added cost in four to five hundred hours of service at ordinary rates.

Considering its economy, brilliant quality of light, and present excellent life performance on direct current, the lamp should have a wider use. What effect the introduction of the tungsten lamp will have on the tantalum, only time can tell. Present appearances would indicate that it will help to extend the use of the tantalum lamp in the smaller sizes. The tantalum lamp will form a good adjunct to the tungsten, as it is more substantial, cheaper, and more adaptable to the

The tantalum lamp is of particular value in train lighting service by reason of its high efficiency, and also because it is substantial enough to stand the vibration and rough service. It can be supplied in 10 candle power size, for 30 and 60 volts, in 2 $\frac{3}{16}$ in. round bulb, and makes a very attractive lamp.

A successful example of the tantalum lamp in central station work is to be found at Muncie, Indiana, a city of 30,000 inhabitants. Provided with an abundant supply of natural gas, distributed by five or more separate companies, and with a widespread use of individual gasoline plants, the electric company has found the use of tantalum lamps a great aid in increasing and holding its customers. Over 10,000 50-watt, 25 candle tantalum lamps have been put into service out of a total amounting to the equivalent of 32,000 16 candle power lamps. Every one of these lamps was sold at 60 cents each, as compared to carbon lamps at 15 cents.

About one half of the tantalum lamps installed are used on a flat rate basis under a two year contract. This rate of 60 cents per month for each 50 watts connected yields an annual income of $144.00 per kilowatt connected. The use of the tantalum lamp, in conjunction with an agressive campaign for business, has assisted to increase the connected incandescent lighting demand 23 per cent. for the past year, in face of most severe competition.

In the lighting of office buildings in the larger cities, such as New York and Boston, the tantalum lamp has proven of marked value. Many such buildings have overloaded lighting plants, or need increased lighting capacity, but do not wish to make additions to their plants, as, aside from the expense involved, it is not possible or practicable in many cases to obtain the additional space required.

Furthermore, the modern office building and hotel must to-day provide a liberal and high grade illumination, and the tantalum lamp gives the distinctively brilliant and attractive quality of light required.

The following large buildings have installed full equipments of tantalum lamps and are realizing benefits in reduction of load and greatly improved illumination.

The Park Row Building, New York City, has 5000 40-watt, 20 candle tantalum lamps in use. In place of the former insufficient and indifferent lighting, the building tenants now enjoy ample illumination of brilliant quality, while the peak of the load has been reduced from 2000 amperes with carbon lamps to 1200 amperes with tantalums. The average saving on the entire load with tantalum lamps is 13 per cent., with a gain of 20 per cent. in illumination.

The Broadway and Maiden Lane Building, New York City, has 6000 40-watt, 20 candle tantalum lamps in service. By reason of other tall buildings which have recently been built around this structure, much natural light has been cut off. This has resulted in an increased demand for electric light, and the use of the tantalum lamp has saved the plant from an otherwise considerable overload.

The Land Title & Trust Co. Building, of Philadelphia, will install over 10,000 40-watt tatalum lamps, saving thereby the expense and trouble of an additional generator.

A most interesting case is the installation of 10,000 40-watt tantalums in the superb new building of the Metropolitan Life Insurance Co., Madison Square and 23d St., New York City. This building is of notable interest by reason of its magnificent and imposing tower, which rises well above that of any other building structure in the world, out-capping even the Singer tower in its sky line. The picture of this building and its massive tower gives an idea of the magnificence of the work as an architectural and engineering feat, and of the striking and artistic effect of the struc-

Fig. 2. Tantalum Lamp for Train Lighting. 10 c.p.

ture as a feature of Greater New York. The building itself occupies an entire block, with a total floor area of 25 acres. The tower just now being completed is the final crowning of the edifice, giving the highest and most massive structure of the kind in the world. Its location opposite the open square of Madison Square Park is a most fitting and fortunate one, as it enables the tower and building to be viewed in full prospective without the obstructing and dwarfing effects of closely adjacent buildings, as in the case of the Singer building tower. Says the *Owners and Builders Magazine:*

"The plans for the building of this tower suggests the famous Campanile, which, for centuries, dominated the sky line of Venice; but two Campaniles might be placed one on top of the other, and they would not be as high as the Metropolitan Life tower. This same comparison may be made with the Madison Square Garden tower. The Metropolitan Life tower will overtop the Singer building in all of its measurements. The Singer tower is 674 feet in height, measuring from the basement to the top of the flagstaff; the Metropolitan tower will be 680 feet from the cellar floor to the top. Measuring from the sidewalk, the new skyscraper on Madison Avenue will be 658 feet, while the Singer tower is but 612 feet to the roof of the topmost lantern, not including the flagstaff. The Singer tower has 47 stories; the Metropolitan structure will have 48 above the sidewalk. The highest lookout in the Singer tower accessible to the public will be the lantern balcony. People looking down from it on the city will stand on a platform 589 feet above Broadway. The highest point for observation in the Metropolitan tower will be the window over the lookout, which is 633 feet above the sidewalk. The difference of 44 feet between the Singer and Metropolitan tower is about the height of the average four-story dwelling house.

Fig. 3. Metropolitan Life Insurance Building

The Singer tower, which is 65 feet square and 47 stories high, weighs 18,365 tons. The gross weight of the Metropolitan tower will be 84,000,000 pounds, or 37,333 tons. It is, however, 10 feet wider than the Singer tower in one direction and 20 feet wider in the other. The difference in weight is also largely accounted for by the fact that the walls of the Metropolitan structure will be of marble from top to bottom. The Singer tower has corners of brick and terra cotta, and central panels of metal and glass.

Engineers usually regard wind pressure of 35 pounds to the square foot as ample for the big skyscrapers. But the conditions which surround the Metropolitan tower are unusual. Standing on a corner and facing Madison Square, with no neighboring towers to break the force of the wind, it is in a sense isolated, and must be self sustaining. The engineers, therefore, in their calculations, increased the allowance for wind pressure from 35 to 60 pounds for the square foot. This will allow for a higher wind than has ever yet been experienced in New York.

The 1,400 windows which will pierce its walls would be sufficient for sixty dwellings of the average four story type.

The building of the Metropolitan Life tower will require 8,135 tons of steel—enough for seven twelve-story skyscrapers, covering a site of the same size, 75 by 85 feet. The lower pillars are remarkable for their weight and dimensions. The corner columns, 38 inches square, weight a trifle more than a ton for every square foot.

