QUESTIONS AND ANSWERS

AUDELS NEW ELECTRIC LIBRARY

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DEDICATED TO ELECTRICAL PROGRESS

AUDELS NEW ELECTRIC LIBRARY

VOL. X

FOR ENGINEERS, ELECTRICIANS
ALL ELECTRICAL WORKERS
MECHANICS AND STUDENTS

Presenting in simplest, concise form the fundamental principles, rules and applications of applied electricity.

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Design, construction, operation and maintenance of modern electrical machines and appliances.

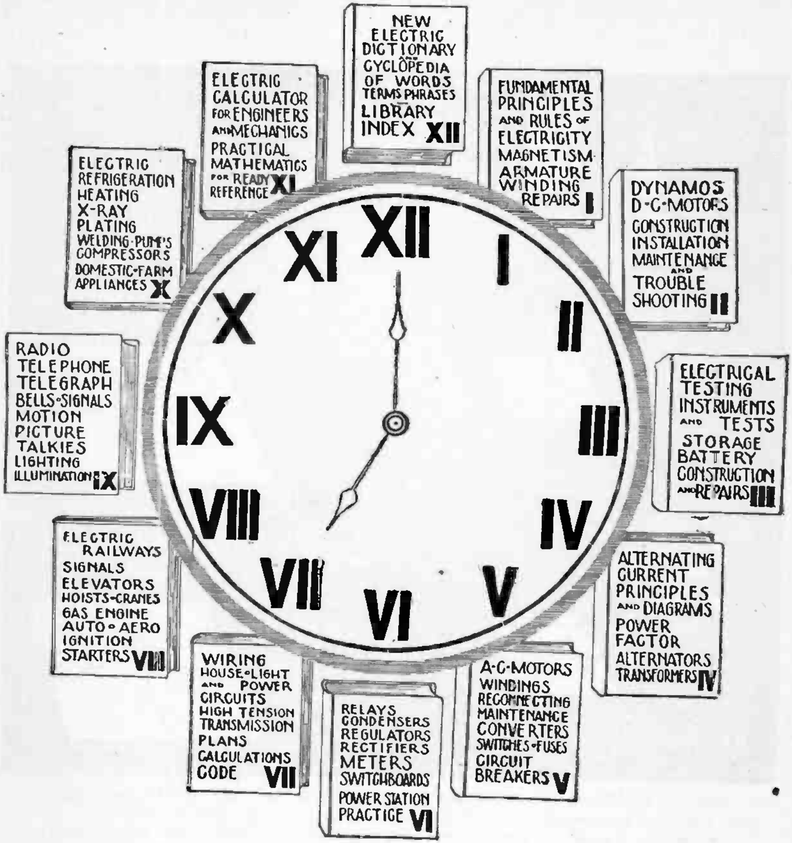
Based on the best knowledge and experience of applied electricity.

by **FRANK D. GRAHAM, B.S., M.S., M.E., E.E.**

THEO. AUDEL & CO., PUBLISHERS
49 WEST 23rd STREET, NEW YORK, U.S.A.

Reprinted 1946

Printed in the United States of America



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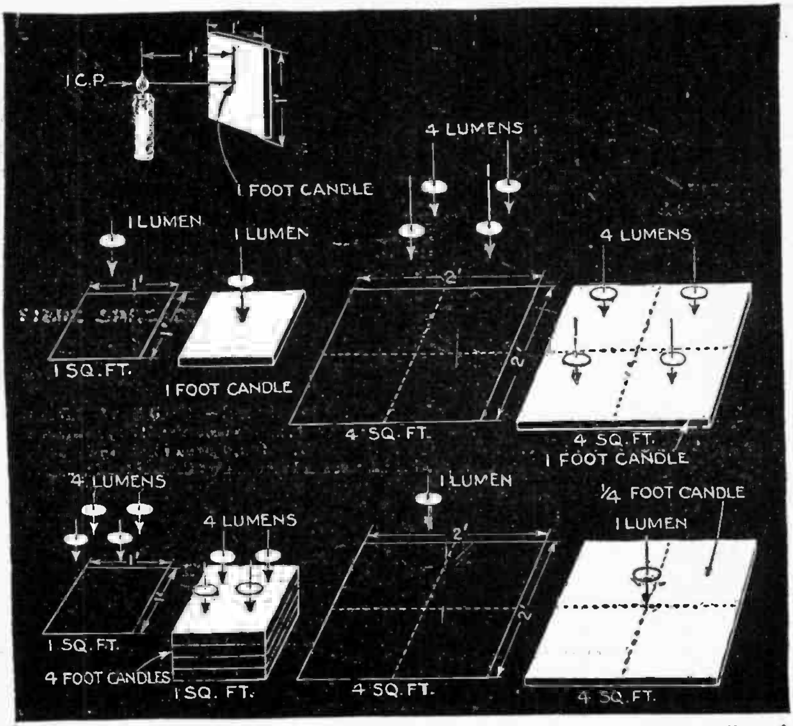

FIGS. 8,392 to 8,400.—Diagram showing the difference between lumens and foot candles. A light source of one-candle power in a particular direction will produce one foot candle of illumination on a point one foot distant from it. One lumen of light flux will illuminate one square foot of area to one foot candle of illumination. The product of foot candles and the area in square feet lighted will give the lumens of light flux on that area.

Foreword

This series is dedicated to Electrical Progress—to all who have helped and those who may in the coming years help to bring further under human control and service to humanity this mighty force of the Creator.

The Electrical Age has opened new problems to all connected with modern industry, making a thorough working knowledge of the fundamental principles of applied electricity necessary.

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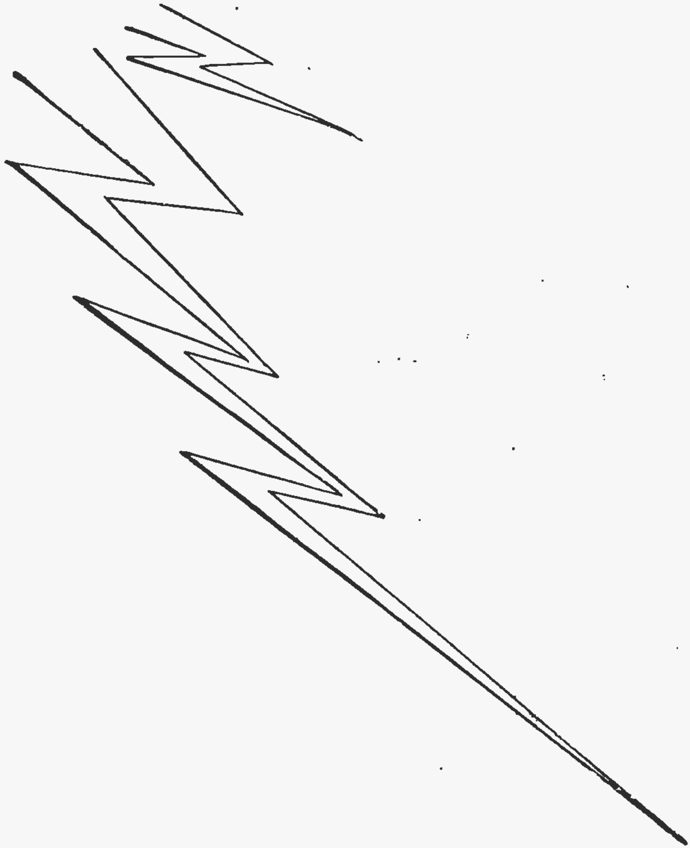
The series will speak for itself and "those who run may read."

The Publishers.



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To quickly and easily find information on any subject, read over the general chapter headings as shown in the large type—this brings the reader's attention to the general classification of information in this book.

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"An hour with a book would have brought to your mind,
The secret that took the whole year to find;
The facts that you learned at enormous expense,
Were all on a library shelf to commence."

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CHAPTER 206

Electric Welding

By definition electric welding is that branch of welding in which *an electric current is used to create the great heat required for jointing together into firm union two pieces of metal.*

Electric welding may be classified:

1. With respect to the method of applying the heat, as

   a. Arc;

   b. Flash;

   c. Resistance.

2. With respect to the kind of electrode used, as

   a. Carbon;

   b. Metallic.

3. With respect to the form of weld, as

   a. Spot;

   b. Butt;

   c. Line or seam;

   d. Tube;
   etc.

4. With respect to the method of bringing the metals together, as

a. Compression;

b. Autogenous.

5. With respect to the method of applying the "added metal" as by

a. Carbon arc with welding rod;

b. Metallic arc.

Source of Welding Current.—Any electric circuit of suitable voltage and amperage, either *a.c.* or *d.c.* may be used for electric welding. Usually in order to keep down the losses involved in reducing the voltage to that required by the arc, a special low voltage dynamo is used.

Two types of dynamos are generally used:

1. Constant voltage,flat compounded;
2. Variable voltage.

The constant voltage machine can be used to supply welding current to any number of welding circuits, while the variable voltage type supplies current for only one welding arc.

The constant voltage machine operates at 60 volts and the current in each arc is adjusted to the proper value by means of an adjustable resistor.

The windings of the variable voltage dynamo are so arranged that the terminal voltage of the machine automatically adjusts itself to that required to maintain the arc.

The open circuit voltage available for striking the arc in this type of dynamo, is usually slightly greater than the voltage of the constant voltage machine. Average values vary from 70 to 80 volts. Resistors are required only for very low welding currents. Any necessary adjustments are made either by shifting the dynamo brushes or by means of a rheostat in the dynamo field circuit. In this type of dynamo a high, open circuit voltage is available for striking the arc, after which it is automatically reduced to that required to maintain the arc.

For metallic arc welding by the hand method, the usual range of arc current is from 50 to 300 amperes at a voltage of approximately 20 volts. For automatic metallic arc welding, a current range of from 75 to 400 amperes is used with an arc voltage varying from 16 to 25 volts.

Carbon Arc Welding.—In this method of welding the electrode is of carbon or graphite and merely creates the arc and melts the metal.

Into this puddle of molten metal is inserted a rod or metallic stick which also melts and fills up the gap and fuses with the metal.

Carbon arc welding differs from metallic arc welding in that it is a puddling process and is somewhat similar to the gas welding process.

Metallic Arc Welding.—A metallic electrode is used in this method. The electrode forms a terminal for creating the arc, and also supplies the added or "filler" metal by melting.

When welding with the metallic electrode an arc is drawn between the parent metal or work and the welding rod, which causes the melted rod to flow across the arc into the molten pool of the parent metal. This deposition of metal is accomplished by contact made between the molten metal and the globules formed on the end of electrode filler wire.

The concentration of thermal energy at the terminal of the wire electrode causes a small part of the work being welded to melt almost instantaneously. and an intermittent flow of metal across the arc stream.

The metal in the arc stream is in both the liquid and gaseous form, the liquid metal being transferred across the arc by molecular attraction, adhesion, cohesion, surface tension or a combination of these.

The transfer of metal is not dependent on gravity since overhead welding indicates that the transfer of metal can be accomplished against the forces of gravity. The metal is melted at the point where the arc strikes the plate or work causing a crater to be formed, which also provides a means of observing the penetration and consequently good fusion while welding, by noting the depth of the arc crater. Metallic arc welding is a widely used method.

The Electric Welding Arc.—An arc is formed by *current flowing across a gap in an electric circuit.*

A small amount of the material, forming the terminals of the arc gap, is heated to an incandescent vapor. This vapor provides the conducting medium in the arc stream by which

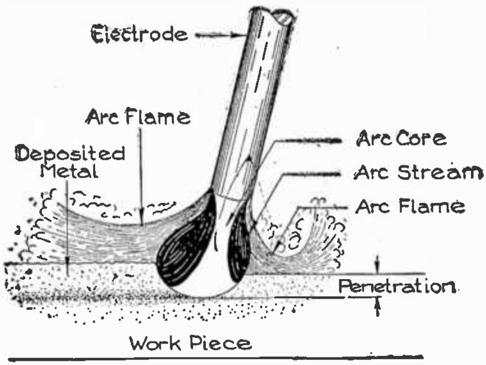


FIG. 7,973.—The welding arc. The terminal from which the current passes to the arc is termed the *positive electrode* or the *anode*, and the terminal to which the current passes from the arc is called the *negative electrode* or *cathode*. Although the exact distribution of heat in the arc between the two electrodes is still unknown, it is the generally accepted theory that approximately two-thirds of the heat is liberated at the positive terminal and one-third at the negative terminal. When *d.c.* is used, one terminal remains positive continuously and the greater portion of the total heat is liberated at this terminal. When *a.c.* is used, the terminals are alternately positive and negative so that approximately the same amount of heat is liberated at each terminal.

the current is carried from one terminal to the other, as shown in fig. 7,973. The temperature of the vapors in the arc and, consequently, the intensity of the light given out are so great that colored glass must be used in order to protect the eyes.

When suitable glass is used, the different portions of the arc can plainly be distinguished from one another. The center is usually referred to as the arc core, and some observers are able to see that this is divided into two portions designated as "arc core" and "arc stream." In general, this portion of the arc will usually be seen as greenish in color, of comparatively small diameter, and forming a direct line between the two terminals.

The point where the arc core strikes on either terminal is seen as a light red or yellowish spot considerably brighter and, therefore, hotter than the metal surrounding it. The metal around this spot is molten and is usually seen as a bright red area. This color gradually shades off into a darker red with lower temperatures, and finally becomes black at a short distance, not over ½ in. from the arc, except in the case of very heavy welding.

Slag, oxides, etc., can be distinguished floating on the molten metal either as light or dark spots, depending upon the melting point of the impurity. Surrounding the arc core is the arc flame which is irregular in shape and in constant motion, being easily deflected by magnetic fields caused by the current in the electrode and in the plate, and also by drafts which may arise by reason of the heat in the arc, or by exposure to wind, etc.

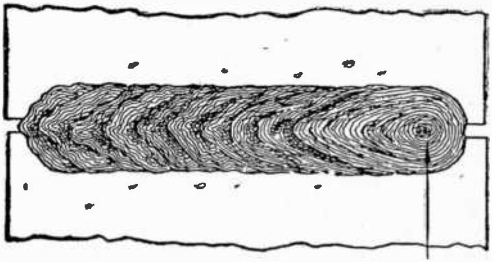
Polarity.—Since the mass of the work to be welded is generally large in comparison with the mass of the electrode, it is desirable to have more heat liberated in the work to bring its temperature to the fusing point at the same time that metal is fused and deposited from the electrode. For this reason, *d.c.* is much more satisfactory for arc welding, since the work can be supplied with a greater amount of heat from the electrode simply by using it as the positive terminal. However, in some cases involving the welding of certain alloy steels and a few other metals, it is sometimes desirable to reverse the polarity and make the electrode positive.

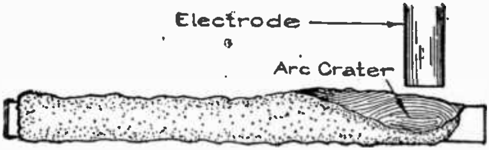
The *a.c.* arc is inherently unstable on account of the fact that both current and voltage pass through zero with each alternation. In order to make it possible to maintain an arc with any degree of certainty, it is necessary to insert a large amount of ballast, either in the form of resistance or reactance; that is, the open circuit or impressed voltage on the welding line must be of a relatively high value compared with that necessary if *d.c.* be used.

If resistance be used for the ballast, there is a great waste of power in the resistor. and if reactance be used, the excess voltage will be consumed as a reactance drop, resulting in low power factor for the equipment.

The polarity of a circuit can be determined in a number of ways.

The simplest and most positive way is to determine it by means of a volt meter. Another method is to draw an arc between either a bare metallic electrode or a carbon electrode and a steel plate. If the plate be positive and the electrode negative, the arc will be fairly stable. If, however, the circuit be reversed and the electrode be positive, the electrode will heat up very rapidly and the arc will become "wild" or it will flutter and be hard to





FIGS. 7,974 and 7,975.—Longitudinal section of deposited metal showing penetration and arc crater. Correct penetration will make certain that the metal of the plate is melted and in condition to receive the metal projected from the electrode, and also that the area of the crater will be sufficient to receive all of the metal from the electrode and not permit any of the deposited metal to overlap on the solid metal of the plate where it will not stick.

keep going. In welding low carbon steels with reversed polarity, the penetration with the metallic electrode is poor, and the deposited metal can often be easily knocked loose.

Penetration.—At the point where the arc strikes the plate, assuming that current, polarity and speed of travel are correct, the metal is melted and seems to be forced out of the pool by some sort of a blast from the arc, as shown in figs. 7,973 to 7,975.

This results in the metal piling up around the edges of a small depression in which the metal is in a molten state. This depression is referred to as the arc crater, and its depth provides a means of observing the penetration during welding, and, to a certain extent, of predicting the soundness of the weld, since one requirement of a weld is to obtain good penetration. The crater depth will depend upon the thickness of metal welded, but, in general, should be at least 1/16 in.

Length of the Arc.—While the correct arc length alone will not insure good welds, it is agreed that a long arc is almost certain to result in a poor weld.

With a short arc, the heat is concentrated on the plate, whereas, with a long arc, a great deal of it is lost into the surrounding space.

A long arc is not as stable as a short one. It tends to wander over a considerable area on the plate and the arc flame blows about very rapidly. This action, however, together with the greater length of the arc, affords considerable opportunity for the air to come in contact not only with the metal passing from the electrode to the plate, but also with the very hot metal in the arc pool or crater. This results in the absorption of oxygen and nitrogen, both of which are detrimental to the quality of the weld.

With a short arc, the flame, consisting of vapors coming out of the arc, acts as a protection and largely prevents the absorption of these outside gases. A short arc will deposit more metal in the weld, at the point needed, than a long arc.

The following table of arc lengths gives the approximate desirable gaps for different electrodes and voltages.

Table of Arc Lengths

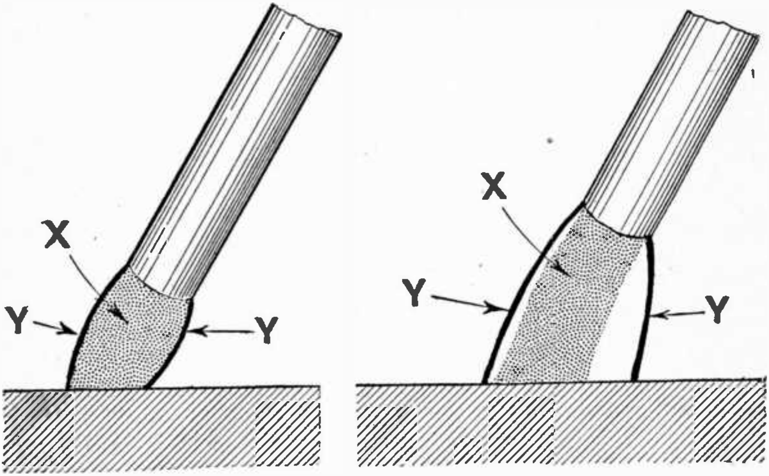
Size of Electrode	Voltage across the Arc	Arc length
1/16	15 to 17	1/16
1/8, 5/32	17 to 20	1/8
3/16, 1/4	18 to 25	3/16

Advantages of the Short Arc

1. Maximum penetration;

2. Slight overlap;

3. Maximum strength;
4. Maximum ductility;
5. Minimum porosity;
6. Maximum amount of metal deposited at the point needed;
7. Makes it possible to use alloy electrodes.



FIGS. 7,976 and 7,977.—*Judging the arc length, 1. By appearance of arc.* If the arc be short it will appear as in fig. 7,976. Here the molten metal X, passing through the arc, will appear to be protected from the atmosphere by an enveloping neutral flame Y. If the arc be too long, the protecting neutral flame Y, will whirl around, exposing first one side and then the other side of the molten metal, as in fig. 7,977, allowing it to become oxidized, and it will have a burnt and porous appearance when deposited. The bead will not have the same appearance as one made with a short arc.

Disadvantages of the Long Arc

1. Minimum penetration;
2. Excessive overlap;
3. Minimum strength;
4. Minimum ductility;
5. Maximum porosity;
6. Uncontrolled deposit;

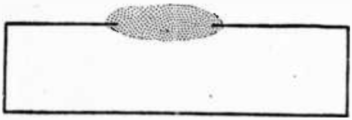
7. Excessive waste of electrode material;

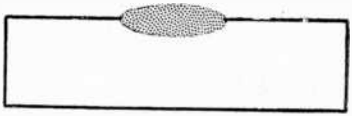
8. Burns out all the alloys in a high grade electrode.

Experience will teach the operator to tell by observation when a short arc is being held.

It is possible to tell by sound, with low carbon steel electrodes, whether the arc be long or short. If the arc make a rapid crackling sound that is fairly steady in intensity, much like the frying of grease in a pan, the arc is short. If the arc make a hissing sound punctuated by explosions occurring at intervals of from ½ to 1½ seconds, the arc is too long.

A short arc throws a steady shower of small sparks, whereas each of the explosions caused by the long arc scatters many larger globules of metal.





FIGS. 7,978 and 7,979.—*Judging the arc length, 2. By appearance of the weld.* Good penetration of the welding metal into the parent metal is not obtained with a long arc and there will be a bad overlap, as in fig. 7,978, while if the arc be short, there will be good penetration and a slight overlap, as in fig. 7,979. Another way to determine if the arc be too long is to examine the crater or depression in parent metal on breaking the arc, and see what the penetration looks like. If there be no penetration in the parent metal, then the arc is too long, providing of course, the proper electrode, current and correct polarity are used.

Figs. 8,024 to 8,031 will further assist in judging the length of the arc.

Metallic Electrodes.—In general, the metallic electrode for welding the commercial grades of wrought iron, plate, structural and cast steel, and to a considerable extent of cast iron, should be a high grade of low carbon steel wire which has a carbon content of .20% or less. Practically all commercial electric welding wire on the market meets this requirement, although there are a number of special electrodes containing greater amounts of carbon, which are used for special purposes.

The medium and high carbon steel electrodes are used where a hard deposit is required, but are not generally satisfactory where strength is necessary. In ordering, electric arc welding wire should be specified, since wire for acetylene welding is often treated in such a way as to render it unsuitable for electric arc welding.

The electrode wire should be cut into pieces convenient for the operation.

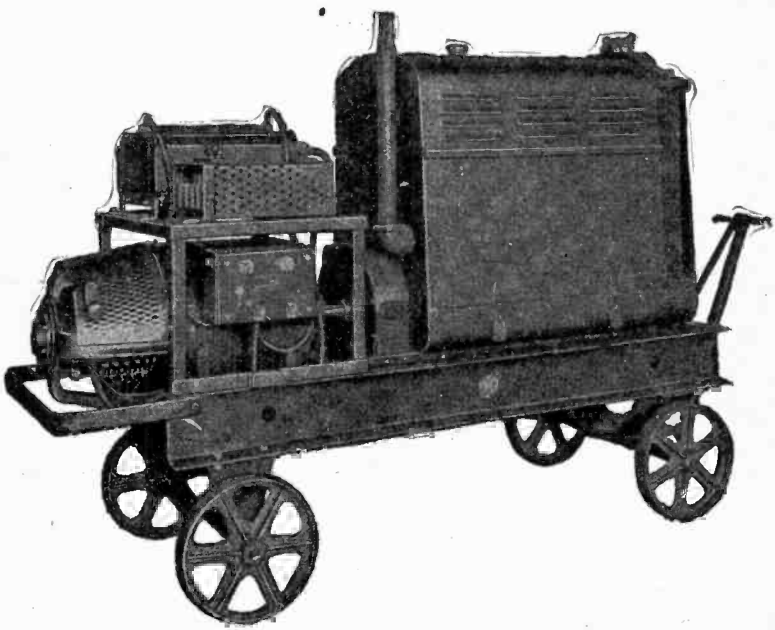


FIG. 7,980.—General Electric portable gas engine driven arc welder. The dynamo is self-excited. A self-adjusting stabilizing reactor automatically steadies the arc under all welding conditions, making the arc easy to start and maintain.

A length of 14 to 18 in. is satisfactory, since it is about the greatest length an operator can handle; at the same time it reduces the number of times the electrode is changed, and consequently the wastage.

With an electrode which is red hot, it is impossible either to start an arc or to maintain it.

The exact temperature varies with different electrodes, but it is advisable to keep the electrode cool. The passage of the welding current and the heat conducted back from the tip tend to heat that portion of the electrode wire carrying current. Accordingly, when the welding current is high for the electrode size, the wire should be gripped in the middle. By this means, the portion carrying current is all consumed before it has time to become too hot for use. With lower current values, the electrode is gripped at the end to save time and to minimize the number of times the arc is interrupted.

Welding Currents.—It is difficult to give universally applicable figures covering current, speed, etc., for electric arc welding because of the effect of conditions under which the work is done, the character of the work, and the varying skill of operators.

The following figures for bare metallic electrodes, are based on favorable working conditions and a skilled operator. However, they are approximations only and are given merely as a general guide.

Electrode Diameter in Inches	Amperes Hand Welding	Corresponding Plate Thickness in Inches
1/16	50–100	Up to 3/16
3/32	100–150	Up to 1/4
1/8	125–175	Above 1/8
5/32	150–200	Above 1/4
3/16	175–350	Above 3/8
1/4	225–400	Above 3/8

NOTE.—*Defective electrodes.*—Occasionally electrodes will be found that are not uniform as evidenced by the fact that, at intervals, the arc will suddenly become wild and erratic and the metal may pass from it in large drops without any apparent change in the electrical conditions or in the manipulation of the electrode by the welder. It is probable that at points in the weld where this action has taken place there will be weak spots with poor penetration. If a strong weld be desired, such an electrode should not be used, and metal deposited under these conditions should be chipped out before proceeding with the weld. Electrodes containing a considerable amount of carbon are generally erratic in this way.

Position of Work.—There are three general positions of work to be welded.

1. Flat;
2. Vertical;
3. Inclined.

Flat indicates that the surface on which the weld is made is horizontal; *vertical* that it is vertical; and *inclined* indicates an angle, not a right angle,

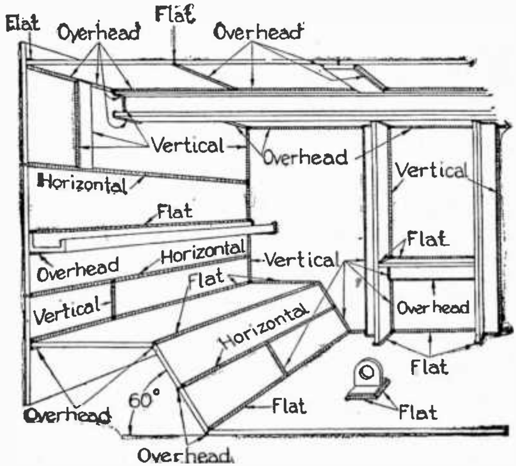
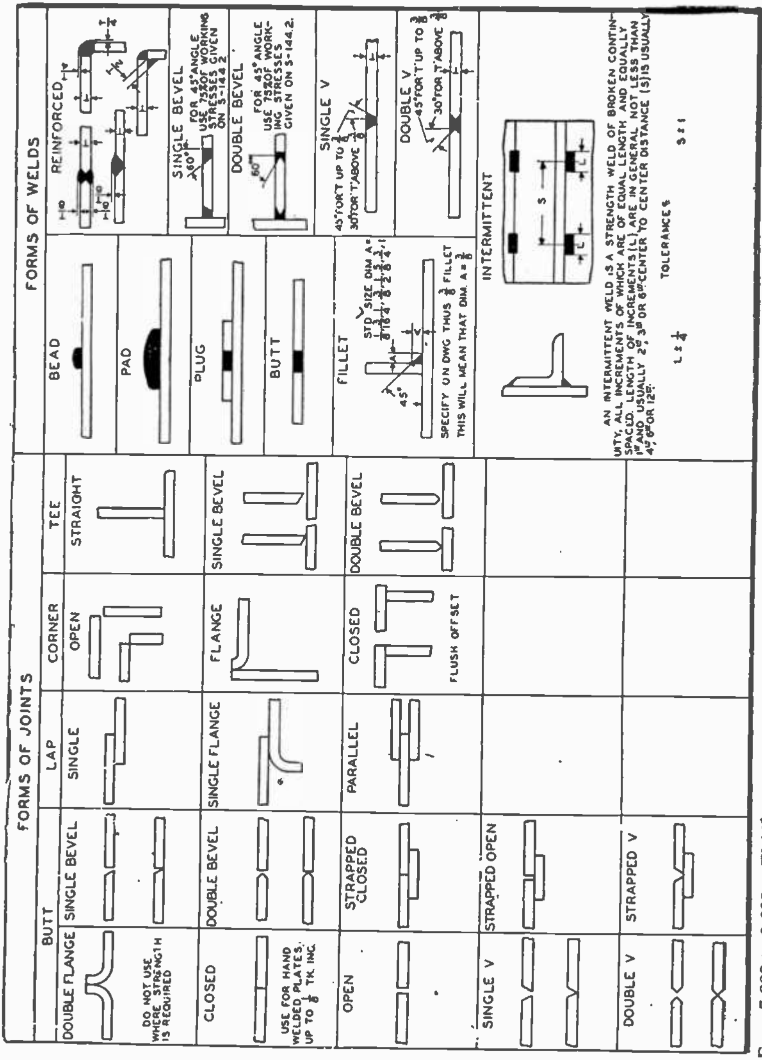


FIG. 7,981.—Various positions of weld.

to the horizontal. When inclined, the angle between the horizontal and the surface to be welded is usually specified.

Position of Weld.—There are four general positions of weld.

1. Flat;
2. Horizontal;
3. Vertical;
4. Overhead.



FIGS. 7,982 to 8,023.—Welding terms.

A *flat* position is one in which the welding material is applied in a generally downward direction.

A *horizontal* position is one in which the welding material is applied to a seam or opening in a plate, the plane of which is vertical or inclined 45°, or less, to the vertical, and the line of weld is horizontal. The electrode is held in horizontal position, or the welding end is inclined slightly downward.

A *vertical* position is one in which the welding material is applied to a vertical surface, or one inclined 45° or less to the vertical, so that the line of weld is vertical or inclined 45° or less to the vertical. The electrode is held horizontal, or the welding end is inclined slightly downward.