In the building of this tower more than 40,000 barrels of cement will be used. Much of it will go into the floors, which will be different from those of the ordinary skyscraper, the latter usually being of terra cotta blocks, held together with cement. In all, 9,000 cubic yards of concrete and fire-proofing will be required for the tower.

At the twenty-fifth, twenty-sixth and twenty-seventh stories, or 334 feet above the sidewalk, there will be a great clock, which will prove a seven-days' wonder for New York and her visitors from foreign shores. This clock is indeed a marvel, in the way of size at least. Its face will be twenty-five feet in diameter, its hands twelve feet in length, and the figures marking the hours and minutes four feet long. It will be possible to tell the time by this monster clock miles in the distance, and the height at which it is to be placed will enable it to show above the surrounding houses, so that it will be of service to persons living far away from its location. There will be four dials, one on each side of the tower, so that every point of the compass will be served by the big clock.

For the transportation of visitors to the several floors of the tower, six express elevators will be installed. Five of these will terminate their trips at the forty-first story and the sixth at the forty-fourth story. The twelve lower stories will be served by the elevators in the adjoining section of the main building, the present elevator corridor giving direct access to the tower. All motive power, heat and light will be supplied by the plant now installed in the main building.

The estimated cost of the erection of this marble tower is placed at about $3,000,000. The ground represents an investment of nearly $1,000,000. To this fully $2,000,000 must be added as the cost of the tower itself. The steel in the structure alone will cost $250,000.

The general dimensions of the great tower are shown in the following table:

Frontage on Madison Ave.	75	feet
Frontage on Twenty-fourth St.	85	"
Height above sidewalk	666	"
Height from cellar floor to top	688	"
Total height from foundation to grillage beams	698½	"
Height of clock face above sidewalk	346	"
Height of loggia floor above sidewalk	392½	"
Top of loggia balustrade and offset level above sidewalk	453	"
Floor of lookout (45th story) above sidewalk	603	"
Center of window over lookout (highest point for observation) above sidewalk	633	"
Tonnage of iron in tower, equal to the entire tonnage of metal in balance of building	8,200	
Number of stories above sidewalk in tower	48	
Number of stories below sidewalk in tower	2	
Total number of stories in tower	50	
Number of cubical feet in tower	3,515,493	
Total net rental floor area, tower (exclusive of walls and corridors)	153,359	
Number of cubical feet in Metropolitan building (exclusive of tower and courts)	12,771,541	
Grand total of cubical feet in Metropolitan building	16,287,034	
Grand total floor area Metropolitan building (about 15 acres)	1,085,663	

SOME FACTORS AFFECTING STATION CONNECTIONS AND SWITCHING ARRANGEMENTS

By R. E. Argersinger

Power and Mining Department, General Electric Co.

In laying out an electrical plant, after determining the number and size of generating units, the general character of the service, and the number of out-going feeders, the next point to be considered is the general system of connections.

Generating stations may be divided into two classes, the first class comprising those stations in which power is generated and distributed at the same voltage. These stations are rarely operated at voltages higher than 13,200, and may be sub-divided into two groups:

(a) Where a small amount of power is to be transmitted to a moderate distance; and,

(b) Where a large amount of power is to be distributed in the immediate vicinity of the station.

The first group is of no particular interest, as far as station connections go, since stations in this group will usually include only one or two machines, with one, or possibly two transmission lines. Group (b), however, covers a large number of plants used for lighting and railway purposes, which usually contain a number of generators and a larger number of outgoing feeders. It is also important in this class of service that the power supply be continuous under all sorts of conditions, and, consequently, elaborate switching arrangements are installed.

Since it is the purpose of this article to discuss briefly only stations for general power service, we wish to point out only one or two interesting features in connection with the general class under (b).

In small plants, one main operating bus, on which all the machines are paralleled, and from which all the feeders are tapped off, is generally sufficient; but when the number of machines becomes large, and especially when a considerable number of feeders are required, it is necessary to install two buses, and in some cases even three or four. The Edison systems are good examples of this procedure. By means of these multiple buses it is possible to subdivide the service; operate different feeders at different voltages; confine all operations to one bus in case of trouble on the other; or to inspect or clean the bus or switches connected to it. In order to obtain the maximum flexibility from a multiple bus arrangement, it is necessary to connect each unit, or each feeder to each bus, through an oil switch so that all switching can be done under load. In some cases, however, where the cost of this large number of oil switches is prohibitive, disconnecting knife switches may be used, which will serve to connect the generator or feeder to the bus after the current is cut off by means of a single oil switch. A second important point in connection with the feeder arrangement is the use of group switches; *i. e.*, switches which are used as ties between the bus and a group of feeders, numbering perhaps four or six, or even more. Such a switch serves to conveniently operate a number of feeders which may supply an interconnected service, or to separate feeders subject to similar operating conditions; and also, in case of trouble in the station, it affords a means of more rapidly disconnecting the load than if each feeder switch had to be tripped individually. In many cases, in stations of this character, a benchboard is of considerable advantage over the vertical panel board. A benchboard allows the control to be confined within a small space by means of electrically operated switches, and consequently increases the convenience of operation. It may happen, however, that the number of instruments is very large compared with the number of switches, and consequently, that the panel board supporting the meters is much more extensive than the benchboard taking care of the control, with the result that when the operator stands at the bench he is too far from the meters on the circuits controlled to read them conveniently. In such a case a bench is of no advantage over the panel board.

The second class of generating stations includes those in which the voltage is stepped up by means of transformers, and the station output distributed over a comparatively small number of lines. This class of stations covers practically all of the large power developments. The simplest arrangement of connections for such a plant can be used when the number of generators, transformers and outgoing lines are the same. This system is commonly called a unit system. Under such conditions each unit, consisting of its line, transformer and generator, will ordinarily be operated independently, and a bus arrangement, sufficient only for transferring from one line to another, or from one transformer to another in case of emergency, is all that is necessary. The most common modification of this system is found in the station where the number of transmission lines is less than the number of transformer banks. This arrangement necessitates the use of a high tension bus on which the transformers may be paralleled, and from which the outgoings line may be taken. If the number of transformer banks does not greatly exceed the number of lines, a single bus should be sufficient, although it will usually be found convenient to sectionalize this bus at such points as will serve to isolate certain portions of it for repairs or cleaning; or in order to isolate a line (which may have broken down electrically), with certain transformers and generators, in order to test it before again placing it in service.