An *overhead* position is one in which the welding material is applied from the under side of any members whose plane is such that it necessitates the electrode being held with its welding end upward. These positions are shown in fig. 7,981.

Type of Weld.—In general, there are four kinds of welds.

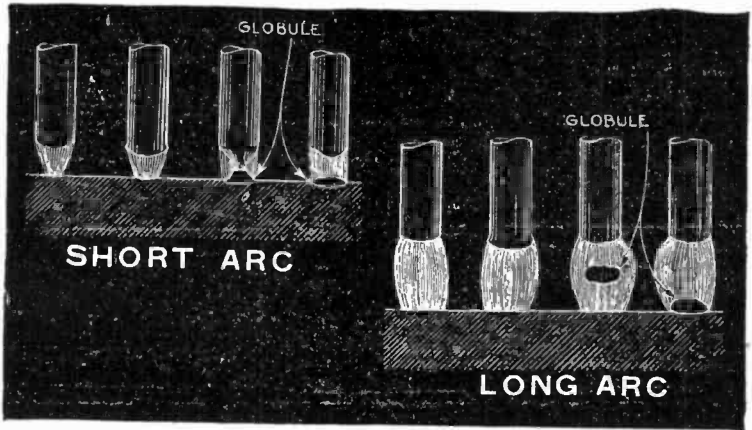
1. Tack;
2. Strength;
3. Caulking;
4. Composite.

Tack Weld.—In this weld the welding material is applied in small sections or spots to hold two edges together, and should always be specified by giving the space from center to center of welds and the length of each weld itself.

It is not necessary to consider the design of the weld. A tack is also used for temporarily holding in place material that is to be solidly welded, until the proper alignment and position are obtained. In this case, neither the length, space, nor design of weld need be specified.

Strength Weld.—This is one in which the sectional area of the weld is sufficient to give the joint the desired tensile strength. At least 80% of the strength of the surrounding material is the minimum. A good welder should always be able to attain at least 100% strength. The welding material may be applied in any number of layers.

Caulking Weld.—In this weld the deposited metal is used to close a seam or opening so that no leakage occurs under a water, oil or air pressure test of at least 25 lb. per sq. in. Neither the ultimate strength nor the design of the weld is of particular importance in a purely caulking weld.



Figs. 8,024 to 8,027.—Short arc. From the globular formation it will be noted that the globule never is subjected to full heat of the arc, as it is in contact with molten metal in plate before it leaves tip of electrode. It will therefore be readily seen that the length of a short arc will vary with the diameter of electrode used, and what would be a long arc on ⅛ in. electrode might be too short for a ¼ in. electrode.

Figs. 8,028 to 8,031.—Long arc. The illustrations show how the globule detaches from the end of electrode and in passing through a long arc to plate is subjected to full heat of arc, and of course the longer the arc the more burnt the globule will be when it reaches the plate.

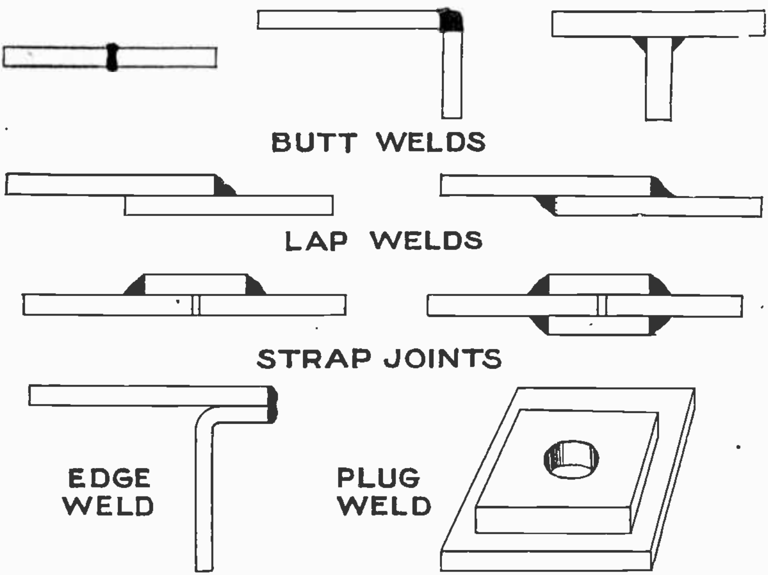
Composite Weld.—This weld is one in which both the strength and density are of vital importance.

The strength must be at least as specified for a strength weld, and the density must meet the requirements of a caulking weld, both as defined above.

Types of Welded Joints.—There are six general types of joints that are used in commercial welding. These may be designated by the manner in which the joint is made as:

1. Butt;
2. Lap;
3. T;
4. Strap;
5. Edge;
6. Plug.

Butt Weld.—The two plates to be joined are brought together, edge to edge, and welded along the seam thus formed.



FIGS. 8,032 to 8,040.—Various types of welded joints.

Two plates when so welded form a flat surface, or a corner, as shown in figs. 8,032 and 8,033.

Lap Weld.—In this weld the edges of two plates are overlapped, and the welding material is so applied as to bind the edge of one plate to the face of the other, as in figs. 8,035 and 8,036.

T Weld.—This occurs where plates are to be welded at right angles to each other, as in fig. 8,034.

Strap Joint.—This is where the junction of the ends of two surfaces is re-enforced by a plate or *strap* of metal covering the joint and fillet welded to each of the adjoining surfaces, as in figs. 8,037 and 8,038.

It is, in reality, a re-enforced butt joint. Two re-enforcing straps are used when a stronger joint is necessary.

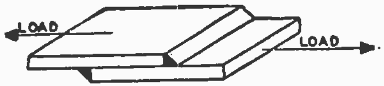
Edge Weld.—Where two comparatively thin, parallel pieces are joined by welding the edges together, the edge weld is used, as shown in fig. 8,039.

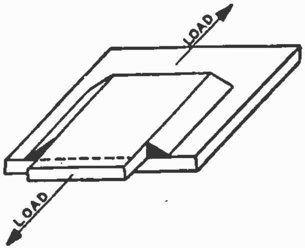
Plug Weld.—Used in joining two plates by welding through a hole in either one, or both of them, as shown in fig. 8,040. This type of joint is very seldom used.

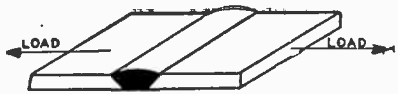
The types of joint shown in figs. 8,032 to 8,040 may be made in a number of ways. The most useful and those most commonly found in commercial welding practice are shown in figs. 8,044 to 8,050.

Expansion and Contraction.—While expansion and contraction cannot be prevented, their effects can be minimized if certain methods be adopted in arranging the parts preparatory to welding, or by the order in which the deposited metal is applied.

For ductile materials, where the parts welded are free to come and go by reason of their ductility, extensive precautions to prevent contraction stresses are probably not advisable.







WELDING MATERIAL STRENGTH

Cynamic, Vibration or Lifting Load } 5000 Lbs. Per Square Inch Maximun

Static Load—11,300 Lbs. per Square Inch Maximum for Throat of Fillet Welds

13,000 Lbs. per Square Inch Maximum for Tension in Butt Welds

15,000 Lbs. per Square Inch Maximum for Compression in Butt Welds

Ultimate Strength—40000 Lbs. per Square Inch Maximum

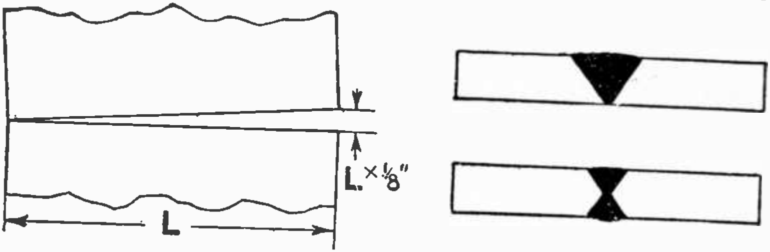
STRENGTH OF FILLET WELDS

Size of Fillet	Allowable Load in Pounds Per Inch Length	
	At 5000 Pounds Per Square Inch	At 11300 Pounds Per Square Inch
⅛ x ⅛	440	1000
3/16 x 3/16	660	1500
¼ x ¼	890	2000
⅜ x ⅜	1330	3000
½ x ½	1770	4000
⅝ x ⅝	2210	5000
¾ x ¾	2650	6000
1 x 1	3540	8000

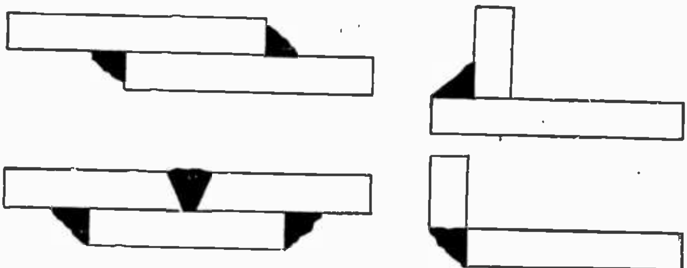
FIGS. 8,041 to 8,043.—Strength of welds. The table showing allowable strength of fillet welds applies to figs. 8,041 and 8,042. For figuring the strength of the butt weld shown in fig. 8,043, use the sectional area of the steel plate at a stress of 5,000 lbs. per sq. in. for dynamic or vibration load and 13,000 lbs. per sq. in. for static load in tension or 15,000 lbs. per sq. in. in compression.

In the case of non-ductile materials and castings or large structures, where the contraction effects are liable to be cumulative and to distort seriously the finished product, considerable attention must be paid to eradicating these harmful effects.

When welding joints formed by plate edges, if the welding be performed by starting at one end of the seam and continuing



FIGS. 8,044 to 8,046.—Various types of butt welds. For thin plates up to ⅛ in. in thickness, the plates are butted together at the end where the weld is to start and spaced apart a distance equal to ⅛ in. per ft. of weld at the other end as shown in fig. 8,044. This is to allow for the contraction stresses set up as the weld progresses. Plates ⅛ to ¼ in. in thickness are spaced a small distance apart at the beginning of the weld. This spacing varies from 1/16 to ⅛ in. When butt welds are made on plates thicker than ¼ in. some type of bevel or V, is necessary in order to obtain the proper penetration. Fig. 8,045, single V weld, the most common type; fig. 8,046 double V weld for heavy plate. L = length of weld.

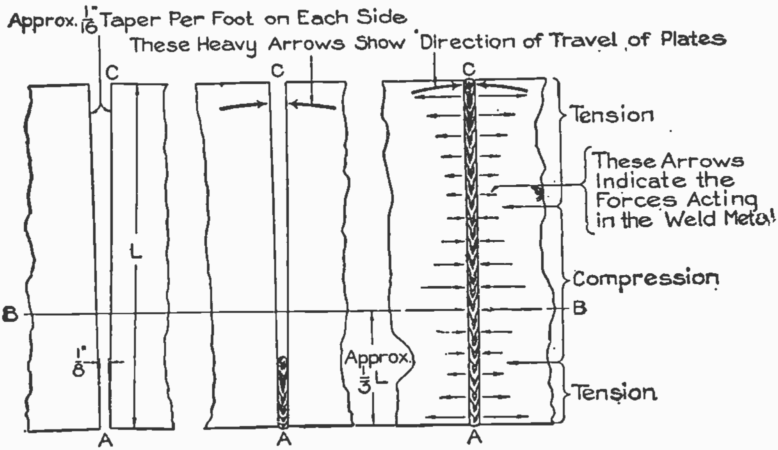


FIGS. 8,047 to 8,050.—Various examples of fillet welds. Lap welds may be made with either a single or a double fillet as shown in 8,035 and 8,036. The fillets may be either the full thickness of the plate, as in figs. 8,035 and 8,036, or they may be smaller as in fig. 8,047. The size of the fillet used will depend upon the strength needed in the joint. As in the case of lap welds, either the single or double fillet may be used for welding two plates together at right angles, as shown in figs. 8,034 and 8,048. The double fillet, fig. 8,034 is always used when strength is required. Fillet welds are used in making strap joints, as in figs. 8,037 and 8,038. In fig. 8,049, a strap joint using both a fillet and a V weld is shown. A corner joint, used when welding heavy steel plate, is shown in fig. 8,050.

until the other end is reached, as in figs. 8,051 to 8,053, the opening at C, will certainly be drawn together as the welding progresses from A to C.

As the welding continues from B to C, the contraction of the fused-in metal will produce stresses, as indicated by the arrows.

Fig. 8,054 shows a method of sequence of welding designed to distribute the heat and contraction stresses more evenly



FIGS. 8,051 to 8,053.—Locked-in stresses in a weld due to contraction. When the joint is completed, the transverse contraction stresses along the joints will be greatly concentrated at the ends A and C. The stresses impair the quality of the weld and, in many cases, develop a fracture on cooling. When a fracture develops where this method is used, it usually occurs at the end where the joint is finished.

throughout the joint, and thus reduce the amount of drawing and prevent concentration of contraction stresses. This order of welding is known as the *step back* method.

When the parts are rigid and no allowance can be made for contraction, or when it is desired to minimize the drawing of the plates, the joint is formed by welding in the order as shown in fig. 8,055.

When welding heavy sections, such as locomotive frame members and similar parts, it is advisable where possible, to spring the butting parts slightly preparatory to welding. Under exceptional conditions, an intermittent procedure may be adopted to prolong the operation and reduce the amount of heat developed in the object welded.

As the distortion caused by welding is due to localized or uneven heating, preheating may be employed to prevent this distortion, and thus reduce the difference in temperature developed between any two points of the parts affected by the welding.

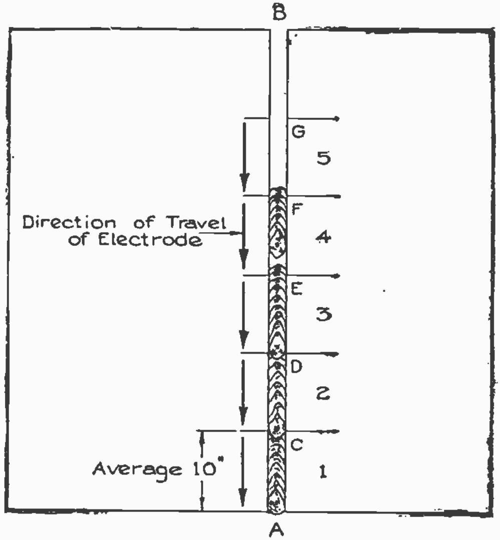


FIG. 8,054.—Step back method of welding to distribute contraction stresses. *As shown* the deposited metal is applied in sections. The sections 1, 2, 3, etc., are welded in numerical order and in the direction shown by arrows. By starting at **C**, section 1, progressing toward the end **A**, section 2 would best be welded in the same manner from **D** to **C**. Each section should he finished at least flush before starting another.

Cast Iron Welding.—A welder is frequently called upon to weld broken iron castings. Cast iron is difficult to weld by any process under the most favorable conditions and the results obtained are more or less inconsistent.

This is due to the brittleness and low tensile strength of cast iron. However, satisfactory welds can be made by the exercise of care in the selection of welding equipment, proper electrodes and preheating the casting. There is no means, however, by which the strength of the welded joint may be accurately predetermined and for this reason the work should never be undertaken unless the person responsible is thoroughly familiar with these facts.

Malleable castings are annealed gray iron castings.

The annealing usually affects the casting only to a small depth, which makes it possible for welding to be done in the annealed or softened section.

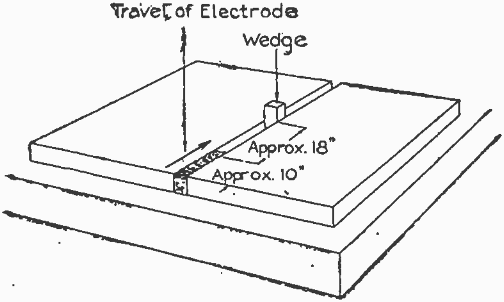


FIG. 8,055.—Method of reducing contraction by locking up the stresses produced. When welding long seams, the drawing may be reduced to almost nothing by the use of spacing blocks or wedges placed in the opening approximately 18 ins. from the section being welded, and toward the end of the seam to which the weld is progressing.

Consequently, the weld metal becomes similar in character to carbon cast steel.

If the casting be machined in the welded section, it must be re-annealed. In welding iron castings and castings similar in character, it is sometimes desirable to make the electrode rod the positive terminal in order to reduce the effective heat in the casting.

Welding Non-Ferrous Metals.—Non-ferrous metals as used commercially have been welded with varying degrees of success. Such metals are more or less difficult to weld with the electric arc, due principally to their low melting points.

Brass.—It is difficult to weld brass due to the vaporization of the zinc content when subjected to the temperature of the electric arc. The addition of metal to brass can be done successfully, but the metal from a brass electrode cannot be added to parent metal of the same composition.

Bronze.—This metal having a low percentage of zinc, can be welded without difficulty either by the metallic or carbon arc process, providing an electrode having a low percentage of tin and zinc is used.

Aluminum.—Great difficulty is experienced in welding aluminum by any process, for two reasons. 1, the metal has a great affinity for oxygen, therefore as it becomes heated a skin of oxide forms on the surface. 2, the metal has a very critical melting point and passes from the solid to the liquid state suddenly. It must be supported at the point to be heated to prevent the hot portion caving in. The only way to attempt the welding of aluminum is by the puddling process using either the metallic or carbon arc.

Copper.—Welding copper to copper or copper to mild steel can be done by either the metallic or carbon arc. It is recommended that a phosphor copper electrode be used in making such welds.

Preparation of the Work.—There are several factors which must be considered when preparing work for welding in order to get the best results.

Provision must be made for expansion and contraction wherever possible. The strength of the weld will depend on the correct beveling and spacing of parts to be welded. Uniform fusion is directly dependent on the proper beveling and spacing.

The cleaning of the surfaces is another important factor, which must not be overlooked and considerable stress should be given this point, so that the welding operator will realize that good welds can be expected only when the joints to be welded are kept clean.

In all cases the material should be cleaned of all rust, scale, paint, dirt or foreign matter. This is necessary in order to exclude the foreign matter from the weld and to help make the operation of welding as easy for the operator as possible. *Foreign matter is usually a poor conductor of electricity and interferes with the control and manipulation of the welding arc.*

The best possible fusion is obtained when welding in a downward horizontal plane position on a flat steel plate.

It follows, then, since this is the easiest and best position in which welding is done, that when possible and economical to do so, arc welding should be done in the downward, horizontal plane position.

When welding in this position the welding wire is held approximately perpendicular to the face of the plate. It is necessary to bevel the abutting edges of plates or sections, except on sections ¼ in. thick or less, to approach this position.

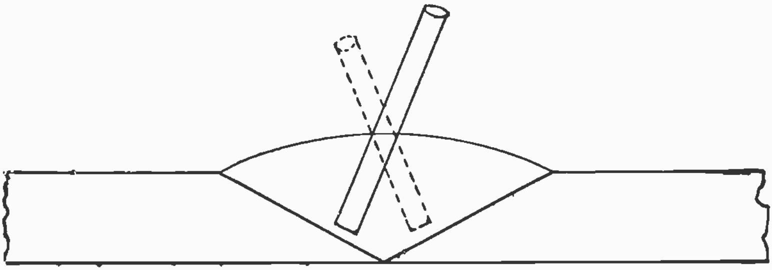
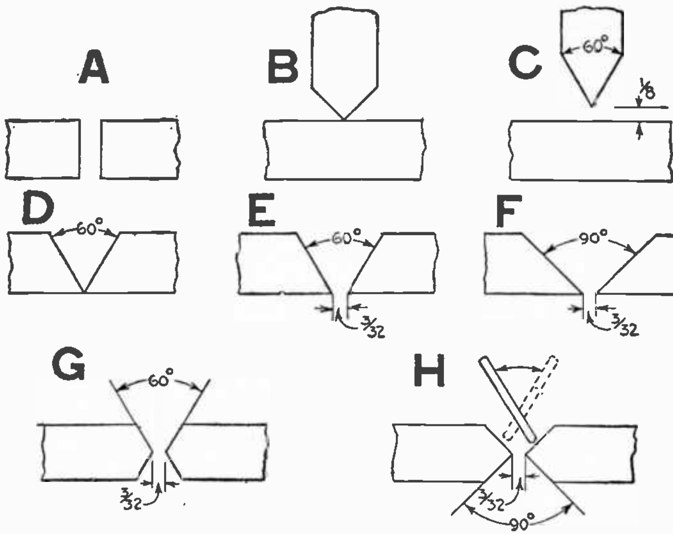


FIG. 8,056.—Best theoretical welding angle.

The best type of welding preparation would theoretically be one giving the greatest included angle if all other considerations be omitted, excepting the angle of the welding wire to the face of the work. A joint of this kind is shown in fig. 8,056. The expense of preparation and welding joints of this type would, however, be prohibitive. It is readily seen that a much smaller included angle will serve the requirements.

Another fundamental of good preparation or joint design is to keep the cross section of the added metal as small as practicable, so as to localize the effective heat in adjacent sections. The accompanying examples figs. 8,057 to 8,064 illustrate the preparation of the most common joints of the butt type. The same principles of preparation apply to other types of joints.

Lessons in Metallic Arc Welding.—While learning to weld, the beginner will find it convenient to use a bench or table such



FIGS. 8,057 to 8,064.—Preparation of joints for welding. A, *very bad*. Except on sections of ¼ in. thickness or less, this is a very poor type of joint where strength of weld is important. The bad feature of this design is that the faces of the original metal are not presented for welding, and fusion to them cannot be obtained unless the arc can play upon them. Closing of the crack by fusion of the edges may look like a good weld but the strength is only equal to the strength of the weld section. However, this preparation is sometimes permissible, for carbon arc welding and for certain thicknesses of metals. B, *bad, except for work where a square corner is essential after welding*. When used, this joint should be prepared as shown in fig. C. This type of joint is better than that of fig. B. However, in this type of joint, great care must be exercised to obtain fusion at the apex of the angle and the vertical plate; D, *good, but can be improved* by adding a free distance between the two sections as shown in fig. E. This type of joint is good especially where more than one layer of metal is to be deposited; F, *better*. This type of joint satisfies all the requirements as to preparation for work welded on one side only; G, *very good*. This joint is better than the preceding one, and is applied on sections which are heavy enough to warrant beveling on both sides. The factors which influence the adoption of this type of joint are strength of weld required, thickness of the section, cost of preparation as compared with the reduced cost of welding and permissible warpage; H, *very best*. This type of joint satisfies the conditions as to arc manipulation and reduced section of weld. Warpage is also reduced, due to the fact that the force on either side is counteracted by the force of the opposite side.

NOTE.—***When repairing cracks in castings***, it is often desirable to drill a hole at the termination of the crack to prevent further breaking. Also, care should be taken to bevel the work to the extreme depth of the crack or flaw, so that it will be a solid section after welded. If this be done the unwelded portion may cause the casting to re-crack, when the added metal cools and contracts.

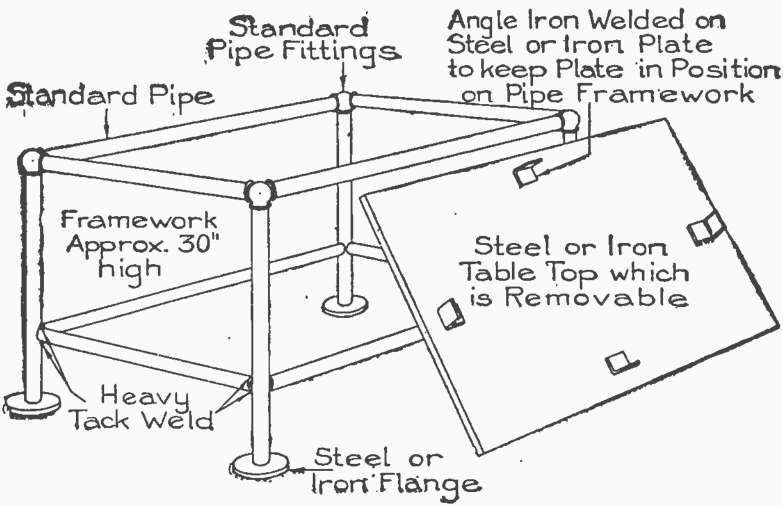
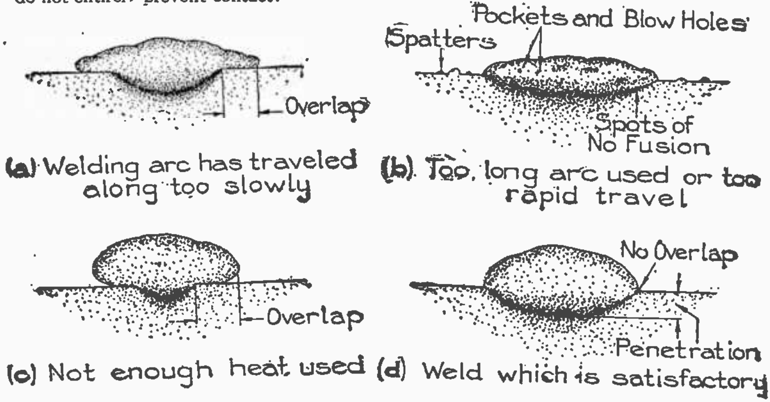


FIG 8,065.—Welding table with removable top suitable for small work which may be picked up and moved about by hand. It may be built of pipe and fittings with a steel plate top to which the positive lead is connected. The work may be set on this bench, the contact being sufficient to carry the current. In many cases, a vise mounted on the table will be found desirable. If the work be too large for the table, it may be set beside the table and a bar laid across to it. This will provide sufficient current carrying capacity, provided scale and rust do not entirely prevent contact.



FIGS. 8,066 to 8.069.—Cross section of beads deposited under different conditions.

as shown in fig. 8,065, with a steel plate top connected to the ground lead.

The welder can sit in a comfortable position, and by avoiding muscular strain, can better concentrate on the exercise. The steel top will catch many of the sparks and prevent burning the floor or bench.

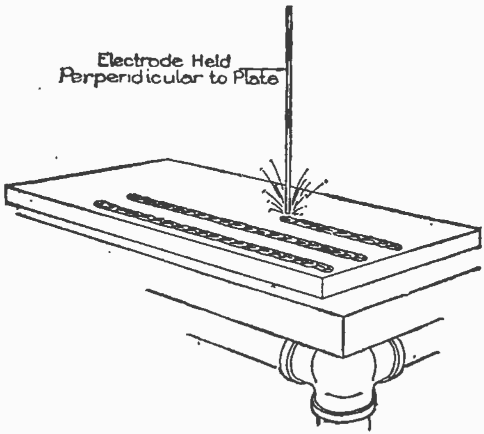


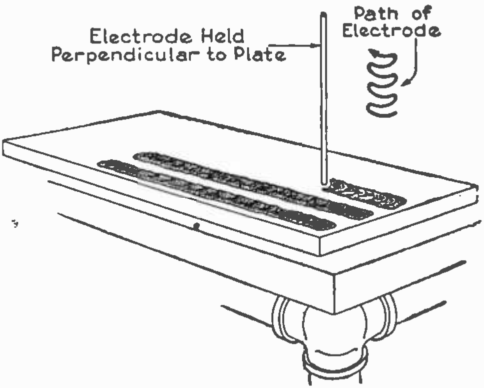
FIG. 8,070.—*Lesson 1. Laying single beads.* Run straight, continuous beads at least 12 in. long. Do not let the arc go out while the bead is being run, except to change electrodes. Uniform width and height of bead. Proper penetration and no overlap. No signs of porosity. Length of bead should equal the length of electrode wire used. ***Instructions:*** Take all the preliminary steps described before and strike the arc near the edge of the plate nearest the student. Move the electrode slowly and steadily across the plate away from the operator, keeping both arc length and rate of travel constant.

The exercise plates can be laid on the steel top, which will make the connection of the ground circuit.

For vertical and overhead welding, the plates can be attached to the bench top by short tack welds. A screen should be placed around the table to protect the eyes of others.

It is recommended that the beginner use a hand shield during the exercises on metallic electrode welding, since it keeps the left hand occupied and prevents using the left hand as a brace for the right hand. Also, the shield can be quickly moved before the face, allowing the operator to direct the

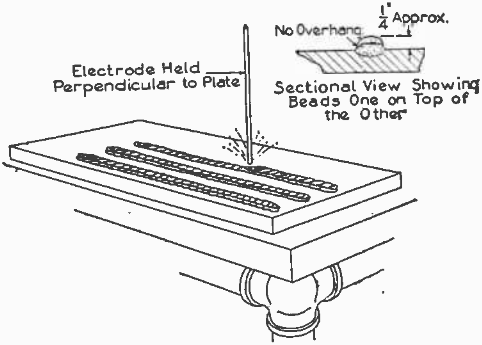
FIG. 8,071.—Position of welder when welding, showing shield, electrode, electrode lead and work table. The operator should try to assume an easy position in which the whole body is comfortable and braced so as to be steady without strain, leaving the right arm entirely free.



FIGS. 8,072 and 8,073.—*Lesson 2. Three parallel beads*. In this and all following lessons, the deposited metal should meet all the requirements of a good weld, uniformity of height and width, regularity of ripples, good penetration, and no overlap nor signs of porosity. These electrode visibly, until the instant before it makes contact and strikes the arc.

The beginner will profit greatly by watching for a time, an experienced welder.