If the number of lines is small compared with the number of transformers, a single high tension paralleling bus is insufficient, since the bus then becomes a very important operating feature, and it is hardly safe to trust to a single bus for the continuous operation of the station. The most flexible arrangement is the duplicate bus, each bus being connected to the lines and to the transformer banks through oil switches. The lines or transformers can then be connected to either bus without interrupting the flow of current. The expense of this arrangement may be reduced by placing an oil switch in the line and one in the transformer circuit, and connecting them to either bus through an air break switch. This still allows any line or transformer to be connected to either bus, but the switching must be done at no load. A still cheaper arrangement consists of a "ring bus;" *i. e.*, a single paralleling bus sectionalized between each group made up of a line and the transformers directly feeding it, the two outer ends of the bus being connected together through an oil switch. This involves practically a second bus running across the station, but eliminates the cost of the additional set of switches required by the ordinary duplicate bus. In some cases it may be feasible to make this ring connection outside the station. This bus arrangement allows any section to be cut out without interfering with parallel operation, and, by proper low tension bus connections, the generators feeding the section cut out may usually be transferred to other transformer banks, the overload capacities of which should be sufficient to carry the entire station output until the high tension bus section can be again put into service. The ring bus, to be of any advantage, must be operated with at least three (preferably more) transmission lines in parallel.

The arrangement of low tension buses will depend to a great extent on whether or not there is any low tension distribution. If considerable power is to be distributed in the vicinity of the station at the generated voltage, it will often be found advisable to use a double set of low tension buses so as to separate the local power from that to be distributed at the high tension voltage. The generators on the buses should be separated accordingly, since the requirements of voltage control on low tension feeders often necessitate special regulation for the low tension distributing bus, which regulation does not apply to the power transmitted at the high voltage.

The double bus also allows the isolation of any generator and the low voltage side of any transformer bank for purposes of testing, as mentioned above, or the operation of any transformer bank with any generator. In order to accomplish the two latter results with only one bus, a transfer bus is often used. This consists of one bus connected through a switch to the line between the generator and transformers. By keeping at least one generator always connected to such a bus, it will also serve as a source of low voltage power for station purposes. Where the number of generators and transformer banks is the same, the transfer bus allows more flexible operation than a single bus to which all generators and transformers are tied directly in parallel. If the units are of large capacity it will usually be of advantage to make the connection to the transfer bus through an oil switch, so that any switching which is necessary may be done under load; and further, by using an electrically operated switch it may be operated from the main control board. In the case of smaller stations, however, and where the service is such that the switch will have to be used only infrequently, a knife switch will usually be satisfactory. This is advisable, especially where transferring is to be done for testing purposes only, or for similar purposes.

Where the number of lines, transformers and generators are all different, it is necessary to have both high and low tension buses, and to operate the generators in parallel on the low tension bus and the transformers in parallel on the high tension bus. If any transferring is to be done on the low tension side, a double bus is necessary. If it is expected to use the double bus only in cases of testing or emergency, it will usually be sufficient to install one oil switch in the generating circuit, with knife switches leading from it to each bus, a similar arrangement being used on the low tension side of the transformer bank. If, however, the double bus is expected to be used frequently, or if the units are large, or if there is considerable local service, it will be advisable to use oil switches for connecting the generator and transformer circuits to each bus, a disconnecting switch being used to isolate the generator and transformer from the bus tie line.

Any double bus arrangement, for either high or low tension, is expensive, not only as regards the bus itself and the space taken by it, with the consequent increase in the size of the station, but also because of the large increase in the number of switches which it necessitates. Therefore, the actual need of a double bus should be carefully considered before it is installed.

In considering the switching arrangements for any given station, the character of the automatic control is an important feature. While outgoing feeder switches are nearly always automatic on overload, it is usually of advantage to have a time element in connection with such automatic operation so that the line switches will not be tripped in case of a slight ground or similar momentary trouble. Consequently, the automatic switches on outgoing lines are usually equipped with time limit relays. The switches controlling the high and low tension sides of transformer banks should also be automatic in order to cut out a bank of transformers in case of internal troubles. Where transformers are paralleled on the high and low tension sides, if three or more banks are installed they may be isolated by the use of inverse time limit relays, since in case of trouble in one bank the current will be fed into the disabled transformer from the two banks still in operation. As the current flowing through the relays on the bank in trouble will be twice that in the relays on the other banks (assuming three transformer groups), the inverse feature of the relays will operate the switches on the bank in trouble before the switches on the remaining two banks open, so that the disabled bank will be cut out without shutting down the station. If only two transformer banks are in parallel, the inverse relay will not be effective, since the current operating both relays will be the same. In such a case a differential reverse current relay must be employed, connected to current transformers on either side of the main transformer bank. This relay will not operate as long as the power is fed through the bank of transformers in its normal direction, but in case of trouble the current flow from one side of the transformer bank will be reversed, with a consequent operation of the relay and opening of the switches on both sides. As a rule, generator switches are non-automatic, in order to avoid their automatic opening in case of heavy overload, or line or transformer trouble. Such an opening would mean the necessity of synchronizing all the generators after any severe overload a condition of affairs which would be very inconvenient. The only objection to this arrangement is, that in case of short circuit in the generator wiring, or in the low tension bus, there is no means of automatically cutting off the machines; but such trouble is so rare that the disadvantages of automatic switches more than outweigh the objections against the risk due to making these switches non-automatic.

It should be borne in mind in laying out any system of station connections where high voltages are used, that metering should be confined to the low tension circuit just as much as possible. Instrument transformers for high voltages occupy considerable space, and are very expensive. Series relays have been developed so that automatic switch operation can be obtained without installing high voltage current transformers, and series ammeters are also being used to some extent as current indicators, placed directly in the high voltage outgoing lines. Under such circumstances, the necessity for high voltage current and potential transformers should be very carefully weighed before an arrangement is made calling for their use.

The above remarks apply, in a general way, to sub-stations as well as to main stations, especially in the case of large distributing sub-stations taking power from a long transmission line. In connection with smaller stations, however, there are one or two points to which attention might be called. Where only one station is fed from one transmission line, specifications are sometimes drawn up calling for oil switches to control the incoming line. Usually there is an oil switch at the generating station end of the same line, with the result that two switches are unnecessarily in series. The sub-station line switch should, in such a case, be of the open air break type, allowing all automatic switching to be done on the main station switch.