He should closely observe the motions used in striking the arc and in moving along a weld. His ear will become accustomed to the sounds of the arc, both when it is too long and when it is of proper length. When at the



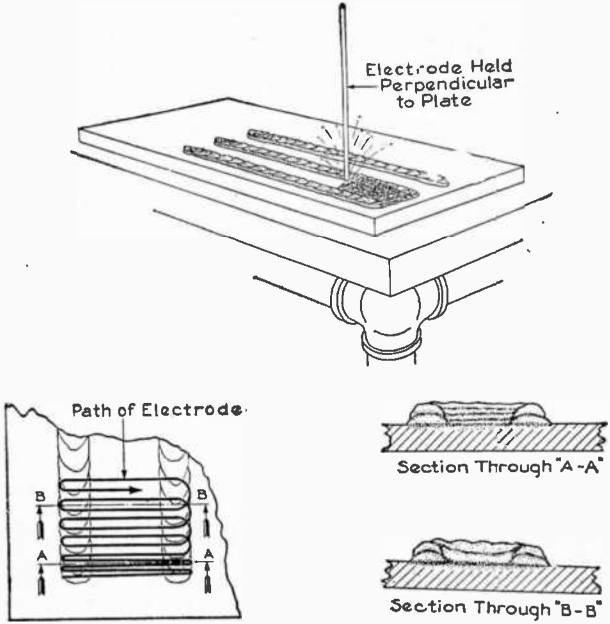
Figs. 8,074 and 8,075.—*Lesson 3. Three parallel beads in two layers.* Current in arc, 50 amperes. The reduction in current is because the conduction of heat into the plate is not as rapid, since the heat is applied to the top of a narrow ridge instead of the broad surface of the plate. A second layer deposited on each of the beads made in Lesson No. 2. Total height of completed beads, ¼ in. *Instructions:* Use for practice the plates from Lesson No. 2 that were not passable. Clean the surface of the preceding beads well with a scratch brush. When a good practice weld has been made, use the plate that passed the requirements of Lesson No. 2. Do not let the metal from the second layer run over the edges of the first layer.

Figs. 8,072 and 8,073.—*Text continued.*

factors will not be mentioned again, but it should be understood that they are of the first importance, and it is assumed that the student will make welds that meet these requirements. The particular requirements of this lesson are: beads each 12 in. long, ⅜ in. wide and ⅛ in. high. *Instructions:* The same as Lesson No. 1 except that, in order to obtain the required width of bead, it will be necessary to spread the weld by weaving the electrode in a crescent motion from left to right and from right to left across the line of travel. The arc will follow a path similar to that shown in fig. 8,073. This cross motion should not be too rapid, or the weld will not penetrate. This movement of the electrode should be governed by the same conditions laid down in the preliminary instructions allowing for the different motion. Each time an electrode is changed, use the scratch brush to clean the surface where the bead is to be deposited and to seal the crater properly. In making this weld, it will be necessary to use more than one electrode per bead. Each time the arc is broken to change the electrode, the arc should be recommenced according to instructions given in the section on *depositing metal.*

proper distance of ⅛ in. the arc will have a very snappy sound like frying grease; a long arc will have a dead, sputtering sound.

By using an electrode holder and electrode; but without any current, he can practice the motions of striking the arc. The hand shield should be used



FIGS. 8,076 to 8,079.—*Lesson 4.* Filling space between welds made in Lesson No. 3. Weld made in two layers. Same height as previous beads, leaving smooth surface. Weld must penetrate plate below and into beads at either side to form a solid mass of metal, as shown in fig. 8,076. *Instructions:* Clean the surfaces where the weld is to be made by means of the scratch brush and repeat each time an electrode is changed. Fig. 8,077 illustrates the manner in which the weld is made. The path of the electrode is as shown. At the start of the weld, the electrode is moved back and forth two or three times to build up the metal quickly to the desired height. A cross section of the weld at the start would have the appearance as shown in fig. 8,078. After building up the weld to the height of the two parallel beads at the start, the path of the electrode is that of an elongated spiral. The weld, from now on, is made in two layers, the bottom layer thoroughly penetrating both plate and parallel beads, and the top layer overlapping the bottom layer about two-thirds of its width. The top layer completes the fill to the top of the parallel beads and gives a smooth finish to the weld. The appearance of a section of the weld is shown in fig. 8,079. The type of bead described and used in this lesson is known as the *rope bead.*

just as though an arc were to be struck, since the operator should form the habit of always covering the eyes before striking the arc. Repeated flashes of the arc on the eyes, even though they are only momentary, will cause eyeburn.

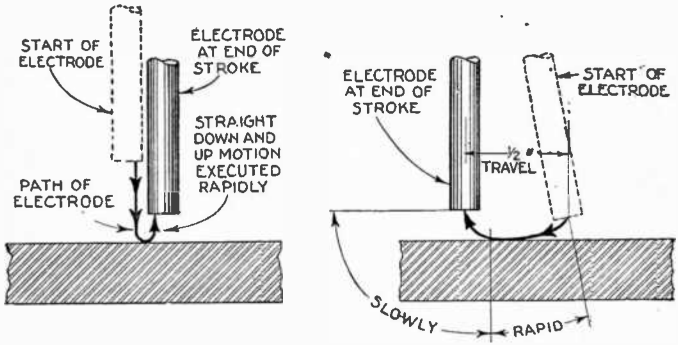


FIG. 8,080.—*Striking the arc, 1.* Insert an electrode wire in the holder, gripping it by the middle. Adjust the current for about 125 amperes dead short when welding. It is possible to determine the current with an ammeter by holding the electrode holder against the plate and reading the current. This value will be roughly about one-half more than when the arc is being held. Lay one of the exercise plates flat on the table. Take the welding position shown in fig. 8,071. Holding the electrode vertical, bring it to the point on the plate where the weld is to be started, but do not touch the plate until the hand shield is moved in front of the face. Touch the electrode very lightly and quickly to the work by a motion of the wrist. This is a quick, picking action. The movement in touching the plate and just freeing the electrode should be quick. Then bring the electrode away more slowly about ⅛ in. or until the arc has the proper snapping sound. Hold the arc a few seconds and then snap it out. If the electrode stick or freeze immediately, bend it from side to side with a steady pull which will probably free it. If this fail and the electrode become red hot, the circuit should be opened by opening the line switch, or by freeing the electrode from the holder, or by lifting the plate from the bench. On cooling, the electrode can be broken away with a hammer. The welder should practice starting the arc in this way, holding the arc a little longer time at each attempt, and moving it slowly over the plate until he is able to start and hold the arc consistently. Move the arc straight along; do not try to spread the bead or to weave or impart a zigzag motion to the electrode holder.

FIG. 8,081.—*Striking the arc, 2.* This method is to avoid sticking. It consists in "scratching" the electrode on the surface of the plate. The withdrawal of the electrode should be slower than the rest of the motion.

The accompanying illustrated lessons by courtesy of the ***General Electric Co.,*** will be found to comprise an excellent course for the welding student.

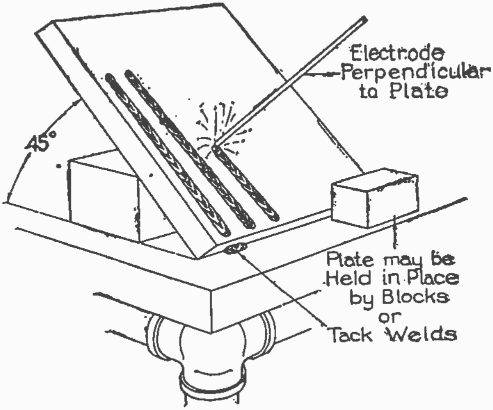
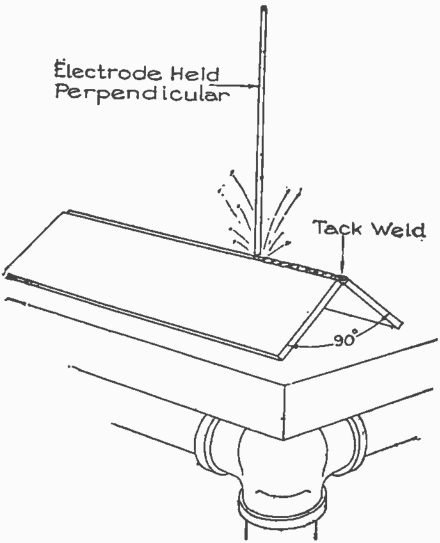
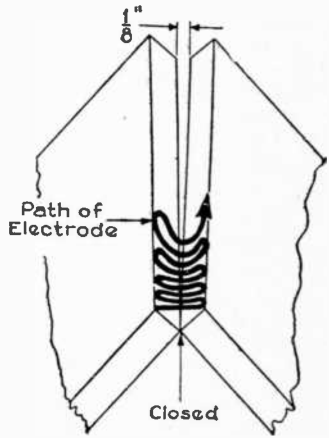


FIG. 8,082.—*Lesson 5. Laying three parallel beads, 45°. **Instructions:*** Similar to Lesson No. 1. The plate may be rested against a brace or welded to the bench top by a weld about ½ in. long, just enough to support it, as shown. Begin weld near bottom of plate. The arc must be kept short, or the metal will run, causing an uneven appearance.





FIGS. 8,083 and 8,084.—*Lesson 6. Straight butt weld method of making right angle butt weld in horizontal position.* Good appearing weld, even across the top without bumps, craters, or

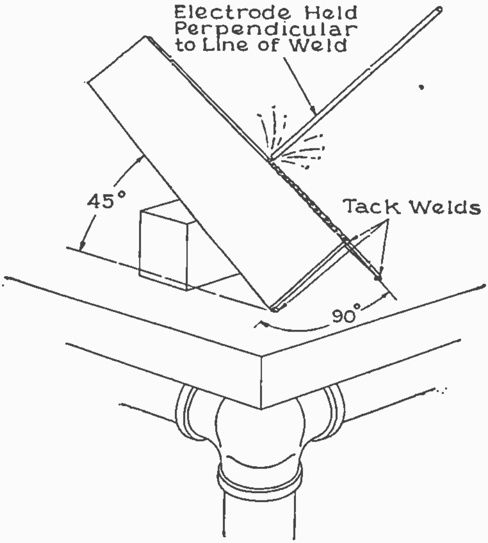


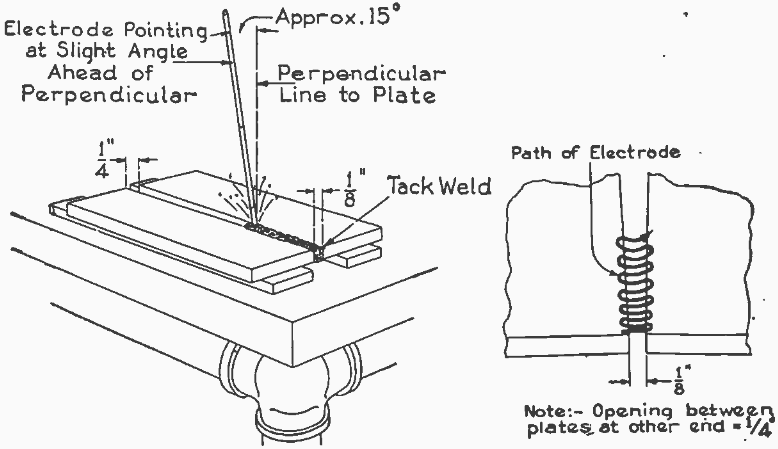
FIG. 8,085.—*Lesson 7.* Right angle butt weld inclined 45° to horizontal. This is the same as Lesson No. 6, except that, after tacking the plates as shown in fig. 8,083, they are placed so the weld makes an angle of 45° with the horizontal. The end having the ⅛ in. opening should be at the top. Begin at the lower end, and weld upward and away from the operator, as shown.

FIGS. 8,083 and 8,084.—*Text continued.*

dribbles over the edges. Weld must extend through bottom of groove, and show on under side. The break should, in general, follow the middle of the weld. The grain of the metal should be uniformly fine and of a dull gray color. *Instructions:* Place the plates at an angle of 90° as shown in fig. 8,083. Assuming that the plates are 12 ins. long, they will be spaced about ⅛ in. at one end, as in fig. 8,084. Tack the plates at the ends where the edges touch. Start the arc at this end and, as the weld advances, the shrinking of the deposited metal will gradually draw the plates together. Therefore, as the arc reaches any point along the weld, the plates at that point will be spaced a slight distance apart. The general rule for spacing the plates in welds of this type is ⅛ in. per ft. length of the weld. At the beginning, the path of the electrode will be a simple, spreading motion to distribute the heat evenly. As the plates become hot, the metal in the weld and at the bottom of the groove tends to fall or sag through. To prevent this, the amount of heat in the middle of the weld is reduced by moving the electrode farther up along the edge of the plates and making a more pronounced horseshoe-shaped path, the sides of the horseshoe being about $^3/_{16}$ in. long. The travel across the middle of the weld should be made faster, and that along the sides of the horseshoe, slower. In this way, the maximum heating is caused along the edges of the cold plate where good fusion is necessary. Do not run over the edges of the plates.

Striking the Arc.—The principal precaution to be observed when striking the arc is to prevent *freezing* or *sticking* the electrode to the work. This is caused in the following manner:

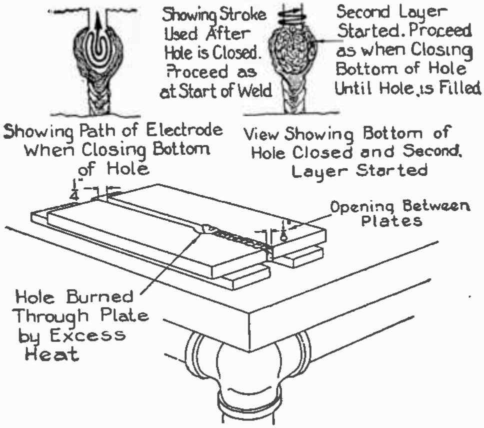
The electrode touches the work only on a small surface, a point, or sharp corner. The heavy current melts this and it sticks to the plate. More of the electrode melts and, as it is being pushed against the plate, the end of



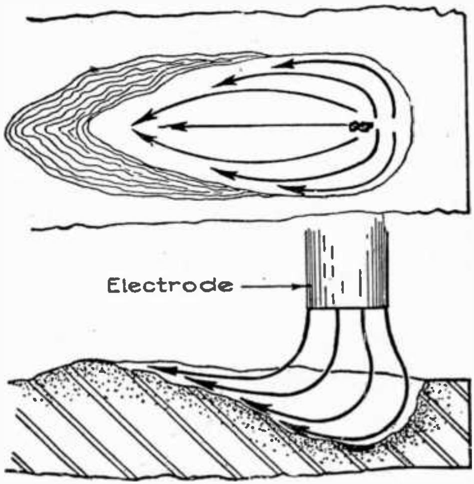
Figs. 8,086 and 8,087.—*Lesson 8. Straight butt weld, plates in same plane.* Same as lesson 6, except position of plates is horizontal. *Instructions:* Place the plates as shown in fig. 8,086, with an opening of ⅛ in. at one end and ¼ in. at the other. Tack the end with the ⅛ in. opening. The path of the electrode will be similar to that in Lesson No. 6, except that the sides of the horseshoe are longer, about ¼ to 5/16 in. The path of the electrode is shown in fig. 8,087. This path must extend over the edges of the plates as shown, in order that the deposited metal will be thoroughly fused with the plate. Figs. 8,088 to 8,090 illustrate the method of filling a hole caused by the use of too great an amount of heat or too slow a feed of electrode.

the electrode will weld fast. The current then rapidly heats the rest of the electrode, unless it is broken away at once. This trouble is avoided by quickness in making the electrode touch the work and in bringing it back just away from the plate. The electrode should be drawn back to the arc length somewhat more slowly than the movement in the first part of the action, as in fig. 8,080.

Depositing Metal.—In advancing the arc, care should be taken not to move the electrode faster than it is possible for



FIGS. 8,088 to 8,090.—Method of filling hole in butt weld caused by arc melting through.



FIGS. 8,091 and 8,092.—Diagrams showing flow of welding metal when welding.

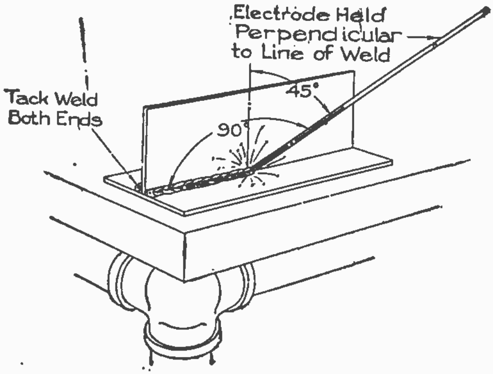
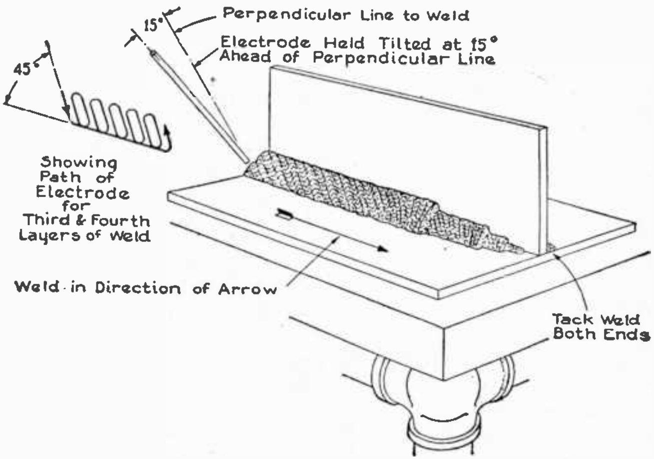


FIG. 8,093.—*Lesson 9. Single fillet T weld.* Clean and uniform surface, indicating penetration into plates at edges of weld. No signs of porosity. Surface of weld should be flat across, not re-enforced or concave. Clean surface of each layer with hammer and chisel, and brush before depositing a succeeding layer. *Instructions:* In making the first bead, the electrode should be moved slowly across the plate, advancing as fast as necessary to keep the proper height of the deposited metal, which should be approximately ¼ in. Since the weld is being made in the middle of the horizontal plate, the heat will be conducted away in both directions by this plate, and, therefore, at a greater rate than by the vertical plate. The crater should be established at the juncture of the two plates, with the greater portion on the bottom plate.



FIGS. 8,094 and 8,095.—*Lesson 10.* Method of making 4-layer T weld in horizontal position.

the arc to melt a place on the plate for receiving the deposited metal. If the arc be moved too fast, the metal will be merely laid on the plate with no penetration.

The operator should keep the arc traveling forward just fast enough to keep it at the forward edge of the crater, as in fig. 7,975.

This is the greatest speed of travel possible with the combination of plate thickness, electrode diameter, and current used. Advancing the arc less rapidly will result in a bead somewhat higher and wider.

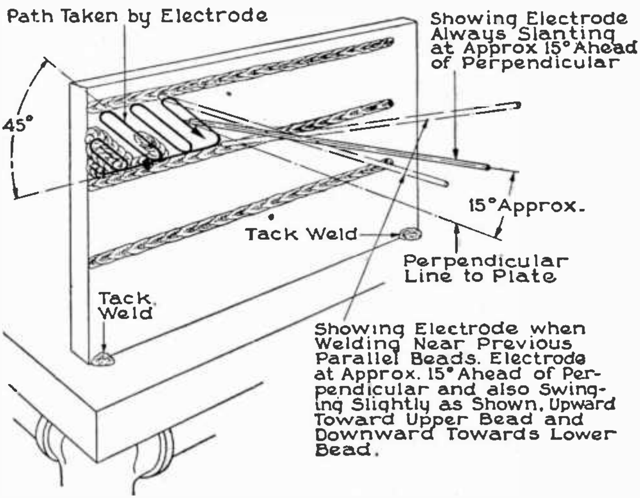


FIG. 8,096.—*Lesson 11.* Method of filling in between parallel, horizontal spread beads on vertical plate.

Too low a speed will result in overlap of the bead, and possibly in oxidized metal caused by the melting of a large crater and exposure of this hot metal to the air. The gases and vapors from the arc will protect the metal in a small crater to a certain extent.

These exercises should be continued until the operator is able to start the arc practically every time.

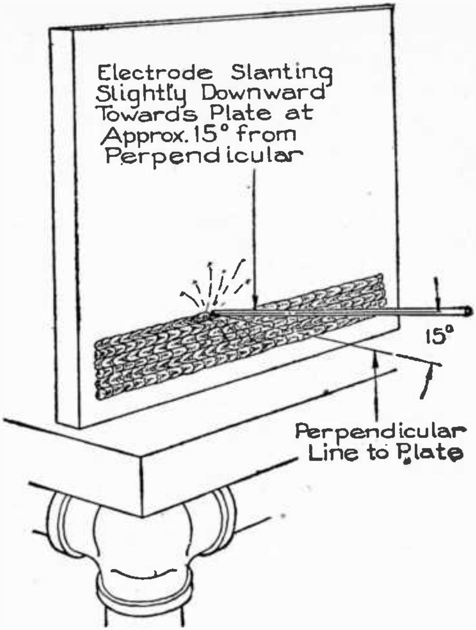
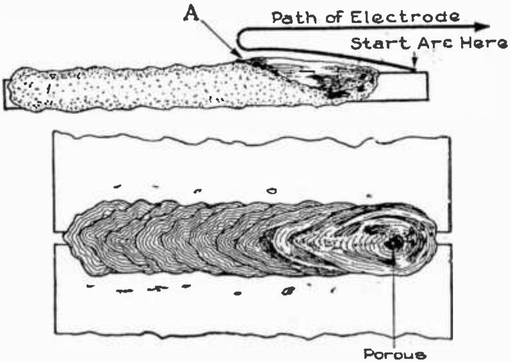


FIG. 8,097.—*Lesson 12.* Method of building up a patch on a vertical plate working upward.



FIGS. 8,098 and 8,099.—Section of deposited metal showing penetration and crater.

Gradually increase the length of the bead and make curved lines, letters. etc., but do not weave.

Now, begin to examine the beads deposited while moving the arc along the plate, by comparing them with fig. 8,099.

The sound of the arc, and its appearance, both from the standpoint of length and size, and also the size and number of sparks, should be noted in connection with the appearance

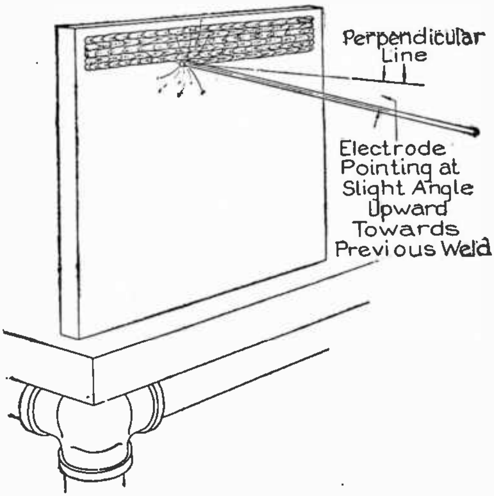


FIG. 8,100.—*Lesson 13.* Method of building up a patch on a vertical plate working downward.

of a bead. Chip off the bead, commencing at the end where the weld was begun, since this is usually the weakest point.

Continue making beads 3 or 4 ins. long until the bead has the appearance of a good weld; that is, even height, width, no overlap, and good penetration.

If a volt meter be connected to measure the arc voltage, it will aid to have someone watch this and report from time to time what the voltage is. It should be kept from 18 to 20 volts and the appearance under these conditions noted.

Now repeat the above exercises, first using a current of 100 amperes in the arc, and then of 75 or 80 amperes.

These currents will require increasingly greater steadiness of the hand, both in starting and in holding the arc after it is started. The observations above as to arc sound and appearance should be checked in each case against the appearance of the bead.

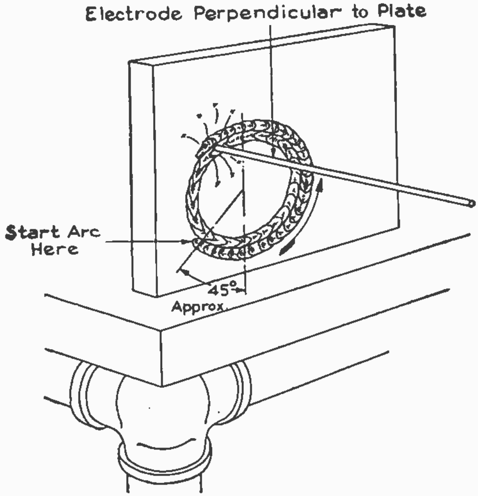


FIG. 8,101.—***Lesson 14.*** *Welding around tubes*. The weld should be made continuously in one direction as shown, from start to finish. Particular attention should be given to obtaining a tight weld at the starting and finishing points, since such a weld under service conditions must be tight under high pressure.

The surface of the bead should consist of regularly spaced ripples with no holes or spongy places.

No large drops of metal should be outside the weld on the plate and, when the bead is chipped off, it should be necessary to cut it away the full width of the bead, thus showing that there is no overlap.

It will be noted that wherever the arc stops, there is a spongy, porous spot in the crater.

In the case of long welds, where it is necessary to use more than one electrode, such a spot will be found wherever the arc is stopped to change electrodes.

When an arc is broken, care should be taken in recommencing to close the gap in the deposited metal and also to guard against leaving a lump of metal on the bead.

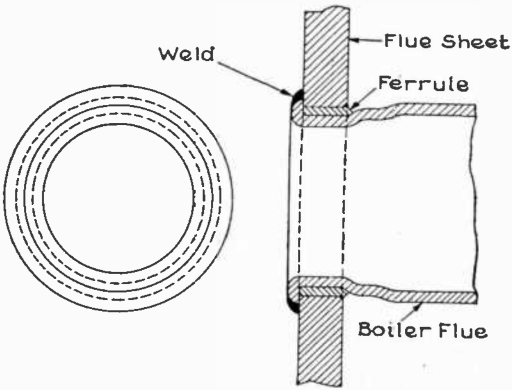


FIG. 8,102 and 8,103.—*Lesson 14. Continued.* Cross section of flue of locomotive showing method of welding tube to flue sheet.

Strike the arc about ¼ to ⅜ in. in front of the crater, and come back as shown in fig. 8,098, holding the arc very closely, and then proceeding in the direction of the weld. The path of the electrode is as indicated in figs. 8,098 and 8,099, the travel back to the point A, being faster than normal. From point A, the weld should be continued at the normal rate.

It can now be assumed that the welder is able to start an arc and to hold it uniformly for a short time.

From this point on, the exercises will take the form of lessons on carbon arc welding as given in the accompanying illustrations with certain conditions specified, and certain requirements which are to be met by the finished weld, before the student passes on to the next lesson.

Lessons in Carbon Arc Welding.—A source of welding current is required which will deliver from a maximum of 400 to 600 amperes down to a minimum of about 40. A carbon electrode holder and electrodes of various sizes are needed. While the hand shield may be used in cutting, it is necessary to use both hands for welding, and therefore, the helmet must be used for the latter operation.

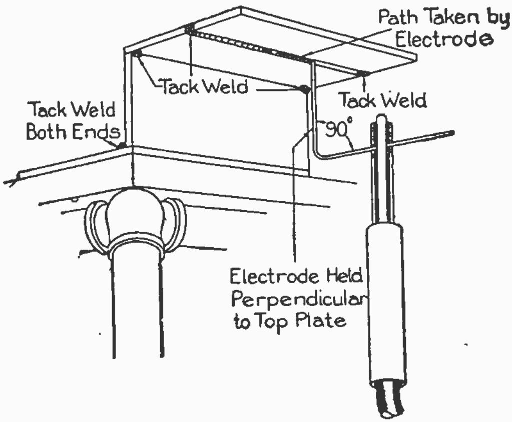


FIG. 8,104.—*Lesson 15.* Method of making an overhead straight butt weld.

Striking the Arc.—The carbon arc is very stable and easy to maintain. The length can be varied over wide limits without causing the arc to go out.

There is no tendency for the electrode to freeze or stick, as in the case of the metallic electrode. Accordingly, the arc can be struck without difficulty at any point, and rapidly moved over the surface of the work to the point where the weld is to be made.

Depositing Metal.—In welding with the carbon electrode, a molten pool should be formed on the work and the added metal deposited in this pool. The arc should be kept at this point until the added metal is thoroughly melted and mixed with the original metal before more material is added.

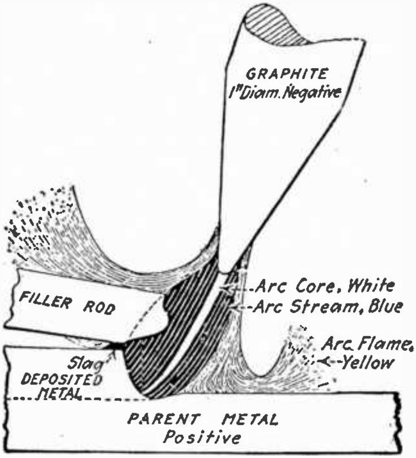


FIG. 8,105.—Correct position for graphite electrode and metal filler rod.

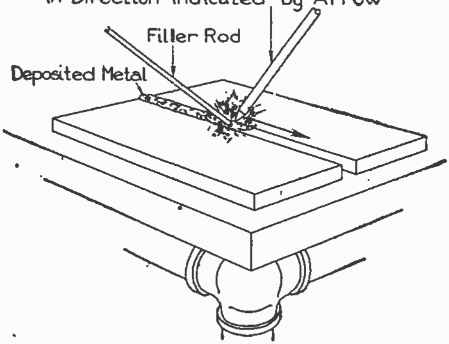


FIG. 8,106.—Direction of travel in making a carbon weld.

The added metal is usually in the form of a long stick of filler rod held in the welder's left hand. When the pool or the work is ready, the end of the filler rod is inserted in the pool, and the arc directed against the rod just above the surface of the molten metal. This will melt through the rod, and leave the end in the molten pool on the work.

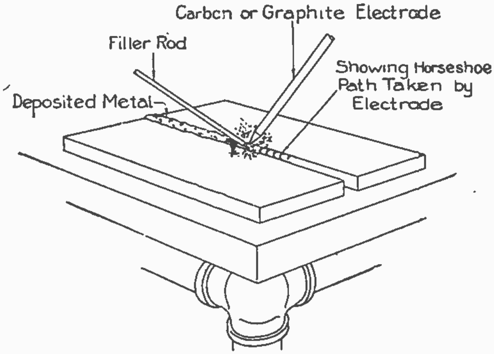


FIG. 8,107.—Electrode travel in making a butt weld with the carbon arc.

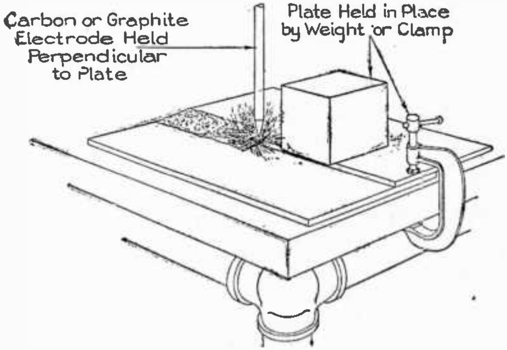
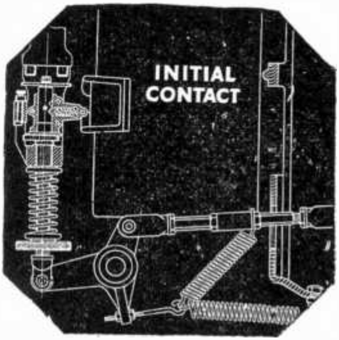
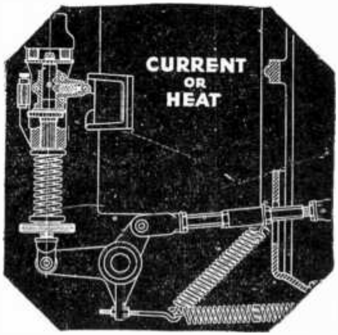
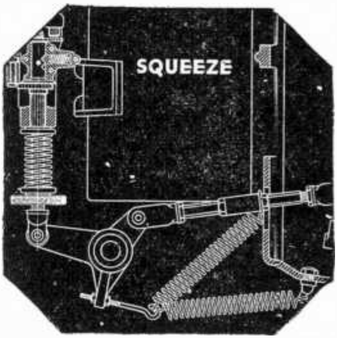


FIG. 8,108.—*Lesson 1. Lap weld of thin sheet metal.* ***Instructions:*** The line of weld will be along the middle of the overlapped portion. Strike the arc at one end, and move it slowly along the line of weld. The heat of the arc should fuse through the upper strip and into the lower. This depends on both the current and rate of travel of the electrode along the weld. Penetration can be increased by reducing the rate of travel until a point is reached where the heat spreads out too wide on the upper strip and causes the fusion of a wide area. When this condition is found, increase the current and advance the electrode faster. Experience will show the best combination to use.

The arc should be played about on the pool until the added metal is all melted down, when, because of the circulation caused by the heat, the molten metal will be well mixed. After this, the filler rod may be again inserted in the pool, and the process repeated, advancing along the line of weld.





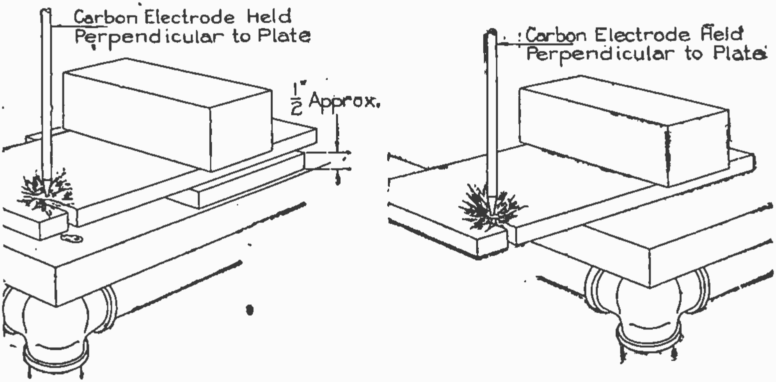


FIGS. 8,109 to 8,111.—A. E. F. spot welder diagrams showing operation. 1. Pressing down on treadle brings welding points on work. This initial contact must press lightly to assure high resistance and heat generation at point of weld, yet not too light to create air gaps. 2. Pressing further on treadle closes switch contact thus applying current. Switch remains closed, automatically opening with a quick break, cutting off current. 3. Treadle continued downward to end of stroke, applying pressure to the then plastic metals, setting the weld.

Position of Electrode.—In welding or building up, the electrode is generally held perpendicular to the surface of the plate, but is inclined ahead about 15° to the line of weld to direct the arc back into the weld.

Direction of Travel.—By welding from left to right, a right handed welder avoids awkward positions. The arc is directed backward into the weld, and the position of the arms and hands is comfortable.

Resistance Welding.—The art of resistance welding was discovered accidentally by Prof. Elihu Thompson in Philadelphia, in 1885. While experimenting with a spark coil operated from a bank of batteries he accidentally welded two steel rods of about ¼ in. diameter.



FIGS. 8,112 and 8,113.—*Lesson 2. Cutting a steel plate with a carbon or graphite electrode. Instructions:* First, melt away the lower part of the plate, and then bring the arc toward the top. This undercutting makes it easier for the molten metal to run out. It is particularly beneficial in cutting heavy parts such as castings, shafts, etc. It is often necessary to follow the molten metal down with the arc to keep it fluid until it runs off. The width of the cut will depend on the size of the electrode used and on the skill of the operator in keeping to a straight line.

By definition, *resistance welding is that method in which a sufficiently strong electric current is sent through the two metals in contact to be welded which melts the metals by the resistance they offer to the passage of the electric current.*

There are several forms of resistance welding known as

1. Butt;
2. Flash;
3. Spot;
4. Seam;
5. Tube.

Each depends on the resistance offered by the metals in contact, to the passage of the current for the production of the

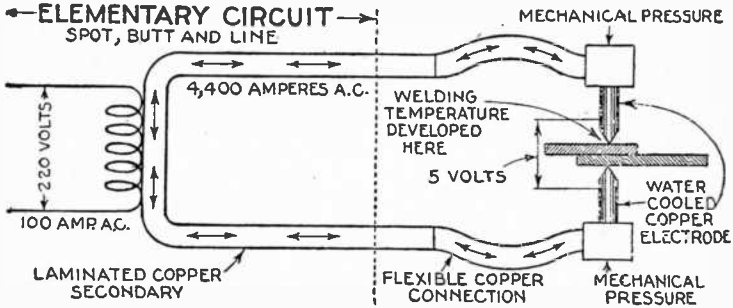
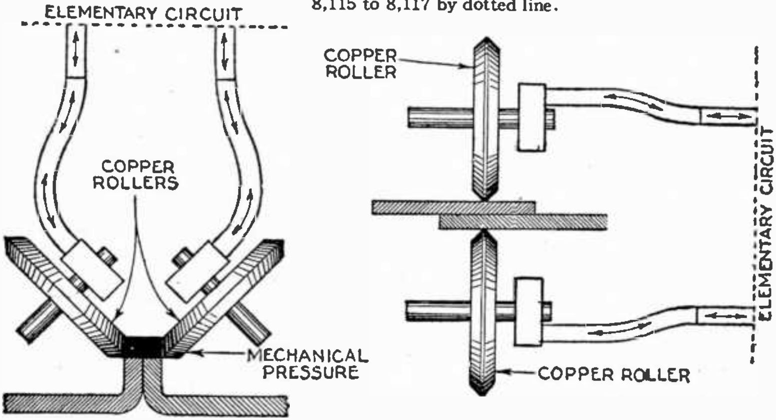


FIG. 8,114.—Circuit diagram for spot welding. Spot welding, for the most part, is used in place of riveting. It consists of 1, discharging an enormous current, at a fairly low voltage through two or more pieces of sheet metal or bar stock; 2, following up the discharge of current with sufficient pressure on the two or more pieces of metal so as to unite the molecules of the metal; 3, cutting off the current before the mechanical pressure is released, so as to prevent burning the die points. The spot welding process is also used largely in the manufacture of wire goods, such as lamp shades, wire cloth, screening, netting, fencing, and an endless variety of objects and utensils for various uses. Above elementary circuit indicated in figs. 8,115 to 8,117 by dotted line.



FIGS. 8,115 and 8,116.—Circuit diagrams for seam welding. *It consists of* passing two or more metal sheets or bars, between the rollers of a seam welder. The electric current passing from roller to roller through the work heats up the parts to be joined in the nature of a spot welder and the mechanical pressure on the roller electrodes consummates the weld.

heat to melt or soften the metal. Usually there is mechanical pressure applied to the soft or melted metal to force the parts together and aid in binding them.

In butt welding, the ends of the pieces to be joined are butted and current passed from one to the other until they become plastic and the pressure binds them.

A modification of butt welding is flash welding.

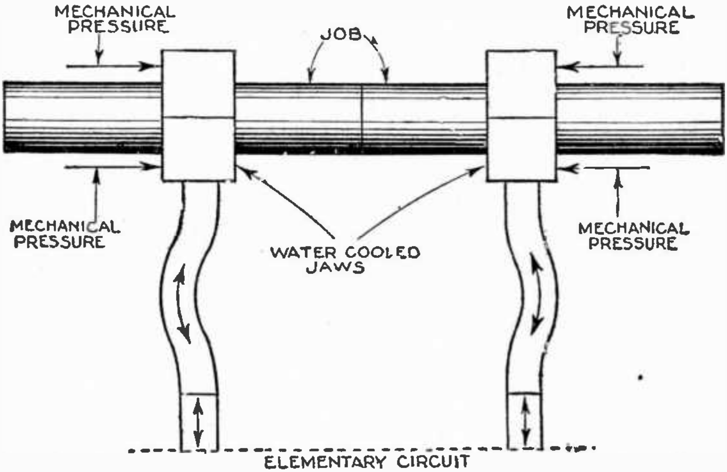


FIG. 8,117.—Circuit diagram for butt welding.

The difference being that current is applied to the parts before they are brought together so that when they meet arcing or flashing takes place and greater heat produced and projections burned away and thereby the surfaces brought closer together; the pressure completing the bond. The flash method has almost entirely superseded the butt weld method.

In spot welding, the parts or pieces are joined in spots.

The metals are brought together either butted or lapped and the electrodes connected to the metals both above and below the particular points where they are to be joined. This creates heat at these points and softens the metals within these restricted areas and by pressure completes the weld. The joining points being wherever the electrodes are connected.

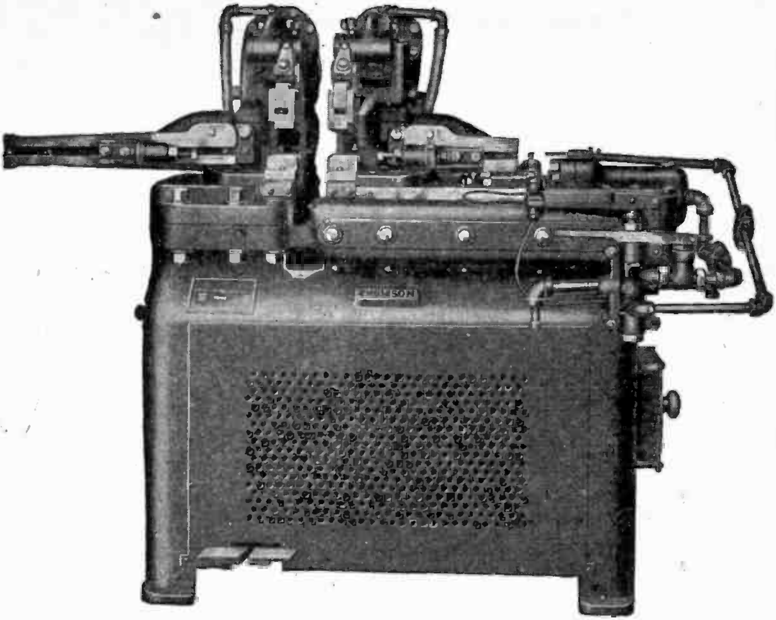


FIG. 8,118.—Thompson butt welder. *Capacity.*—Iron or steel. A cross section from .0123 minimum to a cross section of ¾ sq. in. maximum continuously, or 1 sq. in. at long intervals. Rims 2½ ins. wide by ¼ in. thick by 10½ ins. minimum diameter. Rims 1⅜ ins. wide or narrower and as small as 8 ins. diameter can be handled. Pipe or tubing up to 1 in. diameter extra strong; pipe or tubing 1¼ ins. diameter standard, can be welded by fitting contacts to size.

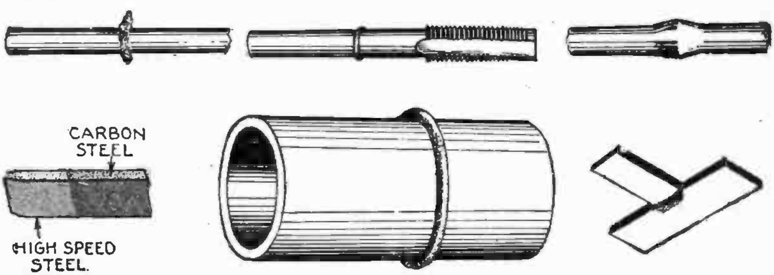


FIG. 8,119 to 8,124.—Various examples of butt welds. Fig. 8,119, flash weld; fig. 8,120, tool weld; fig. 8,121, upset weld; fig. 8,122, high speed steel weld; fig. 8,123, pipe weld; fig. 8,124, tee weld.

Butt Weld Data

(According to Thompson Electric Welding Co.)

Round Iron Diameter	Area in Square Inches	KW Required	Time in Seconds to Make Weld	Cost per Thousand Welds at 1¢ per KWH
¼"	.05	2	3	.02
⅜"	.11	3.5	5	.05
½"	.20	5	5	.07
⅝"	.31	7.5	10	.21
¾"	.44	12	15	.50
⅞"	.60	15	18	.75
1"	.79	18	20	1.00
1⅛"	.99	25	25	1.73
1¼"	1.23	35	30	2.90
1½"	1.37	50	40	3.55
1¾"	2.41	65	45	8.12
2"	3.14	75	50	10.42

In seam welding, the electrodes either in the form of wheels or rollers, move along the seam of work and weld it.

This is used for cylinders or other work of that kind and either the rollers move or the work moves, Pressure of course is applied the same as for the other welds.

The electric current passing from roller to roller through the work heats up the parts to be joined in the nature of a *spot* welder and the mechanical pressure on the roller electrodes consummates the weld.

TEST QUESTIONS

1. *Define electric welding.*
2. *Name the various welding methods.*
3. *Describe the source of welding current.*
4. *What is the difference between carbon arc welding and metallic arc welding?*
5. *What is the action of the welding arc?*
6. *What effect has the length of the arc upon its action?*
7. *Is a short arc more desirable than a long arc?*
8. *What strength of current is required in welding?*
9. *Name the various positions of the work and of the weld.*
10. *What are the various types of weld?*
11. *Describe the following welds: 1, butt; 2, lap; 3, T; 4, edge; 5, plug.*
12. *How can the effects of expansion and contraction be minimized?*
13. *Can cast iron be welded?*
14. *Describe the welding of non-ferrous metals.*
15. *How is the work prepared for welding?*
16. *Make sketches and describe various examples of welding.*
17. *Describe the method of striking the arc.*
18. *What precautions should be taken in advancing the arc?*
19. *What happens when the arc stops?*

20. *How many amperes are required for carbon arc welding?*
21. *What are the characteristics of the carbon arc?*
22. *What is the form of the added metal in carbon arc welding?*
23. *Describe in full detail carbon arc welding.*

CHAPTER 207

Gas Welding

(Oxy-Acetylene)

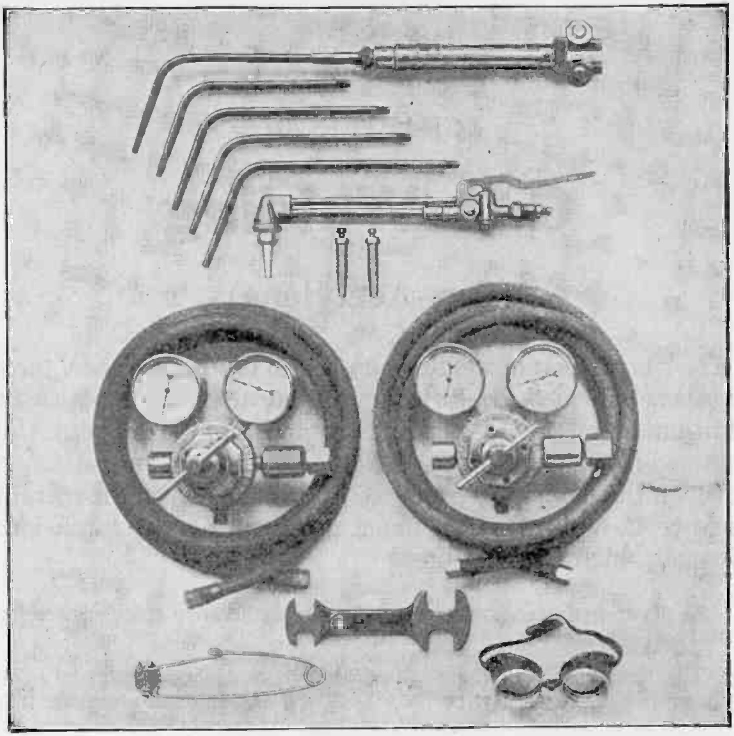
The gas method of welding consists in *uniting the metal pieces by means of a torch flame* of appropriate temperature with the addition of metal of the same composition. The joint thus obtained is called autogenous. The torch used is an instrument in which the flames are produced and projected on the metallic parts to be welded. The flame produced by the torch is of unusually high temperature.

First oxy-hydrogen was used in the torch, then oxy-acetylene, oxygen and coal gas, and oxygen and benzol, etc.

The temperature of the oxy-hydrogen flame is approximately 4,000° Fahr. and the oxy-acetylene flame, 6,300°. Oxygen and acetylene (oxy-acetylene) is the combination of gases most extensively used.

With the oxy-acetylene torch the metals can be welded without adding metal to the weld.

Sections from ⅛ in. thickness up, are welded by fusing the edges and adding filler melted from the end of a wire or rod. All common commercial metals are readily fused with the oxy-acetylene flame, and practically all can be welded. The list includes wrought iron, steel, steel castings, alloy steels, gray and white cast iron, aluminum, copper, brass, bronze, nickel, monel, the principal commercial alloys, the precious and the semi-precious metals. Welding dissimilar metals to each other, such as steel and cast iron, steel and copper is also practicable.



FIGS. 8,125 to 8,137.—Airco-Davis-Bournonville welding outfit showing torch, tips and other parts. The torch comprises a brass handle, to the rear end of which are attached the oxygen and acetylene needle valves; oxygen and acetylene tubes inside the handle, joining the rear end to the torch head, mixing head nut, mixing head and tapered copper welding tip. The needle valves provide ample packing space for the stems and good grip for the fingers when wearing gloves. Hose connections for 5/16 in. inside diameter hose are of the approved standard design now in general use on all makes of torches. The oxygen hose thread is right hand, and the acetylene hose thread left hand. The needle valves screwed into the rear end, are soft soldered in place to insure tightness and permanent position. The tips made of seamless copper tapered, are bent to the welding angle 67½° and threaded at the rear to fit the mixing head. The end of the tip makes up against a flat seat in the mixing head which construction is well removed from the welding heat and which insures against leaks. Copper extension tubes, 9 ins. long, are furnished for welding heavy preheated jobs and for other situations requiring long reach. The extension tube is coupled between the mixer head and tip. Two or more extensions can be joined when necessary to get the reach required. Fig. 8,130 shows cutting attachment.

NOTE.—Airco-Davis-Bournonville oxygen welding pressure regulator. This device has a

The filling material or welding rod as a rule should be of nearly the same chemical composition and physical characteristics as the base metal.

Low carbon steel is generally welded with low carbon rods, cast iron with cast iron rods, copper with copper rods, and so on. When welding dissimilar metals the welding rod as a rule is of the metal having the lower melting point. Thus copper rods are used when welding steel and copper.

An oxy-acetylene outfit consists of

1. Torch with separable tips, mixing heads;
2. Two lengths of hose (black for oxygen; red for acetylene);
3. Two pressure regulators;
4. Cylinder containing oxygen;
5. Cylinder containing acetylene.

The pressures of the gases in the cylinders are too high to be used directly for welding, and are reduced, as they flow through the pressure regulators, to the working pressure required in the torch.

The pressures for welding range from 1 lb. to 20 lbs. per sq. in. for the oxygen, and from 1 lb. to 12 lbs. for the acetylene, depending on the tip size, torch type and thickness of the metal.

Oxy-Acetylene Hand Welding Torch.—This tool mixes oxygen and acetylene in nearly equal volumes, the mixture being burned at the end of a tip, producing a flame of such high temperature that metals are easily fused. A typical torch with some of its various tips is shown in figs. 8,125 to 8,132.

NOTE.—*Continued from page* 5,070

3,000 lbs. high pressure gauge and a 200 lb. working pressure gauge. The 3,000 lb. gauge indicates the pressure in the oxygen cylinder. The working pressure, adjusted by turning the regulator adjusting screw in the front of the case, is indicated on the 200 lb. gauge. A safety disc is provided to relieve over-pressure beneath the diaphragm. Should the safety disc be blown by a leaky seat or over-pressure due to any cause the defect should be rectified, and the safety replaced only by a standard disc.

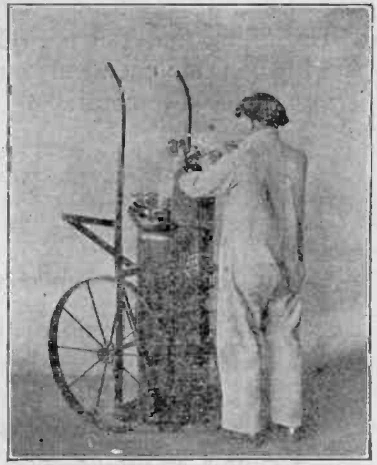



FIG. 8,138.—***"Cracking" the cylinder valve.*** (Airco-Davis-Bournonville.) Open each valve for an instant to blow dirt out of nozzles. Wipe off the connection seat with a clean cloth.
FIG. 8,139.—***Attaching the pressure regulators.*** (Airco-Davis-Bournonville.) Connect the acetylene regulator to the acetylene cylinder and the oxygen regulator to the oxygen cylinder. Screw the nuts up tightly with a close fitting wrench.

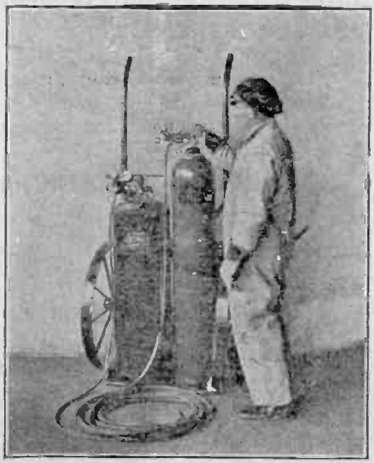



FIG. 8,140.—***Connecting the hose to the regulators.*** (Airco-Davis-Bournonville.) Connect
FIG. 8,141.—***Opening the cylinder valve.*** (Airco-Davis-Bournonville.) Release regulator

The function of the pressure regulator is to reduce the pressure of the gas flowing from the cylinder to the required working pressure in the torch, and to regulate the flow volume. Fig. 8,134 shows the oxygen regulator.

The acetylene pressure regulator shown in fig. 8,133, is of the same design as the oxygen regulator, differing only in the graduations of the gauges and certain details. The high pressure gauge, indicating the pressure in the acetylene cylinder, is graduated to 400 lbs., and the working pressure gauge to 30 lbs.

Welding Rods.—Thin metals can be welded by the fused metal on the adjacent parts, however as before mentioned, for metals over ⅛ in. in thickness new metal should be added by melting from the end of a wire or rod known as a *welding rod.*

Use of inferior or unsuitable welding rod has caused much trouble and loss. It slows up welding and is likely to produce weak and brittle welds. Commercial wire, such as used for fences and other common purposes, is unfit for welding. It is generally high in impurities, sulphur, phosphorus, and occluded gases.

A test for weldability of rods is easily made with the oxy-acetylene torch. The rod sample is laid horizontally and partly fused. Its behavior under the flame and appearance after fusion determine its weldability. The test should be made with a No. 1 (Airco-Davis-Bournonville) tip and a strictly neutral flame. Fusion should penetrate to about one-half the diameter of the rod.

A rod of good weldability will have a surface after this test is made somewhat like that of narrow ripple weld. The metal will have been displaced into smooth blended drops, one merging into another, and none extending much beyond the original rod diameter. There will be little sparking during fusion, and no pinholes in the fused metal after cooling.

A rod of poor weldability will spark excessively during fusion, and the fused metal will spread irregularly, giving evidence of gas inclusions. The fused surface after cooling will be rough and irregular with some pinholes; the metal may have a spongy or "bread crust" characteristic in spots.

FIG. 8,140.—*Text continued*

the red hose to the acetylene regulator and the black hose to the oxygen regulator. Screw the nuts up tightly.

FIG. 8,141.—*Text continued*

screws and open cylinder valves slowly. Never open cylinder valves with regulator screws not released.

Although most of the welding done is on low carbon steel with low carbon welding rod, it is important that the welder know when to use other rods and what to specify when the need arises.

FIG. 8,142.—***Blowing out the hose.*** (Airco-Davis-Bournonville.) Open each regulator with the regulator screw and blow out hose. Release regulator screws.

FIG. 8,143.—***Connecting the hose to torch.*** (Airco-Davis-Bournonville.) Connect the red acetylene hose to the needle valve stamped "ac" and the black oxygen hose to the "ox" needle valve.

NOTE.—***Overheated weld metal,*** or a weld containing films of metallic oxides will be neither tight nor strong; pin holes and porous sections are more than likely to appear when the joint is tested under pressure, or after the welded article has been placed in service. Such a structure in the weld is often the cause of a complete fracture through the weld metal; because the oxide films are planes of weakness.

NOTE.—***It is important*** to select a welding process which is widely and generally used, and of which mechanical men have a good general knowledge. Furthermore, in such work as welding, it is of the utmost necessity that reliable engineering advice and service be readily available on any special problems that may arise, the solution of which may not be suggested by ordinary experience.

NOTE.—***The apparatus*** for applying the welding process should be relatively inexpensive. It should be, if possible, adaptable to a wide range of applications, both in the sheet metal work and in other departments. Portability is a very important asset, especially in plants doing a variety of work.

The following list of drawn and cast welding rods covers general requirements of commercial, manufacturing and repair welding:

Low Carbon Steel Rods.—For general welding of wrought iron and steel, plates, sheets, pipes, castings, etc., in manufacturing, production and repairs.

Mild Steel Rods.—An excellent rod at low cost for general use in oxy-acetylene welding of steel plates, sheets, structural steel, pipe, etc. These should conform to American Welding Society Specification G-No. 1A.

No. 1 Simplex Rods.—Especially developed to produce high tensile strength welds in low carbon or high carbon steel plate, pipe, etc. An approved rod for pipe line welding.

Vanadium Steel Rods.—For all welding requiring higher strength than afforded by low carbon rods.

Nickel Steel Rods.—A nickel alloy for welding nickel steel and other alloy steels when still higher strength than that given by vanadium rods is required.

Chrome-Vanadium Steel Rods.—For wear resisting and special strength welds in steel.

Cast Iron Rods.—For welding gray iron castings, and making clean, sound, soft welds that can be readily machined.

Cast Aluminum Alloy Rods.—For welding automobile crank cases and all aluminum castings.

Drawn Aluminum Rods and Wire.—For welding sheet aluminum and all rolled and drawn aluminum products.

Drawn Copper Rods.—Practically pure copper for welding rolled, drawn or cast copper products.

Drawn Brass Rods.—For brazing and general welding of brass castings.

Tobin Bronze Rods.—For general bronze welding and brazing malleable and gray iron castings.

Drawn Manganese Bronze Rods.—For building up bronze surfaces on cast iron and steel as well as bronze castings where subjected to wear, and where stronger welds than those attainable with Tobin bronze are required.

Fluxes.—These are used in welding cast iron, brass, bronze, aluminum, nickel, monel and the non-ferrous alloys in general, but are rarely or never required in welding low carbon steel. A flux is essentially a deoxidizer.

FIG. 8,144.—***Adjusting the tip.*** Slip tip-nut over mixing head, screw tip into mixing head, screw tip nut into torch handle, tightening it by hand so that tip will be at proper angle.

FIG. 8,145.—***Adjusting the acetylene working pressure.*** Open the acetylene torch needle valve and adjust the acetylene regulator to the required working pressure according to the table on page 5,078. Close the needle valve. Adjust oxygen working pressure in same manner.

Low carbon steel requires no flux because the oxide sometimes produced in welding remains in a molten condition. Cast iron and the non-ferrous metals are welded at lower temperatures, and their oxides as a rule remain solid and tend to mix with the molten metal. Hence, the desirability of cleansing the metal with approved flux. The mechanical or physical properties of fluxes are important as well as their chemical properties.

NOTE.—The cylinders of welding and cutting outfits should wherever possible be used in an upright position to protect the regulators and to insure the best results as regards quality of acetylene and convenience of operation. A specially designed two wheel truck to carry an oxygen and an acetylene cylinder is desirable with all portable outfits. The truck should be provided with chains for holding the cylinders in place so that they cannot fall off when moved.

Intimate mix, proper proportions and purity are essential for the best results. Fluxes should be kept in closed containers when not in use and should as a rule be used sparingly for the best results.

Setting Up Apparatus.—The beginner should practice setting up and connecting the torch, hose and regulators in the proper

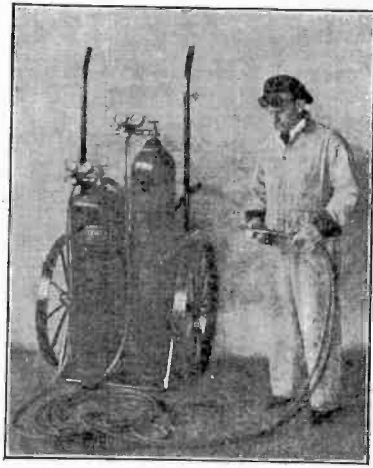


FIG. 8,146.—*Lighting the acetylene.* Open the acetylene needle valve on torch and light torch with a spark lighter.

FIG. 8,147.—*Adjusting for neutral flame.* Open oxygen needle valve and adjust for neutral flame.

manner according to instructions of the manufacturer. The final operations preceding welding are shown in figs. 8,144 to 8,147.