When small sub-stations are tapped off from transmission lines, the character of the incoming line switch should be given careful consideration. If, as is usually the case, there are a number of these small sub-stations feeding from the same line, it is not desirable to allow any trouble on one of the sub-station feeders to open the transmission line switch in the main station. To avoid this, the automatic switch on the sub-station incoming line must be of sufficient capacity to rupture the entire kilowatt capacity back of the transmission line. This may mean an oil-switch with a rupturing capacity of say 20,000 kw., in a sub-station of only 400 or 500 kw. output. In such a case the use of high tension expulsion fuses is to be recommended. These fuses are considerably cheaper than the oil switch of corresponding rupturing capacity, and as they are only expected to operate automatically under emergency conditions, they are very satisfactory. By properly protecting them they may be installed on the outside of the station, with a consequent saving in the sub-station area.

In general, any system of connections should be decided upon only after a careful consideration of the service which the station is expected to supply, and of the arrangement of the generating units. As in all other engineering problems, the relative advantages of flexibility obtained from any arrangement must be balanced against the expenses involved in obtaining such advantages.

TURBINES AS DRIVERS FOR CENTRIFUGAL COMPRESSORS AND PUMPS

By B. F. Bilsland

Power and Mining Department, General Electric Co.

Centrifugal compressors and pumps are so called because the pressure which they impart to a gas or liquid is due to centrifugal force. On account of the relation existing between centrifugal force, speed, and the radius of the path of rotation, such compressors and pumps can be most economically built with small diameters, for operation at high angular velocities. Therefore, direct connected prime movers, when used for driving such machines, must be of extremely high speed. The steam turbine is especially applicable to such work on account of the high speed at which it normally operates, and because of its compactness, and uniformity of rotation.

The General Electric Co. has recently developed a line of high speed steam driven compressor sets, and has also furnished several turbines for direct connection to centrifugal pumps, some of which will be described in the course of this article.

The turbines may be condensing or non-condensing, for high or low pressure, just as in the case of prime movers for electric generators; although the most simple and inexpensive, and consequently the most widely used machine for this work is the high pressure, non-condensing turbine.

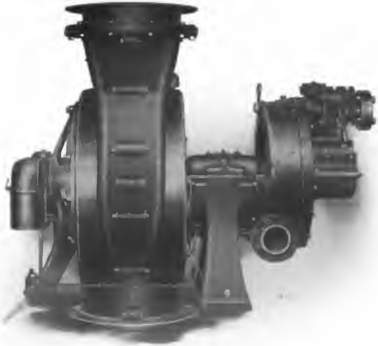


Fig. 1. Curtis Turbine Driven Air Compressor

There is, however, a large field for the application of low pressure turbines to the driving of compressors and pumps, as there are many plants operating with reciprocating engines where a compressor or pump driven by a low pressure turbine could be installed and operated with practically no expense except the initial cost.

The turbines are of the horizontal Curtis type, which was described in the May Review by Mr. R. H. Rice; it is therefore unnecessary to give a description of their construction or operation in this article.

The compressors are even simpler than the turbines, each unit consisting of only casing, impeller, bearings, and guide vanes. The air in entering is conducted to the center of the impeller, scooped up by the impeller blades, and thrown into either the guide vanes or outward channel of the compressor casing. Higher pressures than can be produced economically by one such unit or stage are obtained by operating several units in series, as is done in the multi-stage centrifugal pump.

Fig. 2. Turbine Driven Centrifugal Compressor and Motor Driven Blower in Gas Plant

Owing to the wide range of the turbine speed, any reasonable variation in pressure can be obtained by an adjustment of the turbine governor. This is of great value in some installations. As the turbines that are used for driving these compressors were originally designed for driving electric generators, they are arranged with a closely regulating governor, with the result that a very steady pressure is maintained by the compressor.

While the turbines are capable of giving close regulation and steady pressure, they are of equal value for driving compressors operating on an intermittent service, as the rotating element may be brought up to speed as fast as the friction can be overcome and the necessary energy transmitted to the element. In the case where first cost is an important factor, regulation and economy may be sacrificed by arranging the turbine with a simple throttle governor.

The compressors which have been laid out and considered as standard, range in capacity from 750 to 10,000 cu. ft. of free air per min., with a normal pressure of 0.88 lbs. to 2.7 lbs. per sq. in., and a maximum pressure of 1.5 lbs. to 4.2 lbs. per sq. in. Compressors are being developed, however, which will deliver a pressure of 30 lbs. per sq. in.

A typical turbine driven compressor is shown in Fig. 1. This compressor is rated at 7000 cu. ft. of free air per min., compressed to a pressure of 0.88 lbs. per sq. in. It is driven by a 50 h.p., 3500 r.p.m., non-condensing turbine. The duty of this compressor is to furnish air for making gas.

Fig. 3. Centrifugal Compressor and Positive Pressure Blower

Fig. 2 shows the set as installed by the Mohawk Gas Company, at Schenectady, N. Y. The compressor is shown supported at three points by iron brackets resting on I beams, which have lately been grouted in. The set was started and operated for some time, being supported wholly by the I beams with no grouting, and the operation was perfect. The users and operators are perfectly satisfied with the machine, and cannot speak too highly of it.

The compressor is operated without an inlet pipe connection, and some noise is caused by the air rushing into the opening; this will be entirely eliminated, however, when the permanent intake pipe is installed, the mouth of which is to be located outside of the building. The bearings are supplied by forced lubrication, arranged in the same manner as for our small turbo-generating sets, the pump being located at the outer compressor bearing and driven by means of a worm gear on the shaft.

A motor operated blower, driven by means of belts and shafting, is used as a spare unit, and is also shown in Fig. 2. It is needless to

Fig. 4. Motor Driven Positive Pressure Blower

compare the efficiency, compactness and neatness of the sets.

Leaving the turbine driver for a minute, a typical installation and comparison of our centrifugal compressor and positive pressure blower (constant volume) is shown in Fig. 3. These compressors are installed in the oil house at the Schenectady Works of the General Electric Company. The centrifugal compressor is rated normally at 1400 cu. ft. of free air per min., compressed to 1.7 lbs. per sq. in., and is driven by a 20 h.p., 250 volt, direct current motor of the turbo-generator type, the set operating at 3450 r.p.m. This set has been in operation some time, and has given entire satisfaction. The engineer who has these sets to look after, states that he can get a great deal more out of the centrifugal compressor, and that its pressure gauge, which consists of a column of mercury, is very much steadier than that of the blower. Practically the only attention this machine requires in operation is an occasional adjustment of speed by means of the motor field to compensate for variations in the line voltage.