The following tables give proper pressures for welds and cuts of various thickness:

NOTE.—*Connecting the cylinders.* Roll the cylinders on to the truck and chain them fast. Remove the valve caps and examine the screw threads on the outlet nozzles. Do not attempt to use a badly bruised screw thread or connection seat. A damaged thread is likely to spoil the regulator nut and a jammed seat will leak. Damaged valves are a result of leaving off the valve caps in transit, and the damage generally happens after the cylinders have been turned over to the user. Co-operation to prevent damage to cylinders is always to the user's benefit.

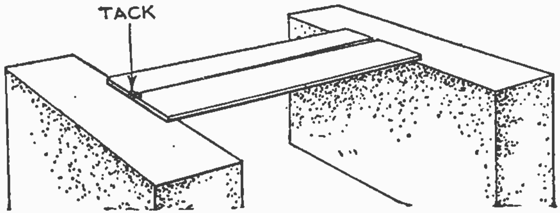


FIG. 8,148.—Plates tacked for welding. *Instructions:* Tack the left end of the plates together. This is done by holding the flame close to the joint until the steel melts and runs together. Remove the flame instantly when the metal flows, as otherwise a hole will be burned through. Warm the two plates by passing the flame over them lengthwise two or three times.

Approximate Acetylene Pressures

(Welding Torches)

Tip No.	Thickness of Metal—In.	Acetylene Pressure*		Acetylene Consumption	
		Min.	Max.	Min.	Max.
Mixer 1- 7 1	1/16	½	2	1.1	3.2
" 2	⅛	1½	3	4.1	6.0
" 3	¼	2	3½	6.8	9.7
" 4	⅜	2½	4½	12.0	17.0
" 5	½	3	6½	17.5	29.5
" 6	⅝	4	7½	25.	36.
" 7	¾	4½	9	30.	45.
Mixer 6-10 6		2	5	19.5	36.
" 7		2½	6½	29.	50.
" 8	1	3	7	37.	60.
" 9	1½	4	8½	49.	75.
" 10	2 up	4½	12	62.	103.

* Oxygen pressures approximately same as acetylene.

Approximate Acetylene and Oxygen Pressures

(Cutting Torches)

Tip No.	Thickness of Metal—In.	Oxygen Pressure—Lb.	Acetylene Pressure—Lb.
1	⅛ to 1	10 to 30	1 to 2
2	¼ to 2	15 to 50	2 to 3
3	1 to 3	25 to 70	3 to 4
4	2 to 6	30 to 80	4 to 5
5	4 to 8	50 to 100	5 to 6
6	6 to 10	60 to 125	5 to 6
7	8 to 14	75 to 150	5 to 6
8	12 to 18	100 to 175	5 to 6

Manipulation of the Torch.—This includes holding the torch at the correct height and angle, directing the flame so as to fuse the base metal evenly, and moving the flame back and

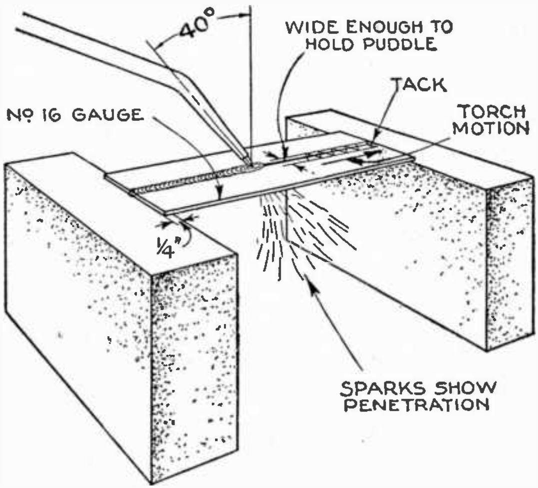


FIG. 8,149.—Position and movement of the torch. *Instructions:* Start welding at the right. Hold torch loosely in the hand and nearly parallel with the top of the welding table. Incline the tip sideways so that it points to the left at an angle of about 45 to 50° to the welding plates. Move the flame across the joint back and forth, giving it a movement of about ⅛ to ¼ in. As the steel melts and flows together move the torch to the left slowly following a zigzag path. Keep the torch in motion, but do not move to the left along the joint faster than the advance of the puddle. Be sure that each plate edge receives its due share of the heat. Hold the torch easily. Do not hold the handle tightly. Gripping it firmly tires the muscles, and makes the arm tremble. Learn to work easily and surely. Don't hurry. Continue a uniform zigzag motion keeping the white hot cone just above the surface of the plate. The rate of welding progress is determined by the puddle. Welding can be no faster than the advance of the puddle; neither can it be slower, because if advance toward the torch and puddle be stopped, the hot metal will drop through. When nearing the end of the joint, lift the torch higher to avoid making a hole in the weld at the end. This is an important point in welding thin metals. Pick up the welded plates with the pliers and examine first for uniformity of torch manipulation each side of the joint. This will be indicated by the heat zone. The heat zone should be of uniform width on both sides of the weld. Turn the piece over and examine for penetration, that is, if the weld penetrated to the bottom of the plates.

NOTE.—Thin sheet steel is often welded with very little or no movement of the torch across the joint, as in airplane and barrel welding. The torch is alternately raised and lowered instead. The beginner is advised to use the zigzag method while learning, because it must be employed on thick beveled plates. He can adopt the production method for thin metals later when proficient in prepared or beveled joint welding.

forth across the joint along an approximately zigzag path.

The combination of correct flame approach to the work and manipulation across the joint may be learned by preliminary practice welding without rod. This practice welding can be done on steel plates about 6 ins. long, 1¼ ins. wide and 1/16 in. thick, using a No. 2 A-D-B. tip.

The operator should be dressed for welding, and should wear goggles and gloves.

Although it is true that light welding can be done without goggles or gloves, it is, nevertheless, necessary to wear them because it is part of the beginner's job to become accustomed to looking at the weld puddle through colored lenses, and to hold the torch and welding rod with gloved hands.

Practice Welding on 1/16 in. Steel without Welding Rod.— Practice welding is done on a welding table or stand.

In the absence of a regular welding table one can be improvised with a work bench, kitchen table or box set so that the top is about 30 ins. from the floor.

Any wooden top must be protected from fire. Cover it with heavy sheet asbestos or with building brick laid flat and sprinkled over with dry sand to fill between. Provide two firebricks for the welding supports and a pair of steel pliers to handle hot metal.

Set the welding outfit alongside the table, at the right, turn on the gases, and adjust the working pressures for a No. 2 welding tip—2 lbs. oxygen working pressure and 2 lbs. acetylene.

Proceed as follows:

1. Lay two of the 6 in. pieces on the fire bricks side by side, bridging across so that about ¼ in. rests on the bricks at each end.

2. Open the acetylene needle valve and light the torch with the spark lighter.

3. Open the oxygen needle valve and adjust for the neutral flame.

4. Pull the goggles down over the eyes.

5. Hold the torch loosely in the right hand, grasping the handle at a point where the hose hanging free nearly balances the overhanging tip.

Proceed as directed in figs. 8,148 and 8,149.

Common Defects of First Welds.—The following defects usually encountered by beginners should be noted:

1. Uneven welds.

Caused by moving torch along the joint too quickly or slowly. Zigzag movement not uniform nor in step with the puddle. Zigzag movements overlapping.

2. Fused portion not in the joint, but at one side.

Caused by not playing the torch over the joint equally at each side.

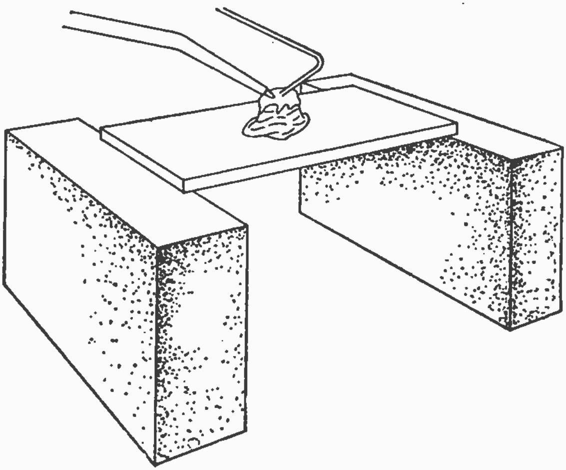


FIG. 8,150.—Building a mound or boss with welding rod. *Instructions:* Build up a mound of fused welding rod in the middle of a welding plate. Alternately fuse the top of the mound and drop the rod until the timing of the two operations is satisfactorily acquired. Practice in building up in this manner is advantageous also in that it is useful when finishing a weld and when necessary to provide a boss or extra reinforcement at any place.

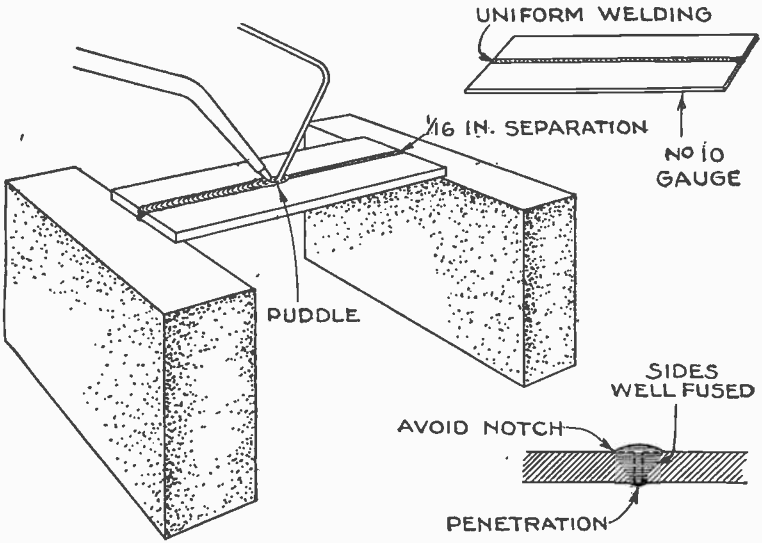
3. Holes in the joint.

Caused by holding flame too long in one place, and overheating the metal.

4. Hole in joint at end of weld.

Caused by not lifting the torch and reducing the heat when end of weld is reached.

Testing First Welds.—If the first weld seem worthy of test,



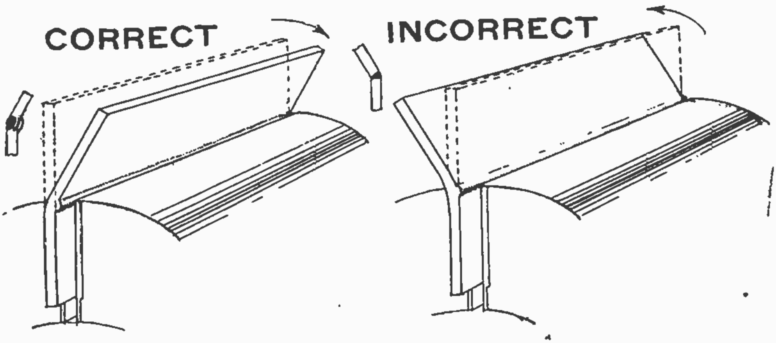
FIGS. 8,151 to 8,153.—Welding plates with welding rod. *Instructions:* Lay two 1/8 in. plates on the fire bricks side by side about 1/16 in. apart. Light the torch, adjust the flame, set the goggles, pick up a 1/16 in. welding rod, heat it 4 or 5 ins. from the end and bend to a right angle. Tack the plates together at the left end. Start welding at the right. Take time to assure penetration to the bottom. Add welding rod to the puddle and build up above the surface about 1/32 in. Hold the torch in the hand loosely; stand relaxed and comfortable. Avoid tension. Acquire the ability to see the welding puddle clearly. If the goggle lenses are too dark, have them exchanged for lighter ones. This is of utmost importance. The welder must see clearly what is taking place in order to do good work. The appearance of the puddle is a guide to flame adjustment. If a white scum be seen floating on the puddle, it indicates an oxidizing flame. Turn the oxygen needle valve slightly to reduce the flow of oxygen. When approaching the end of the joint the torch should be advanced faster and lifted a bit to prevent overheating. Build up the end of the weld so that it is the same thickness as elsewhere. Remove the welded piece with the pliers, cool in a bucket of water and break in the vise. A built up or reinforced weld well made should be nearly as strong as the plate itself and care must be taken to clamp the welded piece firmly and as close to the weld as possible.

NOTE.—When starting a weld, the advance of the torch has to be held down until the metal is flowing freely.

cool the welded piece in water, clamp it in an iron vise with the weld parallel with the top of the jaws and just above them.

The under side should be toward the operator. Strike the top with a hammer and bend over until the piece breaks through the weld.

Examination of the first broken weld will generally reveal defects caused by improper manipulation, incorrect flame adjustment, overheating, underheating, and exposure of hot metal to the air before the puddle is completed.



FIGS. 8,154 to 8,157.—Testing welded plates in vise with hammer.

Continue the practice welding on $\frac{1}{16}$ in. plates without welding rod until able to make a weld fairly uniform in width, of good appearance, without holes or icicles hanging beneath.

An obvious defect of all hand welds made without welding rod, impossible to avoid, is a furrow or depression in the middle, due to the metal sinking down and filling the narrow groove between the plates. This is the reason for using welding rod, to fill.

Building Up Welded Plates with Welding Rod.—Manipulation of the rod consists of holding the end over the joint close to the flame and moving it so that it is momentarily immersed in the puddle ahead of the flame.

NOTE.—*When breaking a weld* in a vise always bend the piece so that the under side or bottom of the weld is put in tension and the top in compression.

The heat of the puddle and flame melts off a drop of metal which blends into the weld. The beginner as a rule will have difficulty in dipping the rod and lifting it at the right moment. If done too soon it will stick because the puddle is not hot enough to fuse the rod, and if done too late the puddle becomes so hot that it drops through. If repeated effort is rewarded with little success, special practice on this phase of manipulation may be necessary; proceed as in fig. 8,150.

Practice Welding on 1/8 in. Plate with Welding Rod.—Procedure on the 1/8 in. plates is the same as on the 1/16 in. steel.

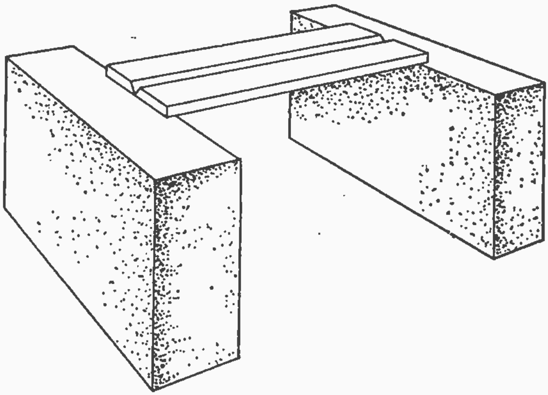


FIG. 8,158.—Plates beveled for welding. *Instructions:* Lay the 6 in. by 1¼ in. by 3/16 in. beveled plates on the fire-bricks with the edges parallel and 1/16 in. apart. Tack at the right end firmly, fusing in a few drops of welding rod. If the edges be thrown out of parallel by tacking pry them open to approximately parallel position. Start welding at the left, using 3/32 in welding rod. Be careful to get thorough penetration and to manipulate the torch so as to cover the larger puddle than the beginner has heretofore produced. Build the weld up square at the beginning. Fill the bevel groove with weld metal, making sure that the base metal on both sides is well fused before covering with weld metal. Build up the weld smoothly about 1/16 in. above the surface of the plates. Finish the weld and build up the end square. Cool the weld piece in water, and break in the vise. A heavy hammer and repeated blows should be necessary to break the weld if properly made.

Give the torch the same zigzag motion, making the movement across the joint somewhat more than on the thinner steel.

The crosswise movement is always governed by the puddle width, the thicker the weld the wider the puddle and the greater the swing of the torch

The advance along the joint will be slower because more metal has to be heated and fused. The advance of the puddle governs the speed of welding. It cannot be held stationary long nor can it be hurried beyond a certain rate for a given size welding tip.

The beginner is likely to time the weld by that required for the 1/16 in. steel.

The result is penetration only part way through, and an open seam at the bottom. The effort should be to work slower to get full penetration.

Proceed as in figs. 8,151 to 8,153.

Probable Defects.—In practice welding on 1/8 in. steel plate with welding rod the following defects should be noted:

1. Uneven welding.

Good penetration in spots and partial penetration between.

2. Oxide inclusions.

These will be indicated by black specks on the broken surfaces.

3. Adhesions.

Sometimes the weld metal will break cleanly from the plate on one side. This indicates that insufficient heat was directed to that side; also that the welding speed was too high.

4. Brittle welds.

Due to use of carburizing flame.

Bevel Preparation.—Up to this time the beginner has been welding steel without bevel preparation. He can now try welding 3/16 in. steel beveled pieces.

One edge of each plate should be beveled to an angle of about 45°. The beveled edges are set together, thus making a groove or trough of about 90°

included angle. The groove is filled with metal fused from welding rod, and the weld should be built up slightly above the plate surface.

Proceed as in fig. 8,158.

Probable Defects.—In welding 3/16 in. beveled steel plates with 3/32 in. rod the following defects should be noted:

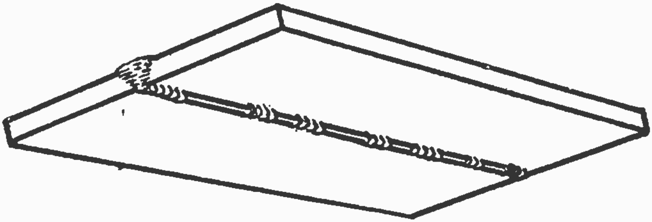


FIG. 8,159.—Underside of weld showing incomplete penetration.

1. The probable outstanding defect will be adhesions on the bevel surface next to the operator while welding.

This is due to not directing the flame against that side so as to thoroughly fuse the base metal before adding weld metal.

2. Oxide inclusions or burned metal.

Due to incorrect flame adjustment and improper torch manipulation that exposed molten metal to the air. The puddle should always be kept covered with the flame until the weld at that point is completed.

3. Incomplete penetration (fig. 8,159).

NOTE.—*Common defects.* 1. Adhesions of weld metal on beveled surfaces; 2, incomplete penetration; 3, uneven and coarsely granular structure in the fracture. Due to improper manipulation and too much oxygen or acetylene. Advice from an experienced operator should be sought. Practice should be continued, striving all the time to avoid the faults pointed out. However, the beginner should avoid long continued welding without rest period. At first the weld period should not be longer than twenty minutes and the intermission five minutes. Later the weld period can be lengthened to thirty minutes. The periods of welding and rest required will vary with the individual and his previous work. When the arm muscles tire and the vision becomes blurred the beginner should stop, remove his goggles and relax. Progress will be made faster this way than by continuous plugging.

Due to not working down to the bottom of the groove until the base metal is well fused in the narrow part of the Vee.

Welding Cast Iron.—Gray cast iron used for making castings is welded with cast iron welding rods or sticks, using a flux. Cast iron melts at a lower temperature than steel—from 1,850° to 2,250° Fahr. whereas steel melts at 2,200° to 2,800° Fahr. depending on the carbon content.

High carbon steel melts at the lower temperatures and low carbon steel at the higher ranges. The melting points of cast iron are below the fusion temperatures of the iron oxides, and it is necessary to use flux to dissolve them in making cast iron welds.

Practice Welding Cast Iron Beveled Bars.—Flux is generally applied by sticking the hot welding rod into a can of flux powder.

The quantity adhering is sufficient as a rule. When welding heavy castings, however, the weld puddle may be dusted with flux from time to time in order to supply the required quantity.

Practice welding on cast iron should be done to acquire knowledge of its peculiarities and the necessary torch and rod manipulation. The welding rods as a rule are used straight which is not quite as convenient for manipulation as the bent rod on steel.

Care must be taken to provide for expansion when welding a gray iron casting and likewise the contraction must be controlled in cooling to prevent cracks in the weld or adjacent to it.

These are best taken care of by preheating the casting to a low red heat, using city gas, oil burners or charcoal. A crude furnace of fire bricks may be built around the part, and the top covered with sheet asbestos except where the weld is to be made. The heat is brought up slowly and as uniformly as possible. When the weld is completed and still in the furnace it is covered with asbestos and allowed to cool slowly.

Heavy castings may require 24 to 48 hours to cool, depending on the size, shape and weight. Welds made with approved cast iron rods and flux in the manner described should be soft and machinable when cold.

Bronze Welding Cast Iron.—Many cast iron repair welding jobs can be done to advantage with bronze welding rods.

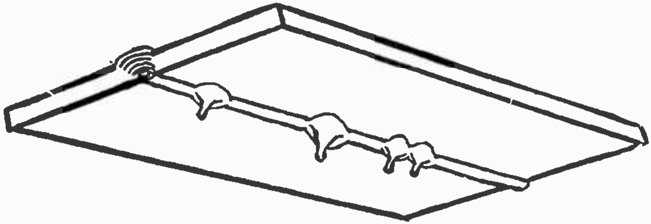
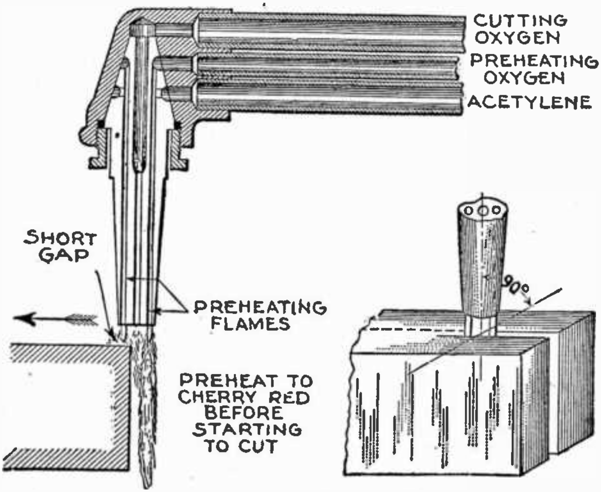


FIG. 8,160.—Underside of overheated weld showing excess metal hanging.



FIGS. 8,161 and 8,162.—Section of cutting torch showing preheating and cutting gas passages. ***Instructions:*** As a rule a cut is started at the edge of a plate or forging. The preheating flames are held above the steel at the edge until the metal becomes bright red, and then the trigger or lever controlling the oxygen cutting jet is pulled, and cutting starts. The torch should be held with the tip vertical and should be kept in a nearly vertical position when making a square cut, or at an angle of about 45° when beveling for welding. If necessary to start a cut in the metal away from the edge, heat the metal to a bright red and hold the heat a little longer than when starting on the edge. Now raise the torch about ½ in. and pull the trigger. As soon as the plate is perforated lower the torch to the normal position, and proceed with the cut. Starting the cut is facilitated by nicking the side of the bar with a chisel so as to raise a burr at the point where the cut is to begin.

The preheat required is less, and the welding rod temperature is from 1,625° to 1,650° Fahr.

Many jobs can be done with very little or no preheating. Flux is used when making bronze welds. The strength of good bronze welds is equal to or greater than the base cast iron.

Malleable Iron Castings.—Malleable iron castings are produced from white iron castings, heat treated.

They are soft and bendable, but not weldable with iron or steel rods. They should be bronze welded when making repairs. The white iron castings can be welded, however, with white iron rods.

Welding Non-Ferrous Metals and Alloys.—Welding of copper, aluminum, bronze, brass, monel, nickel and various alloys is accomplished with the oxy-acetylene torch.

These metals and alloys as a rule are easily oxidized and a neutral or carburizing flame is used; also welding rods and fluxes. Expansion and contraction are greater than with steel. Heat conductivity is higher and larger tips are required for the same thickness than on steel. Copper, for example, requires Airco-Davis-Bournonville tips from one to two sizes larger than for steels of the same gauge.

Welding rods as a rule are of the same metal as the metal welded.

Copper rods are used on copper, aluminum wire on aluminum sheets, aluminum alloy cast rods on aluminum castings, bronze rods on bronze, nickel rods on nickel, and so on.

Ordinary commercial copper is difficult to weld, but so-called deoxidized copper may be welded satisfactorily.

Torch Cutting.—Cutting or burning wrought iron, steel and cast iron with the oxy-acetylene torch, to effect separation, requires a torch designed for cutting and torch manipulation quite different from that for welding.

Proceed as in figs. 8,161 to 8,164.

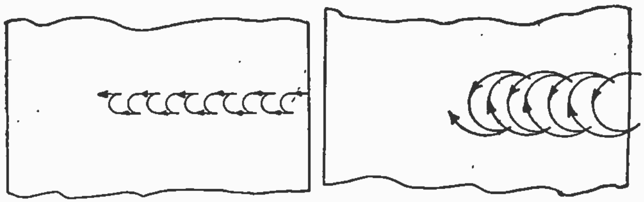


FIG. 8,163.—Movement of cutting torch and tip when cutting thin cast iron.

FIG. 8,164.—Movement of cutting torch and tip when cutting heavy cast iron.

TEST QUESTIONS

1. *What gases are used in gas welding?*
2. *Of what does an oxy-acetylene welding outfit consist?*
3. *Describe the welding rod used.*
4. *For what metals are fluxes used?*
5. *How is the apparatus set up?*
6. *Describe in detail the manipulation of the torch.*
7. *What are the common defects of first welds?*
8. *How are welds tested?*
9. *How are plates to be welded built up with welding rods?*
10. *What is the bevel angle for plates?*
11. *Describe the method of welding cast iron.*
12. *How is a torch used for cutting?*

CHAPTER 208

Pipe Welding

The application of welded joints to pipe line construction is comparatively new, and is rapidly displacing screwed joints especially on pipes of large size. The general acceptance of the

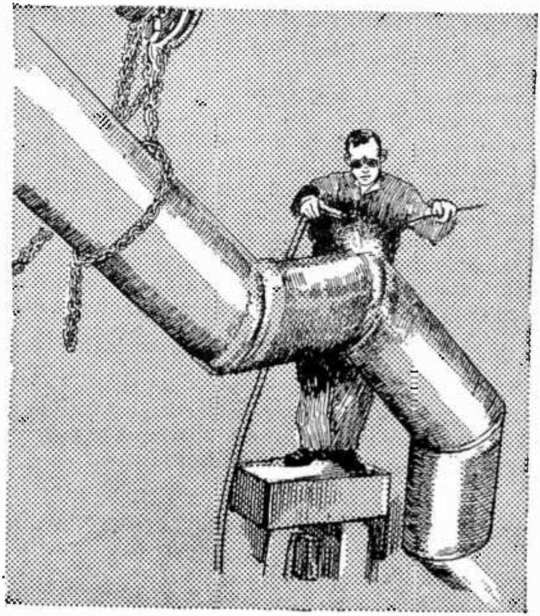


FIG. 8,165.—Welding an off set bend on a large pipe with fittings for the off set turn cut from pipe stock. This is a makeshift job at best. This method requires very careful laying out, gives abrupt turns and would be much more satisfactory if regular welded joint fittings be used.

welded joint and the rapid growth of the use of this modern process was made possible by the perfecting of welding apparatus.

Comparing welded and screwed joints, the welded joint has several advantages which accounts for its growing popularity.

Screwed joint pipe lines require in addition to the pipe, various fittings and the lines must be laid out with considerable precision, otherwise they will not "make up" properly. This extra care and the cost of the fittings is avoided with welded joints. Fig. 8,165 illustrates this point.

The use of special fittings is costly and usually avoided when possible.

In case these fittings are made of cast iron or cast steel it is necessary to have patterns or sweeps made before they can be cast and weeks may elapse before satisfactory castings are received from the foundry. After that it may take some time for them to be machined for use. The welding torch and the cutting torch in conjunction with a few templates are all the tools necessary for the making of almost any type of fitting. If manufactured fittings be not on hand, this work is generally done as the line progresses and the exact patterns of fittings is determined. The fittings made in this way are quickly produced, are much lighter, and therefore, more easily handled than a cast fitting or a combination of cast fittings.

Saving of time by laying lines by the welding process has been found to be in its favor.

In lines joined by screw joints only one section is joined at a time, while in a welded line as many lengths can be joined as there are welders available, which may involve several hundred feet of pipe.

With respect to the apparatus used there are two methods of welding as:

1. With the electric arc;

2. With the oxy-acetylene torch;

known respectively as electric or arc and gas welding.

Types of Joints.—There are two general types of joint:

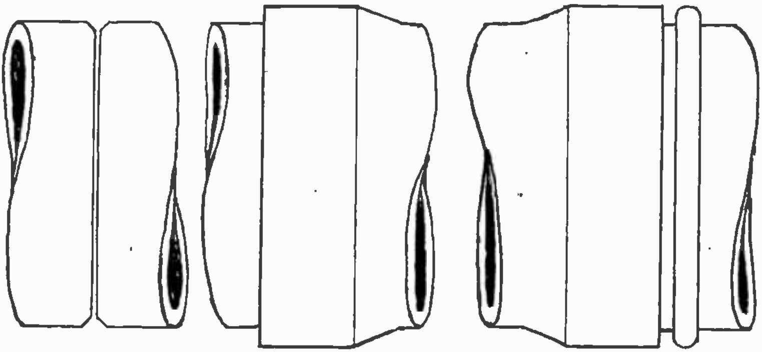
1. Bell and spigot;

   a. Plain;

   b. With welding dam.

2. Butt.

In oil lines the bell and spigot joint is the most popular.



FIGS. 8,166 to 8,168.—Various pipe joints for welding. Fig. 8,166, butt weld; fig. 8,167, bell and spigot weld; fig. 8,168, bell and spigot weld with welding dam.

This type of joint consists of inserting a plain end of pipe into adjacent pipe, the end of which has been *belled* in manufacture to the extent that it will receive the spigot end for a distance of approximately three inches, with a maximum clearance of 1/32 inch.

A variation of this type of joint is the bell and spigot joint with welding dam. The spigot end of the pipe is crimped in manufacture to form an inverted U shaped ridge of pipe metal around the pipe at a distance of approximately 3 ins. from the end of the pipe. When the spigot end is inserted in the bell end of a pipe length, the welding dam butts against the end of the bell. The purpose of the welding dam is to facilitate welding by forming a dam or backing for the welding bead on the spigot end of the joint.

Figs. 8,166 to 8,168 illustrates the three joints just mentioned.

Welding Large Pipe Lines.—Clearing of the right of way, stringing of pipe, and ditching operations are the same for arc welded construction, as for other types.

After the pipe is strung, it is lined up in sections consisting generally of four or more lengths, depending upon length of pipe and topographical conditions.

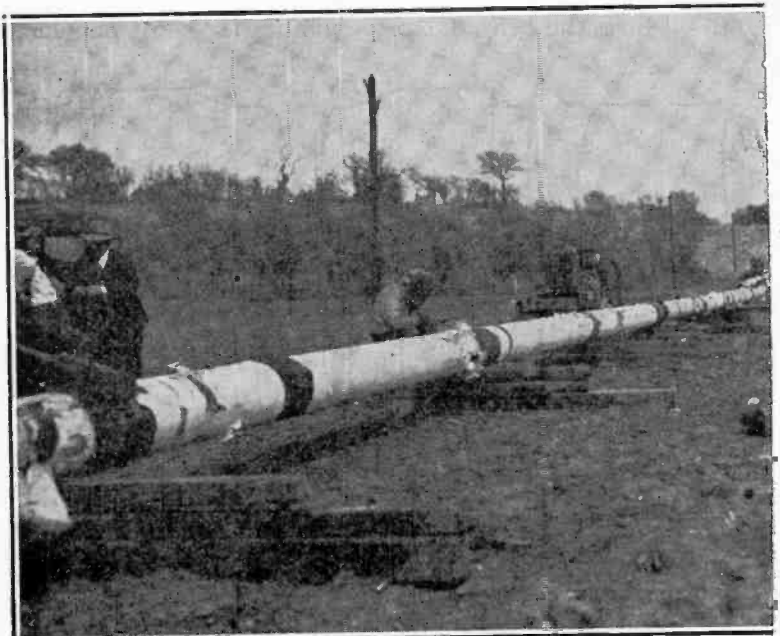


Fig. 8,169.—Section of pipe line being welded. Note the use of wood skids for blocking up section so that it is level. Photographed on Texas Pipe Line Company's Monahans-Port Arthur, Texas, line.

In lining up the pipe into sections, when pipe has bell and spigot ends, the spigot ends are inserted in the bell ends of the adjacent lengths, thus forming a straight line of pipe. The entire section, thus formed, is blocked up level on wood skids parallel and about 3 ft. from line of trench, as shown in fig. 8,169.

Several devices are employed to aid the turning of sections during the welding operations.

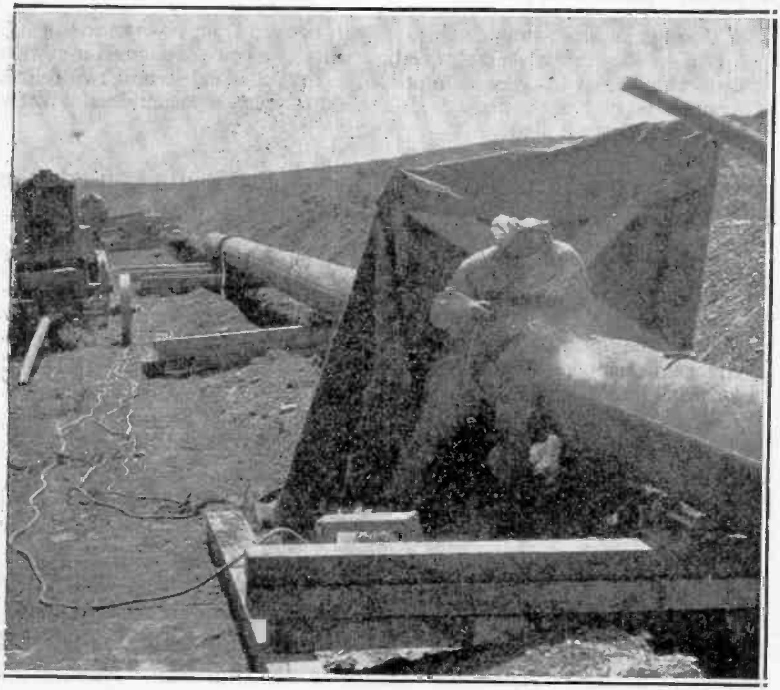


FIG. 8,170.—Section of pipe line placed on dolleys on top of skids to facilitate turning of pipe during welding operations. Photographed on Uinta Pipe Line Company's 200 mile line.

Chock blocks are sometimes nailed to the top skids on which the section rests. These chock blocks are beveled on the face adjacent to the pipe, so that the section will turn easily against the chock blocks. The use of chock blocks also eliminates the necessity of long skids as the pipe is not rolled on the skids, but is turned against the chock blocks.

Long skids are heavy and cumbersome to handle. The placing of chock blocks on opposite sides of the pipe on adjacent skids also tends to keep the section in line before welding.

A recent innovation introduced on a large gas line is the use of dolleys placed on the top skids and on which the section rests.

These dolleys are simple affairs, as can be seen from observation of fig. 8,170. A dolley consists merely of a base which is a piece of channel iron with flanges upturned to serve as support for the roller axles, and two rollers mounted on each of the two axles. These dolleys are especially useful where large, heavy pipe is used.

When pipe with plain ends forming butt joints is used, the joints are tack welded immediately after a section is lined up.

This is done to hold the section intact and in line until the joints are completely welded.

Bell and spigot joints are sometimes tack welded to prevent misalignment of pipe, due to contraction and expansion of pipe lengths caused by abrupt changes in temperature. After the sections are lined up they are then ready for firing line welding.

Two methods will now be described, known as:

1. Firing line welding;
2. Bell hole welding.

Firing Line Welding.—Welds made in a section composed of several lengths of pipe are known as *firing line* or *rolling welds*, as the section is turned or rolled while the joints are being welded, so that overhead welding is eliminated. The actual welding of a section is performed by one operator aided by his helper.

Generally the welder is spotted between two adjacent sections. The operator welds the top half of each joint, starting at the joint farthest from the welder and works toward the next section to be welded. The helper follows, cleaning this first weld, known as the burning in weld, with hammer, chisel and wire brush, removing all oxides, etc.

After the operator finishes the welding of the top half of the last joint in the section, the helper, with chain pipe wrench, turns the entire section 180°.

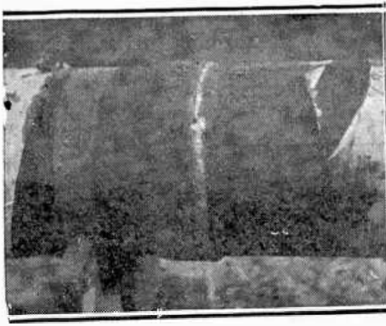
The operator then proceeds to complete the burning in bead in each joint; the helper following, cleaning the balance of the welds, as before. A typical burning in bead, after it has been cleaned, is shown.

FIG. 8,171.—Typical burning-in weld in a plain and spigot joint.

When the burning in welds are completed, the operator is back at the original starting point, having traversed the entire length of the section twice. The operator then starts welding the second bead, or finish bead, welding a complete joint, before moving to the next. The helper turns the pipe, as the operator welds the finish bead in each joint. In the entire welding operation, the operator traverses the length of each section only three times. The finish bead is not cleaned. This leaves the helper free to turn the section, so that the finish bead in each joint may be completed in one operation.

Portions of the burning in bead and finish bead in the same joint are shown in fig. 8,172. A completed arc welded bell and spigot is also shown in fig. 8,173.

After the operator finishes one section, he proceeds to the adjacent section and welds it in the same manner. The welder is moved by tractor, horse or mule team, only after two sections are completedly welded.



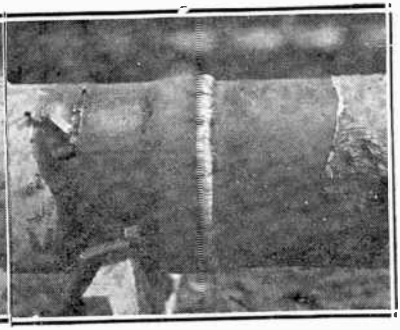


FIG. 8,172.—Pipe line joint showing portions of burning in weld and finish weld in a plain bell and spigot joint. Photographed on Texas Empire 600 mile line.

FIG. 8,173.—A completed arc welded bell and spigot joint. Photographed on Texas Pipe Line Co.'s San Antonio-San Marcus Texas line.

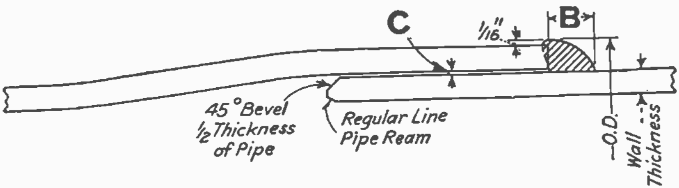


FIG. 8,174.—Dimensions of weld for various sizes and weights of pipe; values given in table below:

Weld Dimensions

Pipe Outside Diameter, Inches	Weight per Foot, Pounds	Wall Thickness, Inches	B Inches	C Inches
6⅝	17.021	.250	.500	.031
8⅝				
10¾				
12¾	40.000	.303	.500	.047
12¾	65.415	415	.520	.040

Bell Hole Welding.—After a section of pipe line is welded, it is placed over the open ditch on single skids and joined to the end of the welded line. This is known as *bell hole welding*. This operation was so called because it is generally necessary to dig out the sides of the ditch forming a bell shaped hole or space in the ditch to permit easy access to the entire circumference of the joint.

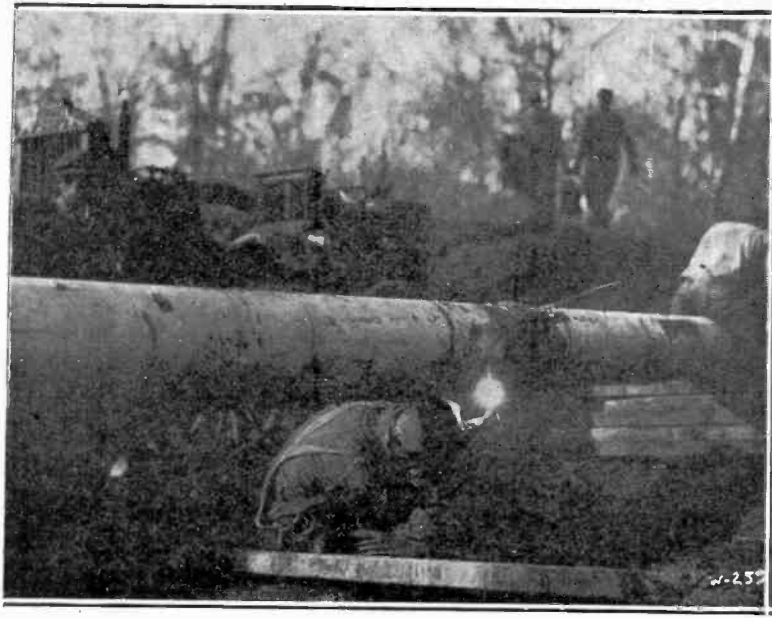


Fig. 8,175.—Operator welding overhead in making a bell hole joint. Photographed on Texas-Empire 600 mile line.

A bell hole connection is the only joint welding of a section to the line which requires overhead welding, as it is impossible to turn the pipe line. Two separate beads are welded in making a bell hole joint, the same as required in making firing line connections, the procedure only being different.

The operator first makes the burning in bead in the top half of the bell hole joint. After this portion of the joint is welded, the helper cleans the bead while the operator continues to weld the lower half of the joint. The operator then stands by until the cleaning of the entire burning in bead is finished. He then proceeds to weld the final or finish bead. A view of bell hole welding is given in fig. 8,175.

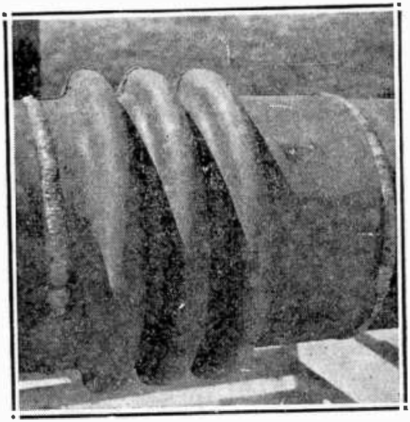


FIG. 8,176.—A type of expansion joint used in arc welding pipe lines. This type of joint is known in pipe line parlance as a *wrinkle belly* joint.

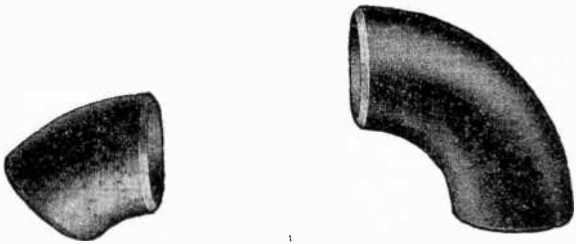
Bending of a section to conform to line of ditch is usually done immediately after the section is arc welded to the pipe line.

All bends in a section are made, where possible, in the middle of a pipe length, rather than at a joint.

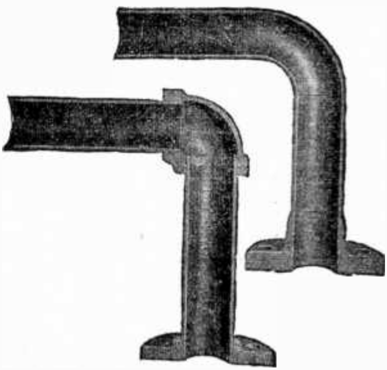
To take care of the expansion or contraction of the line, several methods are employed.

Where expansion joints are not welded into a line, slack is put into the line by forcing the line into the ditch, so that it will lie on the bottom of the ditch, not in a perfectly straight line, but weaved from wall to wall of the ditch. This method of weaving the pipe in the ditch is unnecessary where expansion joints are included in the line. On recent arc welded lines, expansion joints, similar to joint illustrated in fig. 8,176, are used. This type of joint, when placed at intervals in the line, takes care of all expansion and contraction of the line.

Pipe Fittings for Welded Joints.—Various kinds of standard fittings have been designed for welded joints. Standard dimensions have been adopted for each fitting. The fittings consist of elbows, tees, offsets, reducers, crosses, manifolds, saddles, swage nipples, etc.



Figs. 8,177 and 8,178.—45° and 90° tube turns.



Figs. 8,179 and 8,180.—Comparison of tube turn and ordinary screw elbow. Note the easy curve of the tube turn as compared with the shoulders of pipe in the screwed assembly. Also contrast the modern, high hub butt welding flange with the old fashioned flange.

These fittings are now available the same as ordinary screw fittings.

These fittings can also be made in the welder's shop out of the accumulation of short ends of pipe which otherwise would be wasted.

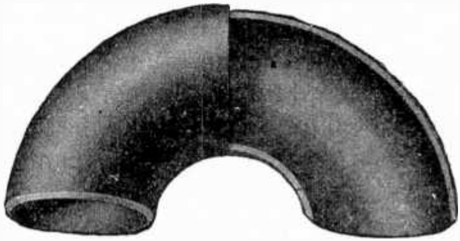


Fig. 8,181.—180° tube turn (return elbow) which can be used as such or quickly cut on the job (as shown in fig. 8,187) to form a turn of any desired angle.

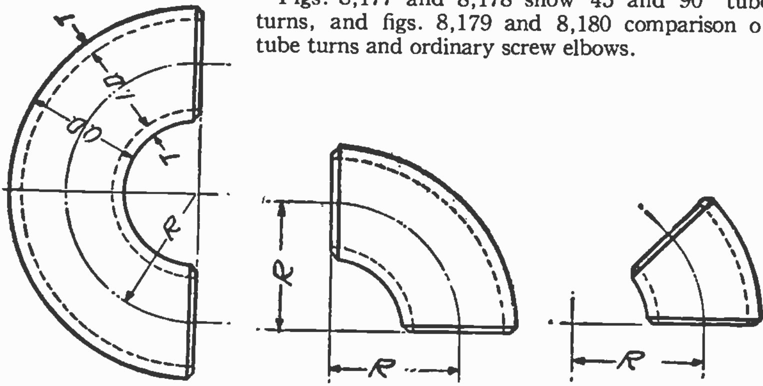
The following tables give the various sizes and properties of tube turns.

Properties of Tube Turns

Standard Thickness—IRON PIPE SIZES—*Series 1½R*

Nominal Pipe Size	Radius Inches (R)	PIPE DIAMETER O. D.	I. D.	Wall Thickness (T)	Weight Pounds (180° Type)	Bursting Pressure Pounds
1″	1½	1.315	1.048	.134	¾	10,600
1¼″	1⅞	1.660	1.380	.140	1	8,770
1½″	2¼	1.900	1.610	.145	1½	7,940
2″	3	2.375	2.067	.154	2¾	6,355
2½″	3¾	2.875	2.469	.203	5¾	6,640
3″	4½	3.500	3.068	.216	9	5,800
3½″	5¼	4.000	3.548	.226	12½	5,310
4″	6	4.500	4.026	.237	17	4,950
5″	7½	5.563	5.047	.258	29	4,360
6″	9	6.625	6.065	.280	45	3,970
8″	12	8.625	7.981	.322	90	3,435
10″	15	10.750	10.020	.365	159	3,120
12″	18	12.750	12.000	.375	234	2,710
14″OD	21	14.000	13.250	.375	300	2,465
16″OD	24	16.000	15.250	.375	393	2,160
18″OD	27	18.000	17.182	.409	544	2,090
*20″OD	30	20.000	19.182	.409	672	1,880

One manufacturer who makes these fittings calls them *"tube turns."* Figs. 8,177 and 8,178 show 45 and 90° tube turns, and figs. 8,179 and 8,180 comparison of tube turns and ordinary screw elbows.



FIGS. 8,182 to 8,184.—180°, 90° and 45° tube turn fittings. The dimension letters refer to the dimensions in the accompanying table.

Properties of Tube Turns

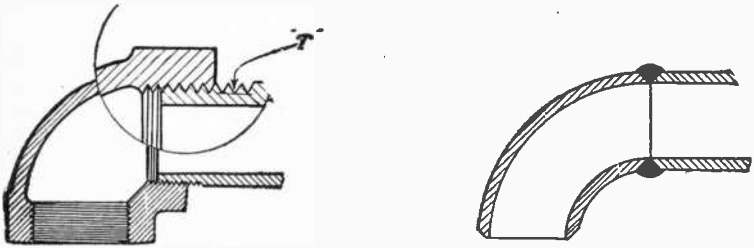
Extra Heavy—IRON PIPE SIZES—*Series 1½ RX*

Nominal Pipe Size	Radius Inches (R)	PIPE DIAMETER O. D.	I. D.	Wall Thickness (T)	Weight Pounds (180° Type)	Bursting Pressure Pounds
1½"	2¼	1.900	1.500	.200	2	10.300
2"	3	2.375	1.939	.218	4	8,630
2½"	3¾	2.875	2.323	.276	7½	9,025
3"	4½	3.500	2.900	.300	12	8,060
3½"	5¼	4.000	3.364	.318	17¼	7,315
4"	6	4.500	3.826	.337	24	6,890
5"	7½	5.563	4.813	.375	41	6,200
6"	9	6.625	5.761	.432	67	6,000
8"	12	8.625	7.625	.500	136	5,335
10"	15	10.750	9.750	.500	215	4,280
12"	18	12.750	11.750	.500	308	3,605
*14"OD	21	14.000	13.000	.500	396	3,285
*16"OD	24	16.000	15.000	.500	520	2,875

***Tentative specifications—these sizes not yet available.**

All stock sizes furnished with ends beveled 45 degrees for welding unless otherwise specified.

Tube turns are used to provide any kind of elbow, offset, branch or compound turn in piping, headers and manifolds, or wherever pipe welding might be used. The 180° return fitting is used in coils, retorts, tube stills, etc. The 90° types and straight pipe are used to make up expansion loops.



FIGS. 8,185 and 8,186.—Sections of screwed, and welded joints. When a screwed fitting is used there is interference with the flow on account of the internal projection of the pipe. This is avoided in the welded joints. It will be noted in fig. 8,186 that the weld metal does not project inside the pipe.

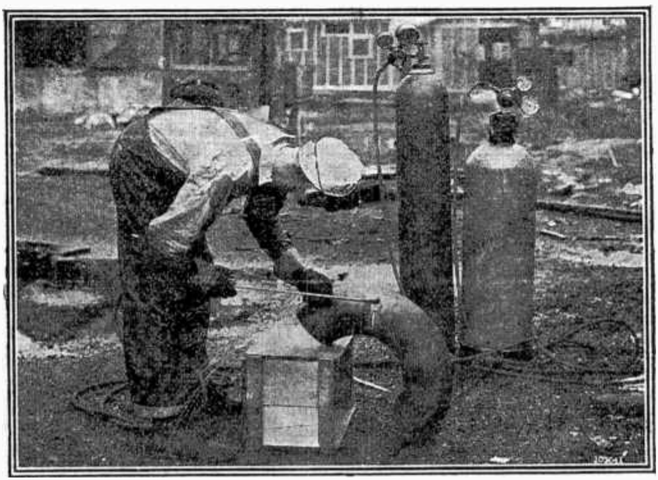


FIG. 8,187.—View showing pipe fitter cutting a 180° tube turn with oxy-acetylene torch. It will be seen from this illustration that the tube turn can be cut for a turn of any angle.

Butt Welding Pipe Flange.—The use of welded pipe joints has been further facilitated by the introduction of specially designed forged flanges and of short radius formed pipe bends of uniform thickness, both made in standard sizes ready for butt welding to the pipe.

In a welded pipe assembly, flanges are required at the connections with valves and similar fittings.

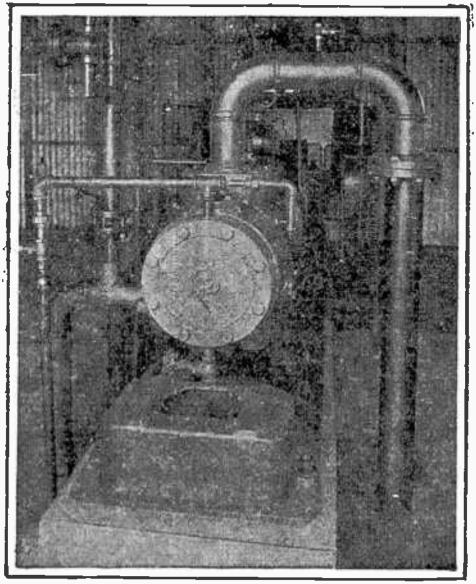
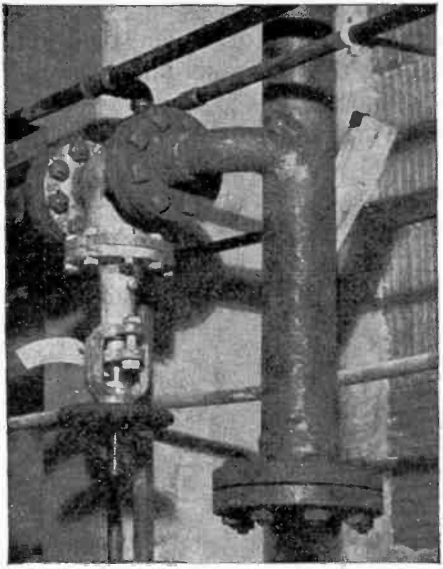


FIG. 8,188.—Gas compressor installation showing welded joint tube turn fittings in suction and discharge connections.

They are also required wherever the line must be broken for purposes of assembling. In most cases these flanges can be welded directly to the pipe. For this purpose the superiority of forged flanges is obvious. Their strength is definitely known, and is ample to resist strains due to expansion and contraction, settling, etc. The inside diameter of these flanges matches that of the pipe, permitting a smooth internal flow. Flanges for low



pressure, 150 lbs. have plain or raised faces, as ordered. Flanges for higher pressures have raised faces. Fig. 8,191 shows the general appearance of a butt weld pipe flange.

FIG. 8,189.—Pennforge flanges in Harvard power house.

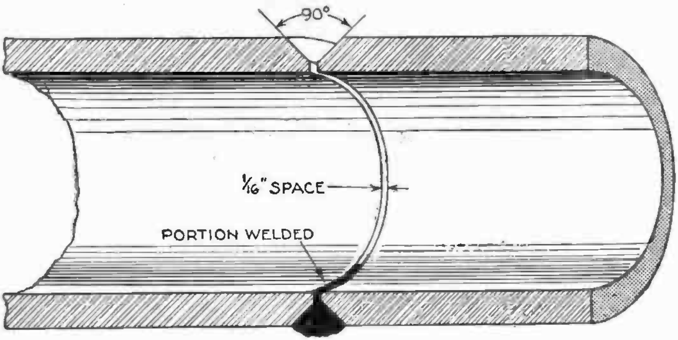


FIG. 8,190.—Placement of pipes for butt weld joint. The ends of the pipes should be chamfered 45° making a 90° V for the weld. The ends must be not less than 1/16 in. apart in order to secure through penetration of the weld. The welding rod or wire should be as near as possible the same carbon content as the material in the pipes. The weld should be built up as rapidly as the molten metal can be handled without overlapping and in a continuous operation all around the pipe. If the welding flame be slowly moved over the first part welded for a few inches, the weld is automatically and homogeneously annealed for all practical purposes.

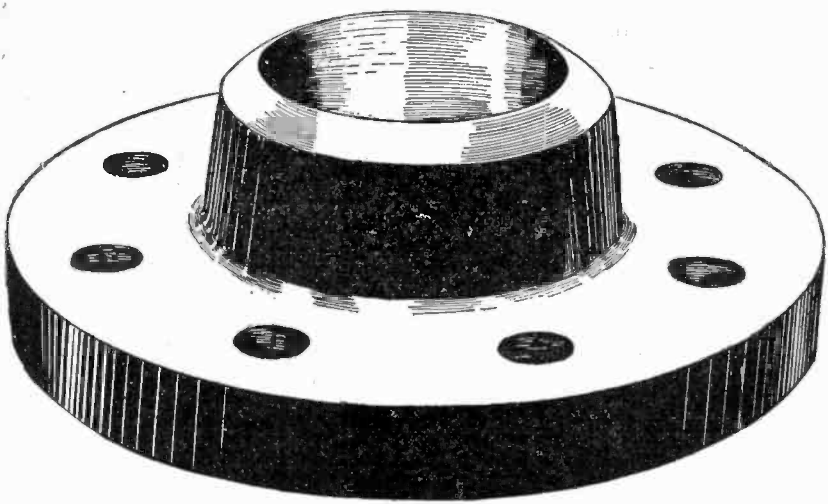


Fig. 8,191.—Pennforge flange as manufactured for welded pipe joint.

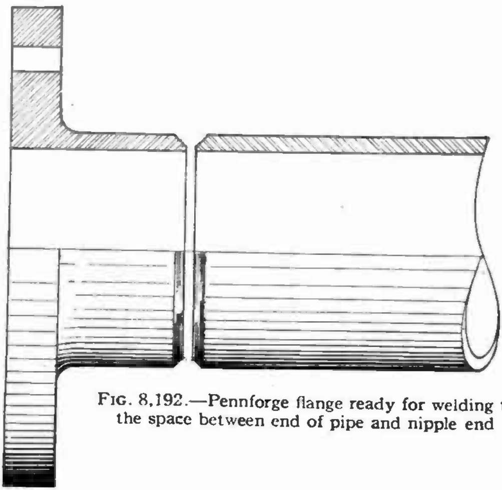


Fig. 8,192.—Pennforge flange ready for welding to pipe. Note the space between end of pipe and nipple end of flange.

When welding flanges, the flange and pipe are clamped in a fixture, or to a companion flange, to line them up correctly.

According to the size and thickness of the pipe, there should be a space of from 1/16 to ¼ in. between the flange hub and pipe when welding. The purpose of this is partly to give working space for welding, and partly to allow the pipe to expand under the action of the pre-heating flame in making the weld.

Before welding, it is necessary to turn the flange so that the bolt holes will line up. Then the flange and pipe are tack welded. After that they may be removed from the fixture and turned over to complete the seam. The table shows correct spacing and tacking.

Spacing and Tacking Pipe Ends for Butt Welds

Pipe size, inches	STANDARD			EXTRA HEAVY		
	Spacing between pipe ends, inches	Number of tack welds for proper strength and alignment	Average length of tack welds, inches	Spacing between pipe ends, inches	Number of tack welds for proper strength and alignment	Average length of tack welds, inches
¾	1/16	2	¼	1/16	2	¼
1	1/16	2	¼	1/16	2	¼
1¼	1/16	2	¼	⅛	2	⅜
1½	1/16	2	¼	⅛	2	⅜
2	1/16	2	⅜	3/16	2	½
2½	⅛	2	⅜	3/16	2	½
3	⅛	4	½	3/16	4	½
4	⅛	4	½	3/16	4	⅝
5	⅛	4	½	3/16	4	⅝
6	3/16	4	⅝	¼	4	⅝
8	3/16	4	⅝	¼	6	¾
10	3/16	4	⅝	¼	6	¾
12	3/16	6	¾	¼	6	1
14	3/16	6	¾	¼	6	1
16	3/16	6	¾	¼	6	1
18	3/16	6	¾	¼	6	1

When butt welding flanges are used, the following features should be included in the specification:

1. Welded standard flanges shall comply with American Standards as to dimensions.

2. The flange shall be bolted to a companion flange or heavy plate during welding.

3. Bolt holes shall straddle natural center lines.

4. The spacing between pipe ends, before tacking, shall be as given in the table.

5. Welds shall be thoroughly fused to the joint edges and shall extend completely to the bottom of the vee.

6. Welds shall have a minimum width of 2½ times the pipe wall thickness and shall be symmetrical with respect to the center line of joint.

7. Welds shall be built up to present a gradual increase in thickness from edge to center.

8. Thickness at the center of the weld shall not be less than 1¼ times the pipe wall thickness.

9. The weld shall be of sound metal free from laps, gas pockets, slag inclusions or other defects.

Methods of Closing Pipe Line for Testing.—Various methods are used to close the ends of completed sections of pipe lines preparatory to applying the required pressure test.