Fig. 5. Turbine Driven Pump for New York City Fire Boat

The positive pressure blower, which is of approximately the same capacity, is driven by a direct current motor by means of pulleys, belts and shafting, as shown. The blower requires a large receiver tank to equalize the pressure and relieve the mains of pulsations and shocks. The receiver tank is entirely unnecessary with the centrifugal compressor, as the latter gives a constant, continuous pressure. Also, the space occupied by the receiver tank alone is greater than that required by the entire direct connected centrifugal compressor set. From the comparison and illustration, you can readily arrive at the relative costs of the two sets.

The installation shown in Fig. 4 is a further illustration of a positive pressure blower. This machine is installed in the iron foundry at the Schenectady Works of the General Electric Company. It is a typical installation, consisting of a mass of belts and pulleys, and occupies a large amount of space. The capacity of this set is approximately the same as that of the turbine driven set shown in Fig. 1.

There is no comparison between these installations in first cost, efficiency, space occupied, satisfaction of operation, and appearance. Another point where the compressor excels the old style blower is in its quietness of operation. While the centrifugal compressors make a slight noise, due to the impellers rotating at such high speeds, this is not of an objectionable nature, and is a small pumps for such speeds. That there is a large field for such sets is shown by the abundance of inquiries for turbine driven pumps.

The General Electric Co. has recently completed an important turbine pump installation on two fire boats for New York City. Fig. 5 shows one of the turbine driven sets, two of which have been installed on each boat. The pumps are rated at 4500 gals. per min.,

Fig. 6. Trial of Turbine Driven Pump for New York City Fire Boat

negligible quantity when compared to the noise of a positive pressure blower, occasioned principally by the belts, meshing of compressor parts, and driving gear.

In addition to compressors, the steam turbine is well adapted to driving high speed centrifugal pumps, and has been successfully applied to this work in several instances. It is sometimes difficult, however, to obtain a pump which will operate at a speed sufficiently high for the turbine to make its most favorable showing, since pump builders have not fully awakened to the advisability of building against a head of 150 lbs. per sq. in. The turbine is rated at 600 b.h.p., at 1800 r.p.m., operates condensing, and is of the four-stage type.

An automatic controlling governor is not used with these turbines, but instead they are arranged for hand control by means of five hand operated valves, each valve giving approximately one-fifth the maximum capacity of the turbine. The standard emergency governor and combined emergency throttle valve are employed, the emergency governor being adjusted to operate at 15 per cent. above normal rated speed.

These machines have met the guarantees made for them, and Mr. Croker. Chief of the New York Fire Department, has expressed himself as being very well pleased with them.

The pumps were given a trial test after installation on the boats. They were operated in series, and under these conditions threw two three-inch streams, at three hundred pounds pressure, as shown by Fig. 6 and the illustration on page 298.

These cuts are interesting from the point of general design of the fire boats, as well as from the fact that they show what actually takes place in case of a fire along the docks. A general idea is given, of the appearance of the towers, and in Fig. 6 the water main heads are clearly shown, from which an idea may be had of the number and size of hose which can be attached to them.

Another fire boat equipment is at present being completed for the Chicago fire boats. The general scheme and advantages of this installation were outlined by Mr. J. H. Clark in the August, 1907, REVIEW. One of these sets is shown in Fig. 7.

In general, each unit consists of a three-unit, three-bearing set, with a common bed plate. The driver is a two-stage, 660 h.p., 1700 r.p.m., condensing turbine of the overhung type, which is direct connected to a 200 kw. (maximum capacity), 275 volt, direct current generator of the turbo-generating type, and a 4500 gal. per min., 150 lb. pressure centrifugal pump. The turbine rotor and generator are mounted on a one piece shaft carried by two bearings. The pump is connected to the shaft and driven by means of a flexible weight carrying coupling, the pump bearing being located in the outer portion of the pump casing.

Each of the machines composing the set is of practically standard design, but the arrangement of the combination, and the scheme of operation is entirely new. The operation is described in Mr. Clark's article, as mentioned. Briefly it is as follows: The turbine drives both the generator and pump continuously, the former being used to generate power for the motors which drive the screws, and the latter supplying the water for fighting fires. The turbine is equipped with standard poppet valves, arranged for hand control by means of a cam shaft, rack and pinion. An emergency governor of the usual type is supplied. The bearings are supplied with oil under pressure, and are of the water-cooled type. Two of these sets are being tested at the Schenectady Works of the General Electric Co., and are giving satisfaction, both as to operation and efficiency.

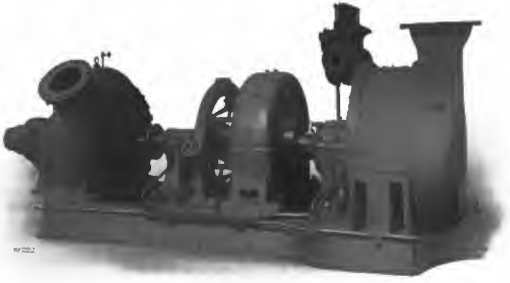


Fig. 7. Turbine Driven Generator and Pump for Chicago Fire Boats

LIGHTNING AND LIGHTNING PROTECTION

By Charles P. Steinmetz

With the change in the character, the size, and the power of electric circuits, the problem of their protection against lightning has also changed, and has become far more serious and difficult. Forms of lightning have made their appearance which did not exist in the small electric circuits of early days, and protection is required not only against the damage threatened by atmospheric lightning, but also against lightning originating in the circuits, and called "internal lightning," which is frequently far more dangerous than the disturbances caused by thunder storms.

The principal difference between lightning, in its broadest sense, and the normal flow of power in an electric circuit is, that lightning is the phenomenon of electric power when beyond control. It is therefore the same difference that exists between a useful fire and a conflagration; and just as we would hardly call a small bonfire a conflagration, so also we do not call electric power which is beyond control, lightning unless it is of destructive value.

Electric power, when getting beyond control, may mean excessive currents or excessive voltages. Excessive currents are rarely of serious moment, since the damage done by them is mainly due to heating, and even very excessive currents require an appreciable time before producing dangerous temperatures. Usually, circuit breakers, automatic cut-outs etc., can take care of heavy currents, the only damage done by such currents being when they occur at the moment of opening or closing a switch by burning the contacts, or where the mechanical forces exerted by them are dangerously large, as with the short circuit currents of the huge modern turbo-generators.

Excessive voltages, however, are practically instantaneous in their action, and the problem of lightning protection is essentially that of protecting against these excessive voltages, or electric pressures.