One method commonly used where the test pressure is high is to make a torpedo shaped head which is welded to the end of the pipe line, and after satisfactory test has been made this end is cut off and used again for the next test. Another type is to weld a disc on the end of a short piece of pipe of the same diameter as the pipe line to be tested, and this section is welded onto the pipe line, as was done for the torpedo type of head.

Still another method used for applying the two mentioned heads is to attach them by the use of a Dresser coupling, and fasten to the pipe line by special clamps on the pipe and head which are connected by bolts to prevent the head being blown off during the test. This type of coupling eliminates the welding operations and leaves the end of the pipe in condition to weld without any further preparation.

Another type of head which is commonly used is one made from a Dresser coupling in which a disc has been welded to one end of the sleeve and the other end of the sleeve left open to be slipped over the end of the pipe to be tested. The sleeve is drilled for about 8½ in. set screws which, when screwed against the pipe line, prevent the head blowing off when the pressure is applied.

It will be evident that neither of the last mentioned methods is applicable when high pressures are specified.

There are several methods in use for this testing. The hydrostatic pressure with a hammer test is probably the most severe. This is made by pumping water into the line at a specified pressure, being sure to displace all air, and hammering the pipe adjacent to the weld. The impact of the hammer blows causes the vibration to travel through the pipe, and any weak joints will generally show up under this treatment.

On account of the inability to get a sufficient water supply, also the difficulty of drainage, this method is seldom used. In the case of high pressure water lines this test is very desirable before the lines are turned over to actual service.

The method commonly employed in testing at ordinary pressures is by the use of air pressure and the application of soap and water solution which is painted over the joint; in case of a leak it will indicate itself by the air bubbles which form on the outside of the joint. This test is extensively used and has been found to be quite satisfactory.

Several important points to be considered in the construction of gas welded steel pipe lines have been touched on in order to indicate the need for careful planning so that satisfactory construction can be expeditiously accomplished.

The use of steel pipe lines is still in its infancy. On account of the tremendous demands gas companies, public utilities corporations, power plants, oil and water companies, and others interested in pipe lines that must be tight, and of low installation and maintenance cost. are turning to gas welded steel pipe lines, as they more effectively meet the demands of the consumers.

FIG. 8,193.—Pennforge butt welding flanges. View showing installation of these flanges in the Harvard University power house.

TEST QUESTIONS

1. *What are the features of welded and screwed joints?*
2. *State the advantages of welded joints over screwed joints.*
3. *Name two methods of welding pipe.*
4. *Describe the various types of joints.*
5. *What is the object of the welding dam?*
6. *Describe at length the welding of large pipes.*
7. *What are dollies?*
8. *What is a firing line weld?*
9. *Describe in detail the method of firing line welding.*
10. *Explain the process of bell hole welding.*
11. *Describe the various fittings used in pipe welding.*
12. *Explain the methods of closing pipe lines for testing.*

CHAPTER 209

Soldering

A knowledge of soldering is useful to the electrician, and the acquirement of proficiency in it will be found of value.

Solder.—By definition, solder is *a fusible alloy.* There are a great many varieties of solder. In electrical engineering, the solder used in practically always *an alloy of tin and lead.*

As the electrical conductivity of such an alloy is usually about one-seventh that of copper, the best joint between copper conductors is made by bringing the copper surfaces as close together as possible and using a minimum of solder.

For jointing, especially where work has to be done in awkward positions, it is essential that the solder should have a plastic stage between its liquid and solid states.

There are two general classes of solder:

1. Soft;
2. Hard.

Soft solder is an alloy composed of lead and tin. Sometimes other metals are added to lower the melting point.

NOTE.—***The soldering amateur*** will agree that soldering is a distinct art in itself, and while it looks easy, it is not; moreover, skill cannot be acquired without considerable practice; however, the information to be obtained in books will be found helpful, not only to the beginner, but also to the experienced workman.

The following table gives the melting points and relative hardness of various *tin lead* solders.

Melting Points and Hardness of Tin Lead Solders

Percentage Tin	Percentage Lead	Melting Temp. Deg. F.	Brinell Hardness Test	Percentage Tin	Percentage Lead	Melting Temp. Deg. F.	Brinell Hardness Test
0	100	618.8	3.9	60	40	368.6	14.6
10	90	577.4	10.1	66	34	356.0	16.7
20	80	532.4	12.16	70	30	365.0	15.8
30	70	491.0	14.5	80	20	388.4	15.2
40	60	446.0	15.8	90	10	419.0	13.3
50	50	401.0	15.0	100	0	466.0	4.1

In the table which follows will be found the proper solder and flux to use with various metals.

Soft Solders and Fluxes for Various Metals

Metal to be Soldered	Flux	Soft Solder: Tin	Lead	Zinc	Aluminum	Phosphor tin	Bismuth
Aluminum	Stearin	70		25	3	2	
Brass	Chloride of zinc, rosin, or Chloride of ammonia	66	34				
Gun metal	Chloride of zinc, rosin, or Chloride of ammonia	63	37				
Copper	Chloride of zinc, rosin, or Chloride of ammonia	60	40				
Lead	Tallow or rosin	33	67				
Block tin	Chloride of zinc	99	1				
Tinned steel	Chloride of zinc or rosin	64	36				
Galvanized steel	Hydrochloric acid	58	42				
Zinc	Hydrochloric acid	55	45				
Pewter	Gallipoli oil	25	25				50
Iron and steel	Chloride of ammonia	50	50				
Gold	Chloride of zinc	67	33				
Silver	Chloride of zinc	67	33				
Bismuth	Chloride of zinc	33	33				34

Common or plumber's solder consists of one part of tin to two parts of lead, and melts at 441° Fahr. It is used by plumbers for ordinary work, and occasionally for electrical work where wiped joints are required, for instance, in large lead covered work.

Medium or fine solder consists of equal parts of tin and lead, or *half and half*, and melts at 370° Fahr. This solder is always used for soldering joints in copper conductors, and for soldering lead sleeves on lead covered wires.

Hard solder is an alloy composed of copper and zinc, or copper, zinc, and silver.

Hard solder in general is sometimes erroneously called ***spelter***.

The following table gives the various hard solders, proper flux, and metals for which they are suited.

Hard Solders and Fluxes for Various Metals

Metal to be soldered	Flux	HARD SOLDER			
		Copper	Zinc	Silver	Gold
Brass, soft	Borax	22	78		
Brass, hard	Borax	45	55		
Copper	Borax	50	50		
Gold	Borax	22		11	67
Silver	Borax	20	10	70	
Cast iron	Cuprous oxide	55	45		
Iron and steel	Borax	64	36		

As will be noted from the table, most of the hard solders are alloys of copper and zinc. An easily fusible hard solder may be made of one part copper to two parts zinc, this, however, makes a joint that will be weaker than when an alloy more difficult to melt is used.

A hard solder that is readily melted is made of 44% copper, 50% zinc, 4% tin, and 2% lead.

A hard solder for the richer alloy of copper and zinc may be produced from 53 parts copper and 47 parts zinc.

Solder must have a lower melting point than the metals to be joined to it.

NOTE.—***Solder containing much lead*** makes a weak joint because the lead does not transfuse with brass.

NOTE.—***Solder containing much tin*** is brittle.

The melting point should approach as nearly as possible that of the metals to be joined so that a more tenacious joint is effected.

The fusibility of a solder can be increased by the addition of a small portion of bismuth.

Soft solder melts at a low temperature compared with hard solder which melts at a red heat.

German Silver Solders.—German silver is a very hard alloy of copper (50 to 60%), nickel (15 to 25%), and zinc (15 to 20%). A German silver containing 1 to 2% of tungsten is called *platinoid*. These alloys have a high electrical resistance, platinoid being higher than the other varieties of German silver; the resistance increases uniformly between 32° and 212° Fahr.

German silver solders possess considerable strength, and are often used for soldering steel. The color is very similar to that of steel.

In preparing German silver solders, the copper is melted first, and then the zinc and nickel added simultaneously.

Hard German Silver Solders

These solders, sometimes called steel solders, contain a large proportion of nickel and are very strong. They require a very high heat for melting, and usually cannot be fused without the aid of a bellows or blast.

No. 1. Copper, 35 parts; zinc, 56.5 parts: nickel, 9.5 parts.

No. 2. Copper, 38 parts; zinc, 50 parts; nickel, 12 parts.

Soft German Silver Solders

No. 3. Copper, 4.5 parts; zinc, 7 parts; nickel, 1 part.

No. 4. Copper, 35 parts; zinc, 56.5 parts; nickel, 8.5 parts.

The following No. 5 formulae given by Kent is similar to No. 4:

No. 5. Copper, 38 parts; zinc, 54 parts; nickel, 8 parts.

Soldering Fluxes.—The word *flux*, means a *substance applied to a metal to make solder flow readily on its surface.*

The action of a flux is largely that of cleaning the surface, and of reducing any oxide on the surface to the metallic state.

If a piece of sheet copper be carefully cleaned by means of emery cloth and heated over a gas flame, the surface will be seen to tarnish rapidly and assume a dark brown appearance. A small piece of rosin dropped on the surface will melt, and when the liquid runs, the initial brightness of the surface will be found to reappear.

There are a number of fluxes suitable for various kinds of soldering, but pine amber rosin is the best for electrical work as it does not cause corrosion. A corrosive flux, such as zinc chloride solution (killed spirits) should be strictly excluded from any electrical work.

The Underwriters' code permits the use of a flux composed of chloride of zinc, alcohol, glycerine, and water.

This preparation is easily applied and remains in place. It permits the solder to flow freely and is not highly corrosive. This flux is made as follows: Zinc chloride, 5 parts: alcohol, 4 parts; glycerine, 3 parts. Anhydrous zinc chloride crystals should be used dissolved in alcohol.

The glycerine makes the flux adhesive. To prevent the alcohol igniting. the mixture may be diluted with water.

For electrical work, especially when very small wires are used, rosin should be insisted upon to avoid any corrosion.

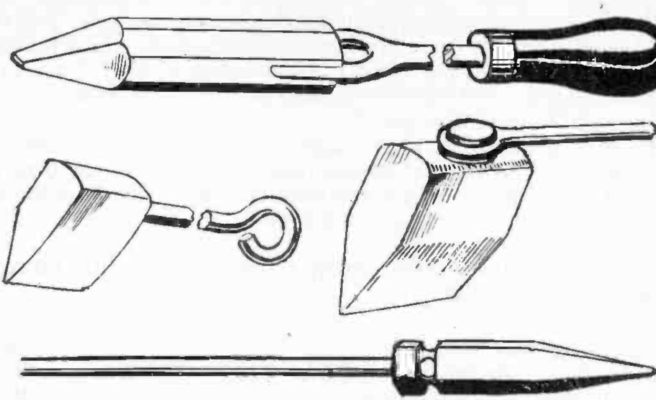
No one flux can be assigned to any one metal as being peculiarly adapted or fitted to that metal for all purposes. The nature of the solder often determines the flux.

The various fluxes and their use are given in tabular form in the accompanying tables. According to Haswell, the proper fluxes to use are as follows:

For iron, use borax
" tinned iron, use rosin
" copper and brass, use sal-ammoniac

For zinc; use chloride of zinc
" lead, use tallow or rosin
" lead and tin. use rosin and sweet oil

Soldering Bolts or Bits.—The erroneously called soldering "iron" or bit consists of a large piece of copper, drawn to a point or edge and fastened to an iron rod having a wooden handle as shown in fig. 8,194. There is a great variety of bits which may be classed:



Figs. 8,194 to 8,197.—Various soldering bits, or so called "irons." Fig. 8,194, ordinary edge bit; figs. 8,195 and 8,196, hatchet bits; fig. 8,197, pointed bit.

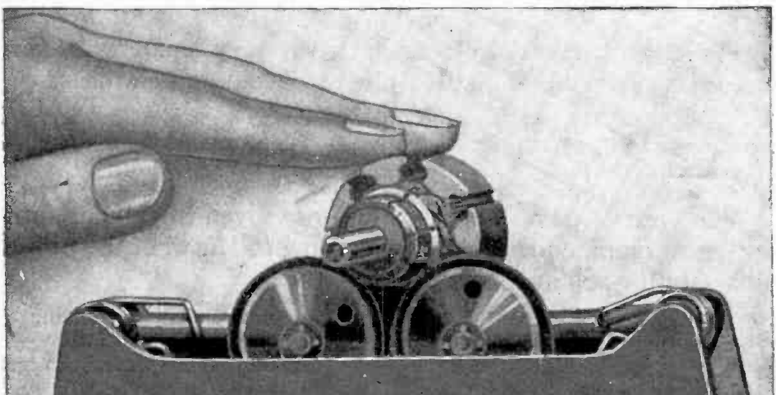
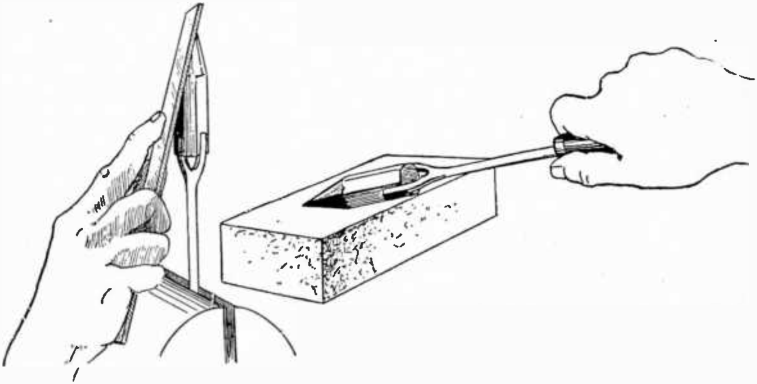


Fig. 8,198.—Chapman manual commutator fluxing machine. ***In construction,*** two cloth rollers carried by a spring actuated lever, dip into a trough of flux and press against commutator as armature is rolled by hand.

1. With respect to their shape, or construction as:
   - *a*. Pointed;
   - *b*. Grooved;
   - *c*. Hatchet.

2. With respect to the method of heating, as:
   - *a*. Externally heated; *b*. Internally heated {electrically, or by gasoline torch.

The various types of bit are shown in the accompanying cuts.



FIGS. 8,199 and 8,200.—Two methods of cleaning the bit. Fig. 8,199, filing; fig. 8,200, rubbing on soft brick.

A heavy bit is preferable for joining work, as one weighing less than two pounds does not retain the heat long enough.

Tinning the Bit.—Preliminary to soldering, the bit must be coated with solder, this operation being known as "tinning."

To tin a soldering bit, heat it in a fire or gas flame, until hot enough to melt a stick of solder rapidly when it is lightly pressed against it.

When the bit is at the right temperature, the heat can be felt when it is held close to the face. When hot enough clean up the surface of the copper with an *old* file.

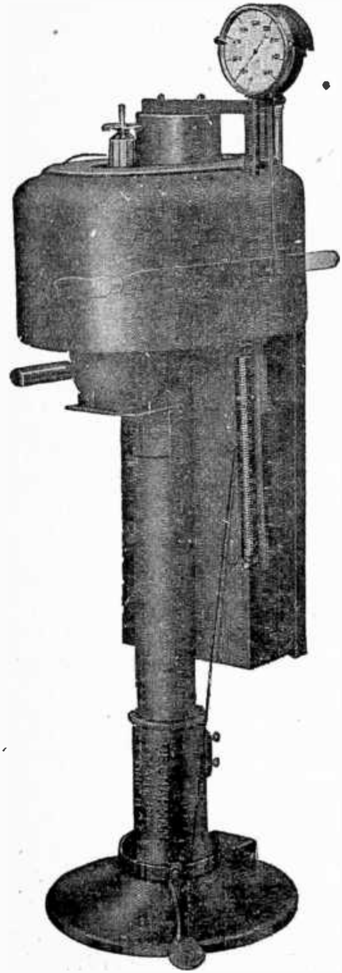


FIG. 8,201.—Chapman "Allatonce" electrically heated commutator soldering machine. View showing general appearance of machine.

If the temperature be too high, the copper surface will be found to tarnish immediately, in which case the soldering bit must be allowed to cool slightly and the cleaning repeated. When the surface only tarnishes slowly a little flux is sprinkled upon it, and then rubbed with a stick of solder.

After the molten metal has spread over the whole of the surface which it is desired to tin, the superfluous solder is wiped off with a clean damp rag.

The surface should then present a bright silvery appearance when properly tinned.

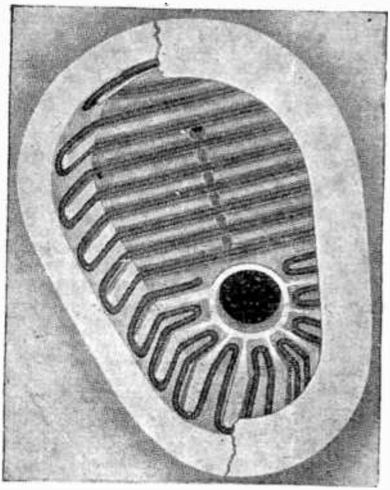
The operation of tinning the bit is shown in figs. 8,204 to 8,206. Once a soldering bit has been well tinned care should be taken not to overheat it. If the bit at any time reach a red heat it will be necessary to repeat the whole tinning process before it is fit to be used again. ***No good work can be done with an untinned or badly tinned bit.***

Soft Soldering.—The theory of soft soldering is that: *as the solder adheres to and unites with the surface of the copper when the bit is tinned, so will it adhere to and unite the surfaces of the metals to be soldered.*

Soft soldering, as well as hard soldering, consists in welding together two or more pieces of similar or dissimilar metals by means of another metal of lower melting point.

In order to solder successfully wire joints, the following instructions should be followed:

1. Clean and tin the bit as shown in figs. 8,204 to 8,206.



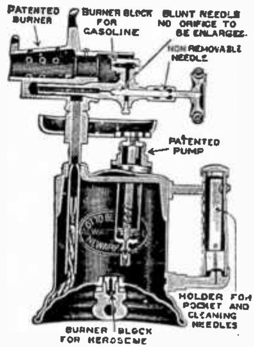


FIG. 8,202.—Electrical heating elements as used on Chapman "Allatonce" commutator soldering machine. Rating of heating elements 1600° to 2200° Fahr. but operated at only about 1200°.

FIG. 8,203.—Bernz gasoline torch with holder for heating soldering bits.

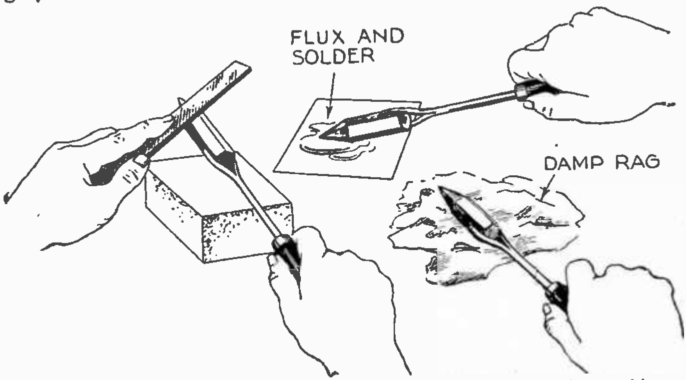
2. Heat the bit in the fire until it reaches the right temperature. Do not try to solder a joint with a bit so cool that it only melts the solder slowly, nor with one so hot that it gives dense clouds of smoke when in contact with rosin. Burned rosin must be regarded as dirt.

3. Remove the bit from the fire and hold it, or preferably support it on a brick or block of other material which does not conduct heat readily.

4. Wipe the surface clean with a rag. Apply solder until a pool remains on the flat surface, or in the groove, if a grooved bit be used.

5. Sprinkle with rosin, lay the joint in the pool of solder and again sprinkle with rosin.

6. Rub the joint with a stick of solder so that every crevice is thoroughly filled.



FIGS. 8,204 to 8,206.—"Tinning" the bit. Fig. 8,204, cleaning bit by filing working surfaces with an old file; fig. 8,205, rubbing the bit on the flux and solder, which may be conveniently placed on a piece of sheet tin as shown; fig. 8,206, removing surplus solder by giving each side of the bit a quick stroke over a damp rag.

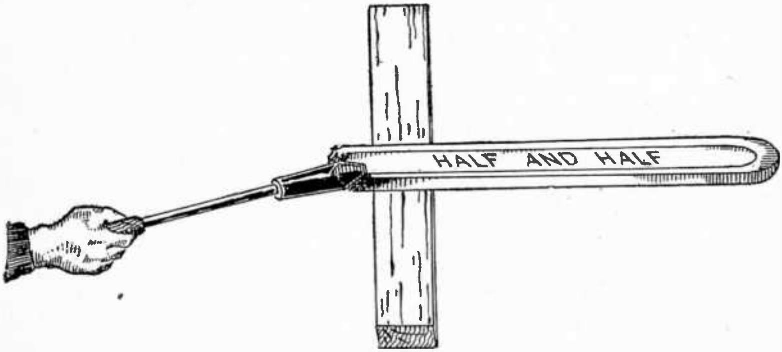


FIG. 8,207.—Picking up solder with a hot bit. This is the proper method for small work. Rest the bar of solder on some support as a brick or piece of wood and touch it with the end of the hot bit. Some of the solder will melt and remain on the bit. It is then transferred to the part to be soldered, and if the surfaces be in proper condition and fluxed when the bit touches the surfaces, the solder will leave the bit and cover the surfaces. ***In picking up solder*** from the stick, care should be taken not to leave the bit in contact with the solder too long or some of it will drop off. The larger the bit and area tinned, the more solder will the bit hold.

7. Remove the bit, and lightly brush superfluous solder from the bottom of the joint. See that no sharp points of solder remain which may afterwards pierce the insulation.

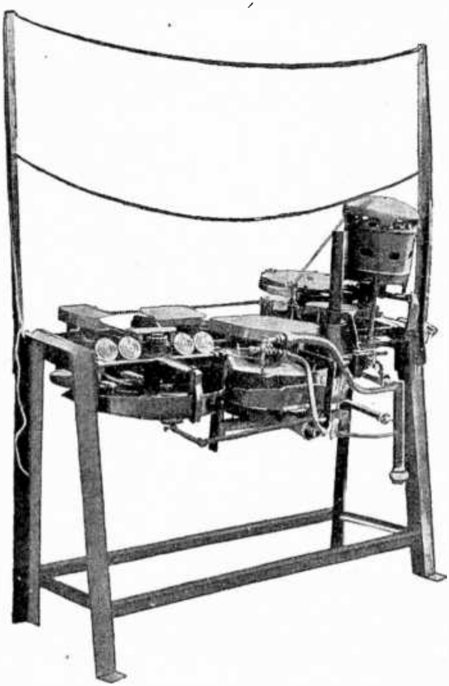


FIG. 8,208.—Chapman full automatic thermostatic wafer soldering machine. ***In operation*** automatic dial feed timing is arranged to take stock from a chute. Timed immersion in flux; four tests for sound stock and proper entry in machine; four throw outs for defective stock or entry. The machine does not stop but throws out the defective pieces and keeps on going. Solders by immersion, and a gentle removal from solder bath, then spun at 1800 *r.p.m.* to throw off excess solder. Cooled in a device to prevent sticking of sections together, and discharged through a non-denting device (not shown).

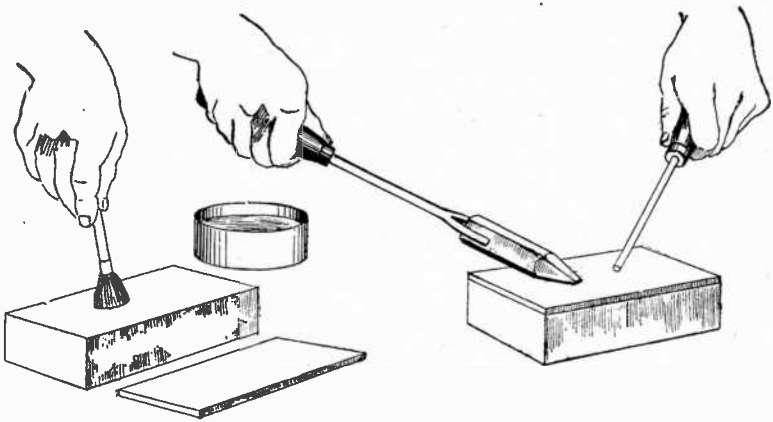
NOTE.—***If the bit be overheated or burned,*** heat to redness and then plunge into cold water, when most of the hard oxidized surface will scale off.

NOTE.—***A soft coal fire*** will quickly destroy the tinning on a bit.

NOTE.—For soldering wire joints see Vol. VII.

When the bit is first placed on the joint, the solder should run up into the joint. This will occur only when the joint is well made and thoroughly cleaned, and if the workmanship be perfect it is even possible to fill the joint completely by feeding in solder below the joint as it melts and runs up into the joint.

A well soldered joint should present a smooth, bright appearance like polished silver. Wiping the joint before it cools destroys this appearance, and is also liable to produce roughness, which is detrimental to the insulation.

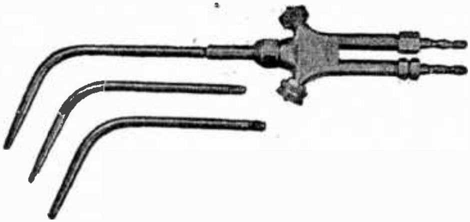


FIGS. 8,209 to 8,212.—*Sweating.* When two surfaces are to be united by sweating, first see that the surfaces are perfectly clean, then flux as in fig. 8,209. Put a piece of tinfoil over one surface and the other surface on top. They should be held firmly together by a clamp or other means and heated as in fig. 8,212 by a hot bit, or if the metal have considerable thickness by a torch, until the solder melts. When cool, the surfaces will be found to be firmly united.

NOTE.—42% tin 58% lead is the strongest of the tin lead alloy. It works good and has sufficient viscosity to fill commutator lead slots automatically. It is therefore not surprising that the nearest commercial composition 40% tin 60% lead (also known as "commercial") is the most popular composition for soldering commutators. It is cheap, works easily and does not throw out of hot commutators as readily as solders containing a higher proportion of tin.

NOTE.—*Soldering Temperature.* The correct temperature for soldering must be determined for each job and flux largely by experiment. It varies with the size of the work, the insulation of the commutator, the solder composition and the nature of the flux. Usual soldering ranges are between 500° Fahr. and 700° Fahr. Do not try to work around 800° Fahr as about this temperature the drosses become soluble in the solder and the solder is said to be "burnt" and will behave badly.

In order to prevent the insulation on the wire near the joint being damaged, the process of soldering should be carried out as quickly as possible, and for this reason the tendency to burn the insulation is less with a *hot* bit (a quick bit) than with a cooler one.



FIGS. 8,213 to 8,215.—Airco-Davis-Bournonville lead burning torch designed for "burning" or welding lead. By attaching a proper mixing head and using City gas instead of acetylene, this torch may be used for soldering. The temperature with gas is about 3,500° Fahr.

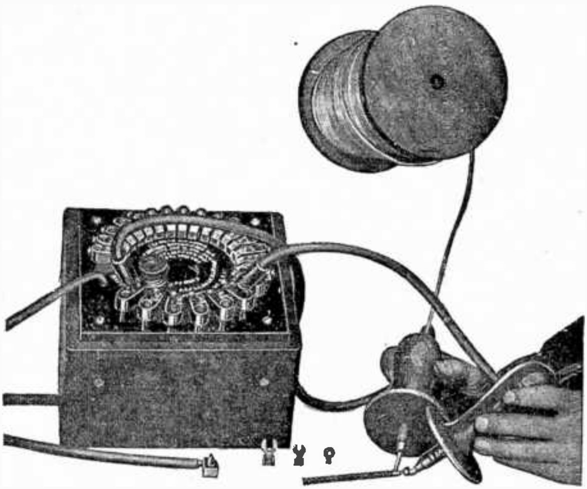


FIG. 8,216.—Chapman universal armeter used with carbon contact resistance soldering leads. Connect pair of No. 8 flexible leads to say O and 5V terminals.

NOTE.—***Block tin*** melts at 446° Fahr. and is used by many especially on very high speed and otherwise heavily worked commutators on account of its 88° higher melting point. Its viscosity is low, that is, it flows freely and it therefore may be necessary to fill the commutator lead slots by hand after it is soldered, but before it cools, using a piece of wire solder or fire block tin.

Sweating.—In this operation *the surfaces are cleaned, heated, and covered with a film of solder.* The soldered surfaces are then placed together and heated by passing the bit over the outside surface until the solder melts and unites the two surfaces.

Sweating is often employed for the temporary holding together of work which has to be turned or shaped, and which could not be so conveniently held by other methods. After having been turned or shaped, the separation of the parts is readily effected by the aid of heat.

TEST QUESTIONS

1. *What is solder?*
2. *Name the two general classes of solder.*
3. *What is the difference between soft and hard solder?*
4. *Of what does common or plumbers' solder consist?*
5. *What is the requirement with respect to the melting point of solder?*
6. *What is a soldering flux?*
7. *Why are some fluxes undesirable for electrical work?*
8. *What is the right name for a so-called soldering "iron"?*
9. *Why should the bit be tinned?*
10. *Describe the operation of tinning the bit.*
11. *What is the theory of soft solders?*
12. *Describe the operation of sweating.*

CHAPTER 210

Electric Heating

The application of electrical energy to domestic and industrial heating has numerous advantages.

For domestic and some industrial purposes, heat is produced by electricity *by forcing it through resistance wires*, raising the temperature of the latter, and applying the heat thus generated to the articles to be heated.

Heating Units.—By definition a heating unit or heating element sometimes called resistor, is *a length of resistance metal in the form of a strip, or coiled wire through which electric current is passed to give off heat*. The heating unit becomes hot on account of the resistance it offers to the current.

Selection of Heating Units.—The choice of material for a heating unit depends upon temperature conditions. All materials used deteriorate to some extent when heated, some will withstand higher temperatures than others. Accordingly in the manufacture of resistance wires there are several kinds to meet the different conditions of service.