The performance of the lightning arrester on an electric circuit is therefore analogous to that of the safety valve on the steam boiler; that is, the function of both is to protect against dangerous pressures—steam pressure or electric pressure—by opening a discharge path as soon as the pressure approaches the danger limit. Absolute reliability in the operation of the device is therefore required, with a discharge producing as little shock as possible, and over a path amply large to carry off practically unlimited power without dangerous pressure rise.

Dangerously high pressures may enter the electric circuit from the outside, due to atmospheric disturbances such as lightning, or they may originate in the circuit.

Excessive pressures in electric circuits may be single peaks of pressure, or strokes, discharges, or multiple strokes, meaning by the latter several strokes following each other in rapid succession, with intervals between strokes varying from a small fraction of a second to a few seconds; or such excessive pressures may be practically continuous, that is, with strokes following each other in rapid succession, thousands per second, continuing sometimes for hours.

Atmospheric disturbances, such as cloud lightning, usually give single strokes, but quite frequently multiple strokes. As shown by the oscillograms of lightning discharges from transmission lines which were secured by Prof. Creighton last year, multiple lightning strokes are very common; therefore, to properly protect the system, a lightning arrester must be operative again immediately after the discharge, since very often a second and a third discharge follow within a second of time, or less. Consequently, a lightning arrester which depends on the operation of mechanical parts to reset itself after a discharge, fails to protect against a multiple stroke.

Continuous discharges, or recurrent surges; *i. e.*, lightning lasting continuously for long periods of time, with thousands of high voltage peaks per second, mainly originate in the circuits due to an arcing ground, spark discharges over broken insulators, faults in cables, etc., and are a phenomenon which has made its appearance only with the development of the modern high power high voltage electric systems, becoming of increasing severity and danger with the increase of size and power of electric systems.

Single strokes and multiple strokes, or in other words, all disturbances due to atmospheric electricity, such as cloud lightning, are safely taken care of by the modern multi-gap lightning arrester. As this arrester has been described repeatedly, it needs no description here beyond the statement that it comprises a large number of spark gaps connected between line and ground, and shunted by resistances of different sizes in such manner that a high pressure discharge of very low quantity, such as the gradual accumulation of a static charge on the system, discharges over a path of very high resistance, and is inappreciable, and frequently invisible. A disturbance of somewhat higher power finds a discharge path of moderate resistance, and so discharges with moderate current, without shock on the system; while a high power disturbance finds a discharge path over a low resistance, and, if of very great power, over a path of zero resistance. That is, the resistance of the discharge path with the present multi-gap lightning arrester is approximately inversely proportional to the volume of the discharge. This is an essential and important feature. Occasionally, discharges occur of such large volume as to require a discharge path of zero resistance, as any resistance at all would not allow a sufficient discharge to keep the voltage within safe limits. At the same time, the discharge should not occur over a path without resistance, or of very low resistance, except when necessary, since the momentary short circuit (short circuit for a part of the half wave) of a resistanceless discharge is a severe shock on the system, which must be avoided whenever possible.

This type of lightning arrester takes care of single discharges and of multiple discharges, with the minimum possible shock on the system, no matter how frequently they occur or how rapidly they follow each other. It cannot, however, take care of continuous lightning; *i. e.*, those disturbances, mainly originating in the system, where the voltage remains excessive continuously (or rather rises thousands of times per second to excessive values), and for long periods of time. With such a recurring surge, the multi-gap arrester would discharge continuously in protecting the system, until it was destroyed by the excessive power of the continuously succeeding discharges.

Where such continuous lightning may occur frequently, as in large high power systems, and where the system requires protection against them, a type of lightning arrester is necessary which can discharge continuously without self-destruction, at least for a considerable time. The only lightning arrester which is capable of doing this is the electrolytic, or aluminum arrester. In its usual form (cone type) it comprises a series of cone shaped aluminum cells, connected between line and ground through a spark gap. As soon as the voltage of the system rises above normal to the value for which the spark gap is set, discharges take place through the aluminum cells over a path of practically no resistance. However, the volume of the discharge which passes is not produced by the normal voltage on the system, but is merely due to the voltage over the normal, since the normal voltage is held back by the counter e.m.f. of the aluminum cells. As a result, with thousands of strokes per second following each other, or in other words, with a recurrent surge, the aluminum arrester discharges continuously. As it can stand the continuous discharge for half an hour or more without damage, it protects the circuit against continuous lightning for a sufficiently long time for the cause of the high voltage to be found and eliminated.

Even the cone type of aluminum arrester discharges with a slight shock on the system, since the voltage must rise to the value of the spark gap before the discharge begins; therefore, in systems where even a small voltage shock is objectionable, as in large underground cable systems, and also in cases where it is necessary to take care of recurrent surges for an indefinite time, the no-gap aluminum arrester becomes necessary. In principle, this type is the same as the cone type, but the aluminum cells are connected between the conductors and the ground without any spark gap, and are continuously in circuit, taking a small current. For this reason the cells are made larger and of different construction, so as to radiate the heat from the current, which, while small, would still give a harmful temperature rise if allowed to accumulate. Being continuously in circuit, a no-gap aluminum arrester allows no sudden voltage rise whatever. Its action is similar to that of a fly wheel on an engine—while it allows gradual changes of voltage, any sudden change of voltage is anticipated and cut off, just as any sudden change of speed in an engine is checked by the fly wheel. The no-gap aluminum cell, therefore, can hardly be called a lightning arrester, but rather fulfills the duty of a shock absorber, or of an electrical fly wheel, on the voltage of the system, and as such finds its proper place on the busbars of the station or substation.

CARE AND INSPECTION OF LIGHTNING ARRESTERS

By V. E. Goodwin

Power and Mining Department, General Electric Company

The fact that no piece of apparatus in an electrical transmission system has a more difficult function to perform than the lightning arrester equipment, is very often overlooked by operating and designing engineers. Lightning arresters are frequently placed in the most inaccessible places, and as a rule are never inspected or adjusted after their installation. These arresters operate satisfactorily for a few months or a year, and then perhaps suddenly fail to extinguish the dynamic arc, and shut down the system. These failures at present represent only a small per cent. of the total number of arresters which the General Electric Co. has installed, but I believe they could be reduced to an inappreciable number if proper care and inspection were given the arresters, provided, of course, that proper arresters have been installed to meet the requirements of continuous lightning.

A few operating companies have realized the importance of proper inspection of arresters, and have a specialist on protective apparatus whose duty it is to examine the lightning arrester equipments systematically, and to report the results of each storm or lightning disturbance on their system.

To be complete, this report should contain at least the following items regarding each storm:

1. Date of each disturbance.
2. Cause and location of the trouble.
3. Interruptions to service, time and location.
4. Damage to apparatus, giving location and name of apparatus damaged.
5. Action of the arrester. (See note below)
6. Estimated protection afforded.
7. Condition of telephone service.
8. General comments.

In making reports special attention should be given to the nature of the lightning, as described elsewhere in this issue by Dr. Steinmetz. In every case it is important to determine if any accidental grounds occurred on the system, and when possible, if the principal disturbance was a primary or secondary effect of lightning.

Once each year a general report should be made out containing a summary of the reports on individual storms. This annual report should be carefully compared with those of previous years, noting especially any increase in the size of the system, and the character of the new apparatus; also, a comparison of the interruptions and damages to apparatus, and of changes, if any, in the lightning protective devices.

The action of the arrester should be intelligently and carefully studied. This can best be done by means of tell-tale papers placed in various sections of the arrester. For this purpose a specially treated fireproof paper should be used. These papers allow punctures of various sizes, depending upon the amount of discharge, but will not take fire and burn up as is often the case with the ordinary test papers.

It is of the utmost importance that arresters of any type be examined systematically every day, and also after every electrical storm or discharge. The punctured test papers should be collected at the same time and carefully filed. It should also be seen that there are no loose connections, and that the gaps are in proper condition. Since the knurled points along the gaps burn away with a number of discharges, the cylinders should be occasionally turned on their spindles so as to present new surfaces for discharge. Arresters should be kept free from dust, which may accumulate in the gaps or on any of the working parts. If a compressed air jet is not available, a pair of hand bellows will be found convenient for this purpose.

All repairs on arresters should be made promptly, and no arrester should ever be reconnected to the line in a damaged condition. Direct current railway arresters are probably given less attention than even the high voltage types. The type of apparatus used for this service has a very much lower puncture value than that used for high voltage service, and it is therefore imperative that these protective devices be more properly adjusted and inspected.

One of the great advantages of the aluminum cell arrester lies in the fact that it is tested daily. This operation not only keeps the films in perfect condition, but gives the attendant an accurate indication of the operating condition of the arrester.

"NAVIGATING THE AIR"

The Schenectady Section of the American Institute of Electrical Engineers gave a new distinction to its winter series of lectures on the night of March 19th. The subject selected, "Navigating the Air," was ably treated by Mr. Augustus Post, the well-known aeronaut, who was aide to Alan R. Hawley, pilot of the "St. Louis" in the Gordon-Bennett race at St. Louis. It will be remembered that this balloon remained in the air over thirty-six hours, and traveled seven hundred and eighteen miles. Mr. Post divided his lecture into three heads: History of aeronautics, balloons, and aeroplanes. In a brief review of the historical side of ballooning, Mr. Post referred to the important work done by the balloon at the siege of Paris. Here it was the only medium of communication between the besieged and the outside world, the railroad stations being turned into balloon factories. Sixty-two ascensions were made, and two and a half tons of letters were carried. In describing "What we do in a balloon," Mr. Post said: "The matters of food and clothing became of the utmost importance. We had condensed meat tablets, chocolate and soups in tins, with lime packed around them so that when you put water on the lime it slaked and heated the inner can to the point of boiling. We had to keep a very careful lookout as to where we were going. One problem ever present was that of crossing the Great Lakes. With a steady wind that might easily be done, but if they loomed up when your ballast was nearly exhausted, and in almost calm weather, the drifting slowly over the water would be beset with difficulties and unpleasant risks. Then again one had to be ready for all sorts of changes in temperature. Thermos, bottles, blankets, tin pails, and water proof bags to pack things in were a part of the equipment. There was precious little sleeping done, as observations of various kinds had to be taken every few minutes. As a matter of fact, we did not get any sleep from half-past six Monday morning until ten o'clock Wednesday night. We had an omen of good luck in starting, for a dove alighted on the top of the balloon and sailed away with us for quite a distance. We had supper about midnight. This consisted of hot soup, sandwiches, and hot coffee, eaten with an appetite that was nothing short of superb. Then, wrapped up on our blankets, we were at peace with all the world, and the balloon rode on. No one can quite realize the beauty of a night passed under the great starlit heavens, with the brilliant moonlight making everything as bright as a silver day. As you sail suspended between earth and sky, it seems as if you were in a world of your own; you are far away from the madding crowd and everything is still."

Many of the incidents of the famous Pittsfield ballon ascension, the first ascension of Aero Club members in this country, and those of the more recent St. Louis race, were shown in a series of moving pictures. As in these pictures the various balloons were seen to rise and pass quickly out of sight in the distance, one could readily understand, as Mr. Post put it, that "ballooning made the United States look like a ten-acre lot." Mr. Post then discussed the construction and operation of aeroplanes, or machines heavier than air, and his description of the work of Ludlow, Archdeacon, and Farman was followed by moving pictures of these remarkable aerial vehicles in rapid flight.

The instruments used in taking observations in air travel, loaned for the occasion by Mr. Albert C. Triaca, Director of the International School of Aeronautics, New York, were exhibited, and a collection of photographs of important events in Aeronautics was on view.

In speaking of the part which electricity is destined to play in aeronautics, Mr. Post said that even now, without the use of the electric lamp, and the electric spark for ignition in the motors, flight would be impossible. Indications are already presenting themselves that electricity will be resorted to for the final solution of the problem of the perfectly efficient airship. It may be specially utilized in controlling the various rudders, in equilibriating devices, etc. The transmission of power by wireless may materially simplify the problem.

NOTES

The annual report of the General Electric Company for the fiscal year ending January 31, was issued on May 5th. The gross turn over, nearly $71,000,000, is the largest in the history of the Company, and the profit, $6,948,682, while relatively small, is very encouraging considering the peculiar conditions existing in 1907, viz: the high cost and inefficient quality of labor, due to the unprecedented demand for workmen; the great reduction in the value of raw materials on hand, due to financial depression, and necessitating a cut of about $2,000,000 in inventory value; the necessity for a large appropriation to cover possible bad debts and for carrying accounts due from customers caught in the depression and temporarily unable to meet their obligations; and the writing off of nearly $4,000,000 out of the year's expenditure of about $6,000,000 for plants, equipment, etc.

The report shows that out of about $35,000,000, the original value of and expenditures for plants and equipment in the last fifteen years, $23,000,000 has been written off, leaving a book value of but $13,000,000. With further writing off unnecessary, and a cash balance of $12,250,000, and surplus profits of $16,500,000, there should be no doubt as as to the payment of dividends.

During the past year $13,000,000 was added to the working capital by the issue of stock and bonds.

In August the Company was entirely freed from floating debt, and had large bank balances with which to successfully meet the panic when money was unprocurable.

Other items of interest are: the taking over of the Stanley G.I. Mfg. Co., of Pittsfield; the purchase of 700 acres of land near Erie, Pa., for the location of another plant; the acquisition and development of a copper mining property, railroad, and smelter in California.

* * *

Mr. Bernard E. Sunny, who for years has been prominently connected with the exploitation and development of the electrical industry in the Middle West, has resigned as Vice-President and Western Manager of the General Electric Co., to accept an appointment as Vice-President of the American Telephone and Telegraph Co., with headquarters in Chicago. He has, however, been elected a Director of the General Electric Co., and therefore his relations with the Company will not be wholly severed.

For ten years prior to 1888, Mr. Sunny was Superintendent of the Chicago Telephone Co., and is therefore thoroughly familiar with the many details of telephone work.

Entering the services of the Thomson-Houston Co. in the above year, he remained with that company until it was consolidated with the General Electric Co., in 1892, since which time he has been intimately associated with the interests of the latter concern.

He is a man of strong personality and purpose, possessing a large number of friends, a rare judgment in business matters, and a marked ability for successfully accomplishing large undertakings.

Mr. J. W. Johnson was appointed Manager of the Chicago office of the General Electric Co. on May 1st. He has been Assistant Manager of the office for several years, and is well qualified by ability and experience to assume his new responsibilities. He is succeeded as Assistant Manager by Mr. F. N. Boyer.

* * *

Mr. John R. McKee, formerly General Manager of the Power & Mining Department of the General Electric Company, has been appointed Chairman of the Sales Committee. Mr. A. R. Bush has been appointed Manager of the Power & Mining Department.

* * *

Mr. A. J. Lighthipe, who has been engineer of the San Francisco Office of the General Electric Co., since 1891, has accepted a position with the Los Angeles Edison Electric Co.

Mr. Lighthipe has been identified with electrical industries since 1879 at which time he entered Mr. Edison's Laboratory after completing his studies at Stevens Institute of Technology. Later in the same year he was sent to London with the loud speaking chalk telephone, and since that time has been associated with the following interests:

International Bell Telephone Co., Antwerp & Verviers, 1880–81; the French Edison Co., 1882; the German Edison Co., 1883; the Brush Electric Co., New York, 1884; Manufacturing at Philadelphia, 1885–86; Electrican, Wilmington City Electric Co., 1886–89; Supt. of Construction, United Edison Mfg. Co., San Francisco, 1890; District Engineer, Edison General Electric Co., San Francisco, 1890–91, Engineer of San Francisco, Office of General Electric Co., 1900.

* * *

Mr. Thomas Vincent Bolan of the Philadelphia Office of the General Electric Co., died at his home in Philadelphia on February 18th.

Mr. Bolan was born in London, England, on October 31, 1865. He was a graduate of Georgetown College and of the Massachusetts Institute of Technology, where he pursued a course in Electrical Engineering.

After graduation, he entered the employ of the General Electric Company, one of his early works being the installation of the Providence, R. I. trolley system.

Later, he specialized in cotton mill work and had charge of several important cotton mill installations in the South. He rose rapidly in his profession and at his death was regarded as one of the best engineers in his line.

For the past ten years he has been in charge of mill power work at the Company's Philadelphia Office. He was an associate member of the American Institute of Electrical Engineers.

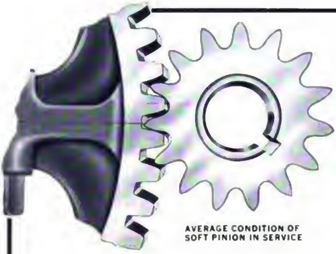
* * *

Mr. Conway Robinson, with the A.C. Engineering Department of the General Electric Co., was married on April 21st., to Miss Jane Stockton Dorsey, of Baltimore, Md.

Mr. Robinson has been appointed Manager of the Works of the Tokio Electric Co., Tokio, Japan.

* * *

Mr. Eugen Eichel, formerly connected with the Engineering Department of the General Electric Company, has opened an office in Berlin as consulting engineer.



AVERAGE CONDITION OF SOFT PINION IN SERVICE

Railway Motor Gear Economies

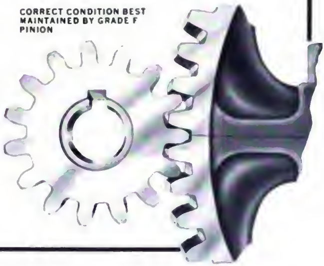
Why use a worn pinion with a new gear when the new GE long life "Grade F" Pinion will last substantially as long as a cast steel gear?

Consider the inefficiency of gears operating under these conditions — the abnormal demand on the power station — the racking wear on motors and trucks — the noise and annoyance to passengers — all due to the loss of original accuracy of tooth dimension

The vital factor

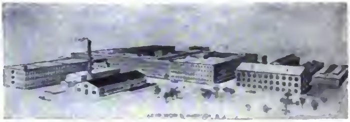
of gear economy is the maintenance of correct outline of teeth. The ordinary soft pinion wears out in about the proportion of three pinions to one gear. The correct outline of tooth is best maintained by the new

General Electric Grade F Pinion



CORRECT CONDITION BEST MAINTAINED BY GRADE F PINION

Special Notice to Lamp Purchasers



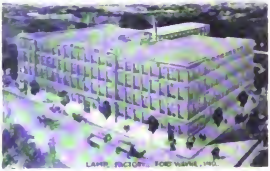
The increased demand for Edison Lamps during the past year taxed to the utmost the facilities of the General Electric Company.

Although the Company produced over 35,000,000 lamps some customers were disappointed in not obtaining all the Edison Lamps they desired and had to use other kinds.

The Company has worked day and night to correct this condition. Extensive additions to its manufacturing facilities have now placed it in a position to promptly supply all customers' demands. Edison Lamps are obtainable as promptly as any customer may require.

Annual Productive Capacity Fifty to Sixty Million Lamps

Twelve Million Lamps in Stock



All Types of Carbon, GEM, Tantalum, Tungsten Lamps

Factories at
Harrison, N. J.
Newark, N. J.
Lynn, Mass.
East Boston, Mass.
Fort Wayne, Ind.
Toledo, Ohio

Main Lamp Sales Office:

Harrison, N. J.

1670