Classification of Heating Units.—The numerous applications of heating units give rise to various types which may be classified:

1. With respect to form, as

   a. Wire;
   b. Strip.

2. With respect to service, as

   a. Stove;
   b. Immersion;
   c. Space, etc.

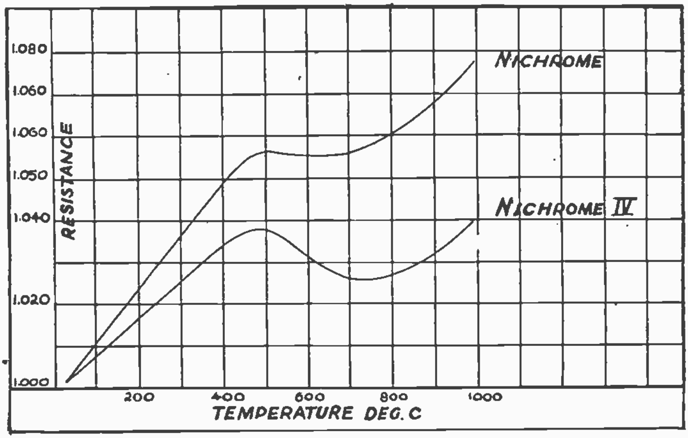


FIG. 8,217.—Temperature coefficient curves of "Nichrome" and "Nichrome" IV here shown represent wire slowly cooled from 1000° C. as specified by the American Society for Testing Materials. Slight variations from this curve may be expected due to variations in methods of annealing of different sizes of wire.

3. With respect to the general application, as

   a. Domestic;
   b. Industrial.

Design of Heating Units.—To obtain satisfactory and efficient results in electric heating the unit should be properly proportioned, located, placed and suitable for the service.

Refractory materials surrounding resistor elements should possess high thermal conductivities, otherwise the resistors will not be able to dissipate their heat as rapidly as it is generated, and will be subjected to undue temperature rise.

As the flow of heat through materials is inversely proportional to the length of the path, the refractory material surrounding resistors should be of minimum thickness consistent with safe mechanical and dielectric strength.

Selecting Nichrome IV resistance wire for illustration, the accompanying table gives size of this resistance wire suggested for a given number of watts at 110 volts. The sizes selected are those which will operate at approximately 1700° Fahr. in open coils and are suitable for radiant heaters, range units, etc.

Nichrome IV Wire, 110 Volt Circuit

Watts	Amperes	B. & S. Size	Ohms 75° F	Length
300	2.72	25	37.6	19 Ft. 4 Ins.
325	2.95	24	34.7	22 5
350	3.2	24	31.6	20 5
375	3.4	24	30.1	19 6
400	3.64	23	28.1	22 10
425	3.87	23	26.4	21 5
450	4.10	22	25.0	25 7
475	4.32	22	23.7	24 4
500	4.55	22	22.5	23 0
525	4.77	22	21.5	22 0
550	5.0	21	20.5	26 7
575	5.23	21	19.6	25 6
600	5.46	21	18.7	24 4
625	5.67	21	18.0	23 5
650	5.91	20	17.3	28 5
675	6.15	20	16.6	27 3
700	6.36	20	16.1	26 5
725	6.58	20	15.6	25 7
750	6.82	20	15.0	24 7
775	7.04	19	14.5	30 0
800	7.26	19	14.1	29 0
850	7.72	19	13.3	27 5
900	8.17	19	12.5	25 10
950	8.63	19	11.9	24 6
1000	9.08	18	11.3	29 2

For other voltages divide the number of watts required at that voltage by the voltage factor (next table). Select nearest number of watts in the 110 volt table, multiply the length in 110 volt table by voltage factor. Suppose a device should require 550 watts and the supply voltage is 150. Factor for 150 volts is 1.36 and $\frac{550}{1.36} = 405$ watts. Nearest value in 110 volt table is

400 and would require No. 23 wire. This size should be used on 150 volts but length should be 21 ft.×1.36 or 28 ft. 7 in.

Voltage Factors on Basis of 110 Volts

Voltage..........	100	120	150	200	220	240	32
Factor...........	91	1.09	1.36	1.82	2.0	2.18	0.29

Nichrome Wire—110 Volts

Watts	Amperes	B. & S. Size	Ohms 75° F	Length	
250	2.27	25	43.6	21 Ft.	2 Ins.
300	2.72	24	36.4	22	0
350	3.2	23	31.0	24	0
400	3.64	23	27.2	21	0
450	4.10	22	24.1	23	5
475	4.32	22	23.0	22	4
500	4.55	22	21.8	21	0
550	5.0	21	19.8	24	5
575	5.23	21	18.9	23	2
600	5.46	21	18.1	22	4
615	5.6	20	17.7	27	6
640	5.82	20	17.0	26	6
660	6.0	20	16.5	25	8
700	6.36	20	15.6	24	4
750	6.81	19	14.5	28	5

Nichrome Ribbon—110 Volts—1/16" Width

Watts	Amperes	Thickness	Ohms 75° F	Length	
400	3.64	.003	27.2	9 Ft.	10 Ins.
425	3.87	.0035	25.6	10	9
440	4.00	.0035	24.7	10	5
450	4.1	.004	24.1	11	7
475	4.32	.0045	22.9	12	5
500	4.55	.0045	21.8	11	8
525	4.77	.005	20.8	12	6
550	5.0	.005	19.8	11	11
575	5.23	.0056	18.9	12	10
600	5.46	.0056	18.1	12	3
625	5.68	.0063	17.4	12	11
650	5.91	.0071	16.7	13	11
660	6.00	.0071	16.5	13	10
675	6.15	.008	16.1	15	0
700	6.36	.008	15.6	14	7
750	6.82	.0089	14.5	15	1

Another example follows taking the alloy "Nichrome" which is suitable for electric irons, toasters, hot plate, space heater, etc.

The second and third tables on page 5,130 give size for a given number of watts at 110 volts.

For voltages other than 110 divide the number of watts required at the given voltage by the voltage factor page 5,130. Select nearest number of watts in the 110 volt table, multiply the length in 110 volt table by the voltage factor. Suppose an electric iron take 550 watts and the supply voltage is 100. Factor for 100 volts is .91 and $\frac{550}{.91}=605$ watts.

Nearest value in 110 volt table is 600 watts which requires 12 ft. 3 ins. of 1/16×.0056 "Nichrome" ribbon. This gives the size to be used on 110 volts, but the length should be .91×12ft. 3 ins. or 11 ft. 2 ins. The winding for 550 watts, 110 volts would then be 11 ft. 2 ins. of 1/16×.0056 "Nichrome" ribbon.

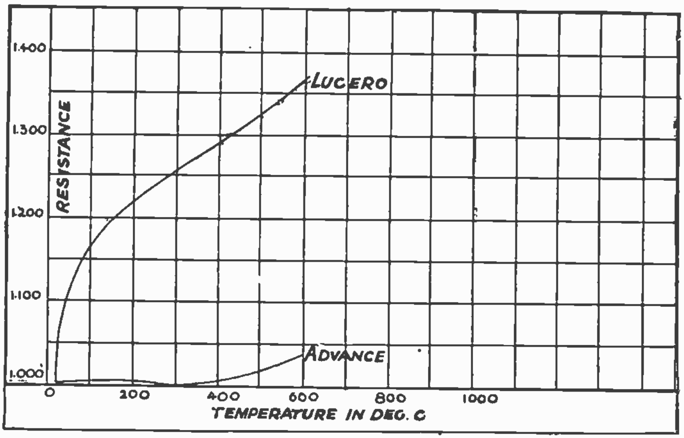


FIG. 8,218.—Temperature resistance curves for "Advance and Lucero" resistance wire showing change in resistance of one ohm of wire with increasing temperature.

Immersion Heaters.—These devices for heating liquids are made in a variety of forms to suit different conditions.

The various methods of heating water may be classed:

1. With respect to capacity, as
   a. Non-storing;
   b. Storing.

2. With respect to the heating element, as
   a. External element;
   b. Immersed element.

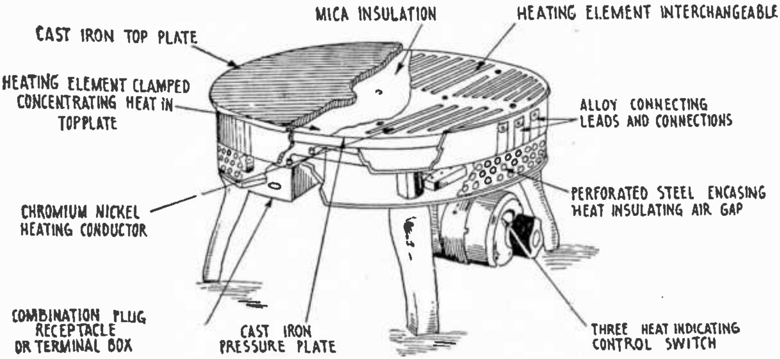


FIG. 8,219.—Electric disc stove. Adapted to laboratory and other industrial purposes. The maximum surface temperature is 750° Fahr.

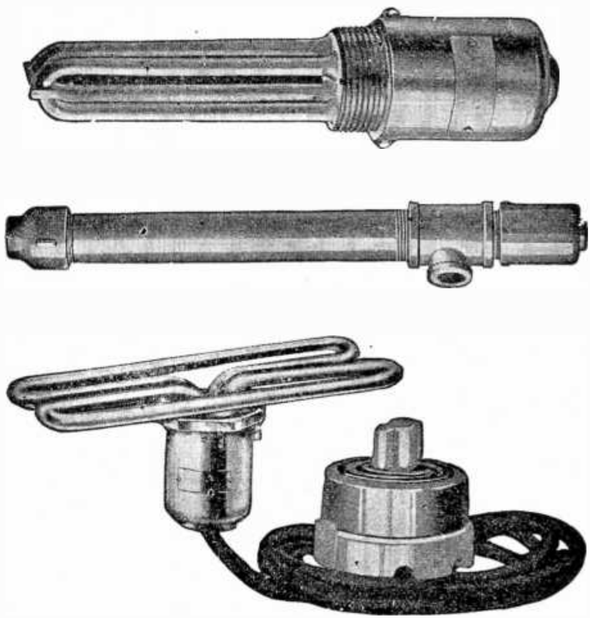
The so-called "instantaneous" is an example of the non-storing class and consists of a heating element and coil of pipe through which water passes, the rate of flow, and consequently the temperature being controlled by a valve. Nothing can be more ridiculous than to call these affairs "instantaneous" heaters, as no physical change takes place instantaneously.

The average use of water is from 20 to 125 gallons per family per day; temperature 104° Fahr. for bath purposes; 150° Fahr. for dish washing.

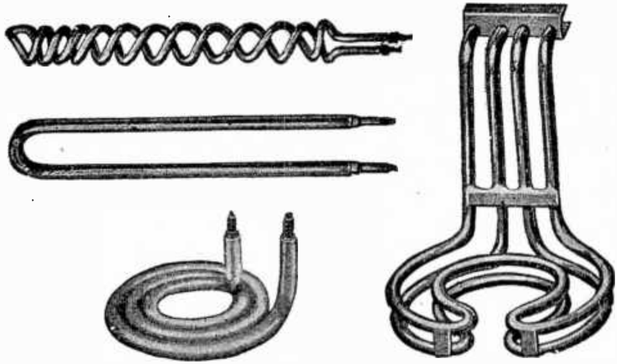
If water be heated as required for use, a large demand, 2 to 5 *k.w.* is created for a short time and under usual conditions, does not secure a sufficiently low energy rate to be economical.

The rate can be lowered by using a lower demand, .5 to 1 *k.w.* over a longer time or continuously, that is, heating the water in advance and storing it in a suitable heat insulated tank.

The demand can also be lowered by arranging a double throw switch to permit use of either range or water heater, but not both at same time. Effective heat insulation on the tank, to reduce heat loss into the room, is required where water is stored. Automatic temperature control aids in securing constant temperature of stored water, and automatically adjusts the average current consumption to the existing hot water requirements.



FIGS. 8,220 to 8,222.—Cutler-Hammer water immersion heaters, for *a.c.* or *d. c.* circuits. Fig. 8,220, pipe outlet type heater. Cord and switch removed; fig. 8,221, circulation type heater. Cord and switch removed; 8,222, bottom outlet heater complete with cord and switch. These heaters are adapted to applications such as water tanks, sterilizers, stills, vulcanizers, glue cookers and other industrial applications where it is necessary or advantageous to have the heater immersed directly in the water. This method of heating liquids results in highest heating efficiency since there is practically no direct loss of heat to the atmosphere, the heat is imparted directly to the water. In addition with the heater inside the tank, it is usually a simple matter to insulate the entire tank to prevent losses by radiation.



FIGS. 8,223 to 8,226.—Cutler-Hammer tubular heater units of special shapes and sizes, showing the adaptability of these heater units.

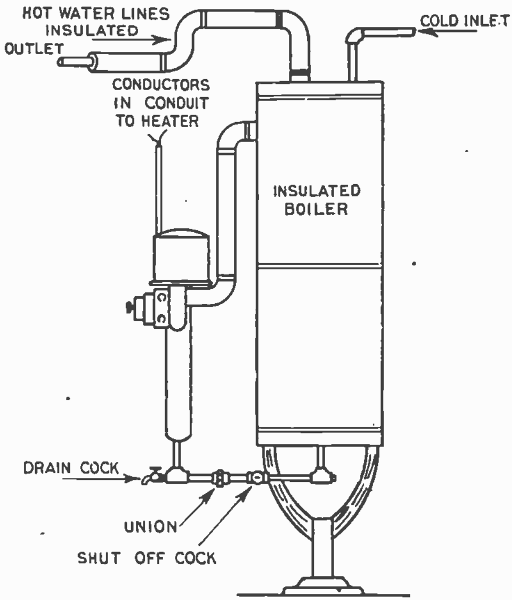


FIG. 8,227.—Wiegand "Chromalox," side arm type electric water heater attached to storage tank.

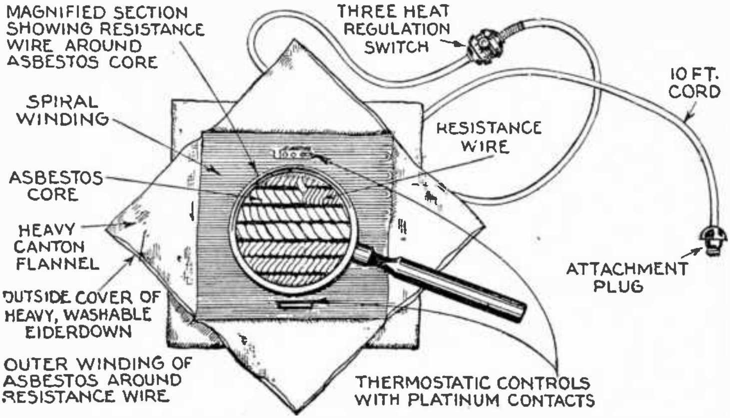


FIG. 8,228.—Electric warming pad. *It consists of* a flexible heating element with an outer cover of eiderdown which is removable and washable, so that the pad may always be kept in a sanitary condition. The pad is arranged for three heats, which are regulated by means of a switch so designed as to be easily operated in the dark, the sense of touch enabling the user to change from one heat to the other. It also contains two thermostats to prevent over-heating. *Never* leave a pad applied to a patient unable to remove same.

Efficiency and Gallons per 24 Hours

of Water Heated to 104° Fahr.

(36 gal. tank covered with 1 in. hair felt insulation on tank and 1 in. magnesia covering circulation piping. Cold water 39° Fahr. Faucet close to tank.)

Kind of system	Kind of equipment	Watts	Efficiency per cent.	No. gal. hot water available (at 104° Fahr. per 24 hrs.)
Storage	Outside circulation	600	82	75
Storage	Outside circulation	1,000	76	117
Storage	"Clamp on"	750	78	89
Intermittent	Outside circulation	3,000	73	330
Intermittent	Outside circulation	5,000	69	525

Space Heaters.—As its name implies a space heater is for diffused instead of concentrated heat, such as room heating.

For this purpose the unit is made from ribbon in the form of a strip.

The electric energy required to heat an ordinary sized room when the outside air is near the freezing point ranges from about 1 to 2 watts per cu. ft.

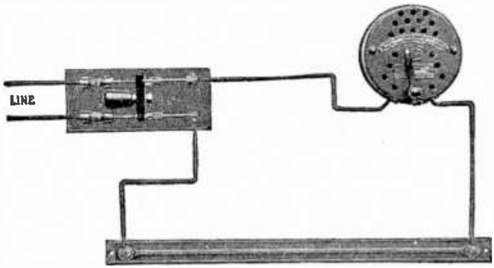


FIG. 8,229.—Cutler-Hammer space heater with rheostat heat control.

The following table shows the loss of heat per sq. ft. of window and wall surface, for one degree Fahr., difference of inside and outside temperature, the loss being expressed in heat units per hour.

Loss of Heat per Sq. Ft. of Surface

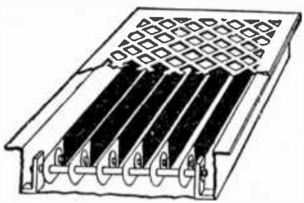
Kind of Surface	B. t. u. per hour	Kind of Surface	B. t. u. per hour
4 in. brick wall.......	68	Window, single glass....	.776
8 in. brick wall.......	46	Window, double glass...	.518
12 in. brick wall.......	32	Skylight, single glass....	1.118
16 in. brick wall.......	26	Skylight, double glass...	.621
20 in. brick wall.......	23	Ceilings, fire proof......	145
Floors, fire proof......	124	Ceilings, wooden beams.	.104
Floors. wooden beams..	683	Ordinary wooden wall, lathed and plastered..	.1

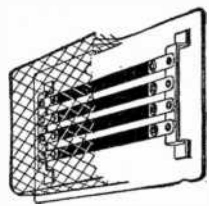
Example.—What will be the loss of heat per hour in a single room, wooden structure when the temperature inside is maintained at 70° Fahr., while the outside is at 32°. Size of room 10×10×10, having three 3×6 windows. Here all surfaces must be considered.

Area of windows = 3 (3×6) = 54 sq. ft.
Area of walls = 4 (10×10) − 54 = 346 sq. ft.
Area of floor = 10×10 = 100.

B.t.u. lost through windows	= (70−32) × .776 × 54 = 1,592.4
B.t.u. lost through walls	= (70−32) × .1 × 346 = 1,314.8
B.t.u. lost through floor	= (70−32) × .083 × 100 = 315.4.
Total loss of heat per hour	= 3,222.6 *B.t.u.*

FIG. 8,230.—Cutler-Hammer space heater: view showing general appearance and size shown by a 2 ft. rule.





FIGS. 8,231 and 8,232.—Application of space heaters under floor and on wall.

Space heating units as made by Cutler-Hammer are two feet long and may be used singly or in groups. These units have a capacity of 500 watts each and may be connected to *d.c.* or *a.c.* circuits of proper capacity and for any voltage between 100 and 125, or 210 and 250. Each heater is stamped with the voltage for which it is designed and should not be used on systems of higher voltages. Being made up in the 500 watt capacity, they provide a very flexible scheme for heating. Only as many as are actually required need be installed, yet additions can be made easily. They can be mounted in groups, or singly at different locations. The mounting holes permit the use of ordinary screws for mounting. There is no assembly.

The number of heaters required depends on many factors. An outdoor crane cab in a northern state would require more heat than one in a locality where the winters are moderate. Also a cab of good construction will be warmed satisfactorily with fewer heaters than one of poor construction.

The watt rating of a heater is determined by three general considerations:

1. Safe heater temperature.

   One that will insure a satisfactory length of life.

2. Desirable operating temperature for the service.

3. Fire risk.

FIG. 8,233.—Wiegand one inch wide, strip heater designed for use in building special machinery where heat is required at some local point on the machinery as is the case in package forming and sealing machines, marking machines, and other manufacturing process equipment These strip heaters are rated at comparatively high wattage per sq. in. They safely operate at red heat, not exceeding 1,300° Fahr. The single end strip heater shown has the usual advantage of bringing the terminals to one end which is often desirable in machine building

The maximum safe operating temperature of the space heater is between 700° and 800° Fahr.

This is the approximate operating temperature of the standard 500 watt space heater when used under the conditions for which it is primarily designed, that is, for heating air at atmospheric temperatures and with free ventilation. It is evident that if the heaters be mounted in an enclosure which is at a much higher temperature than atmospheric or living room temperatures, the temperatures of the heater will be increased and it will therefore be over-rated and its life will be shortened. It is also evident that if the heaters be crowded together so that there is an interchange of heat between them, one acting to heat its neighbor, the safe operating temperature will be exceeded and the heaters may burn out unless the rating be reduced.

Example.—Assume that a standard space heater is installed in a plate warmer for keeping plates or dinner service warm. It is evident that while a standard rating might be used, the temperature of 700 to 800° Fahr. in contact with or close to chinaware, would be very apt to cause breakage. Therefore, the plates should be spaced away from the heater and preferably shielded from direct radiation and convection, or a lower rated heater used. For example, a 220 volt heater on a 110 volt circuit, which will deliver 125 watts.

In the same way the temperature must be considered from the operation or service standpoint in many industrial processes. In a package sealing machine, for instance, while a standard rating might be safe so far as the heater is concerned, the high temperature might burn the glue or overheat the paraffin. Therefore, a lower rating would be called for, not on account of the life of the heater, but on account of operating conditions and results to be accomplished.

Building Heating, Thumb Rules.—As a rough approximation, a rule of thumb is as follows:

.35 watts per cu. ft. (See *A*)
Plus 3.5 watts per sq. ft. of wall area (See *B*)
Plus 35. watts per sq. ft. of glass area (See *C*).

A. This takes care of the heat required for raising the temperature of the air approximately one complete change of air per hour. For more frequent changes, increase the wattage proportionately.

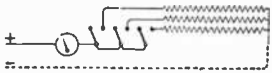
B. This takes care of the loss of heat through the walls. In figuring the wall area, the area of the four sides of the rooms and the ceiling and the floor are all included and a deduction is made for the glass area. The rule assumes good building construction, such as a good 12 in. brick wall or well made, double frame wall.

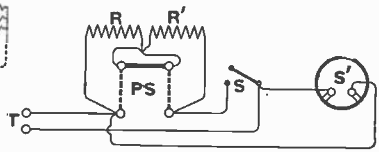
C. For measuring glass area, the overall area of the frame is measured and this area is deducted from the total wall area.

The above rule assumes a temperature elevation of 70° Fahr. or, in other words, external temperature of zero, room temperature of 70° Fahr. If the room adjoin other heated rooms, allowance must be made, based on the difference in temperature between the room under consideration and the adjoining rooms.

This thumb rule is for rough estimates only. It will agree quite closely with more complicated calculations in some cases, but on the other hand, there may sometimes be a considerable error so that it must be used cautiously. The following two examples will illustrate how the above rule is applied:

Example.—Small house 12 ft.×10 ft.×9 ft. high, good construction, 12 in. brick walls, with 3 windows each 3 ft.×5 ft., is to be heated to 70° Fahr. with zero temperature outdoors and one complete air change per hour.





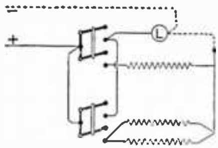


FIG. 8,234.—Arrangement of internal circuits for heaters in which each resistance section is controlled by a separate switch.

FIG. 8,235.—Internal connections of a cooker. T, terminals; PS, parallel or series switch; S, ordinary switch; S′, two pin socket for plug connection; R,R′, resistance sections. Current is turned on or off from R,R′ at S, while PS. puts R and R′ either in parallel or series. S′, allows of the attachment of an auxiliary heater. This arrangement is applicable to other types of heater, and S′, would then generally be omitted.

FIG. 8,236.—Arrangement of two circuit heater with pilot lamp L. When either switch is put on, L lights up. The top switch controls one-third of the heater resistance, and the bottom switch two-thirds.

$$.35\ (12\times10\times9)$$

$$\text{Plus } 3.5\left[(12\times10\times2)+(12\times9\times2)+(10\times9\times2)-(3\times5\times3)\right]$$

$$\text{Plus } 35(3\times5\times3)$$

Equals 4,022 watts. Eight 500 watt space heaters should be used, which will give a total of 4,000 watts.

Example.—Room 12 ft.×10 ft.×9 ft. high, good construction with well made, double frame walls, with two exposed walls containing 3 windows, each 3 ft.×5 ft. Room is on top floor, with ceiling (roof) exposed, with the room adjoining the 10 ft. wall heated to 70° Fahr. and that adjoining the 12 ft. wall 60° Fahr. The room beneath is heated to 70° Fahr. Two complete air changes per hour.

$$.35\times 2(12\times 10\times 9)$$

$$\text{Plus } 3.5\left[(12\times 10\times 1)+(12\times 9\times 1)+(10\times 9\times 1)\right.$$

$$\left.+\frac{70^\circ-60^\circ}{70^\circ}(12\times 9\times 1)-(3\times 5\times 3)\right]$$

$$\text{Plus } 35(3\times 5\times 3)$$

Equals 3,339 watts. Seven 500 watt space heaters should be used, which will give a total of 3,500 watts.

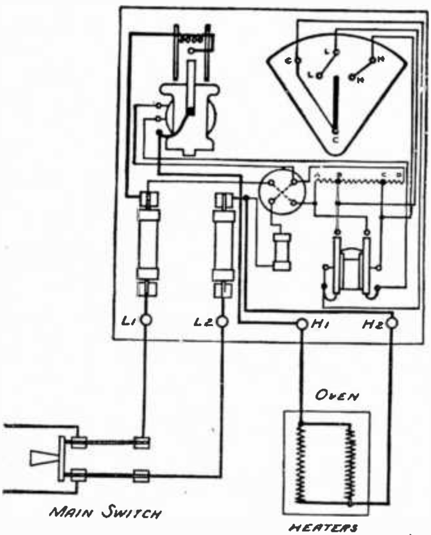


FIG. 8,237.—Control panel with switches, fuses and thermostat for the automatic regulation of heat.

Regulation of Heat.—To properly control the heat output, regulation of wattage may be required to:

1. Heat up rapidly from room to operating temperature; that is, to supply the heat of absorption and latent heat.

2. Provide for changes in operating temperature.

3. Provide for operation at uniform temperature where the heat requirements vary during operation.

The following methods of regulating wattage are in most common use:

1. By dividing the heater into sections and changing the voltage impressed on each section by connecting the sections in different combinations.

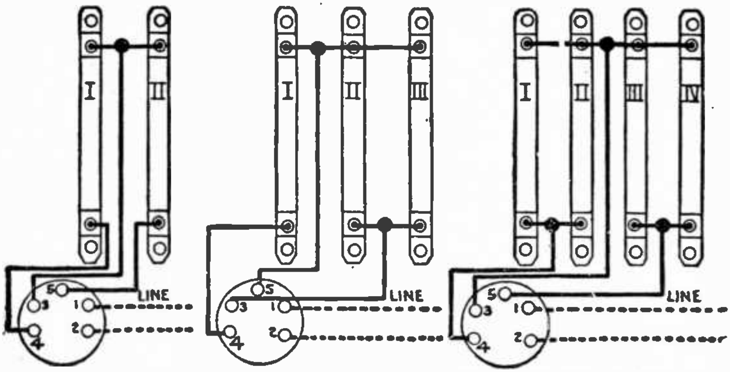


FIG. 8,238.—Two heaters and snap switch. ***High,*** full heat, heaters 1 and 2; ***medium,*** one-half heat, heater 2 only; ***low,*** one-quarter heat, heaters 1 and 2; ***off.***

FIG. 8,239.—Three heaters and snap switch. ***High,*** full heat, heaters 1, 2 and 3; ***medium,*** two-thirds heat, heaters 2 and 3 only; ***low,*** one-third heat, heater 1 only; ***off.***

FIG. 8,240.—Four heaters and snap switch. ***High,*** full heat, heaters 1, 2, 3 and 4; ***medium*** one-half heat, heaters 3 and 4 only; ***low,*** one-quarter heat, heaters 1, 2, 3, and 4; ***off.***

2. By dividing the heater into sections each designed for line voltage, and providing each section with a switch.

3. By the use of a series rheostat. This gives closer regulation than methods 1 and 2, and does not complicate the heater by sectionalizing it. Rheostat control is particularly well suited to heaters developing small wattages.

4. By connecting the heater intermittently to the line, opening the circuit when the maximum operating temperature is reached and closing the circuit when minimum operating temperature is reached. This is the method generally employed in automatic temperature control. A thermostat or other

temperature responsive device is used and for low wattages, opens and closes the circuit directly, or for higher wattages actuates a suitable magnet switch.

5. By a time switch for connecting and disconnecting the heater at predetermined times.

Figs. 8,237 to 8,240 show how some of the methods of regulation just described are accomplished.

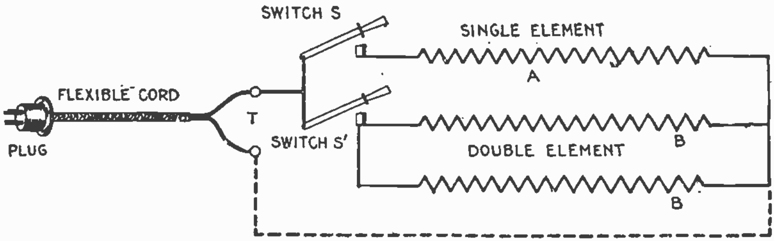


FIG. 8,241.—Arrangement of internal circuit for heaters giving three heating values. *In the diagram* A, represents one-third of the heating circuit; BB, two-thirds. With switch S, on, one-third of full heat is given; with S′, two-thirds, while with both S, and S′, on, the heater works with full power. At T, are two terminals to which the ends of the flexible cord from the plug are secured.

Non-Metallic Heating Units.—These are suitable for high temperature service such as applications in which the temperatures range from 1900° Fahr. (1038° C.) to 2750° Fahr. (1510° C.).

This temperature range covers the heat treatment of high speed steels, firing of ceramic ware and the heating of metals for forging. Non-metallic heating units are manufactured in cylindrical rods of carborundum brand silicon carbide. Silicon carbide has no known melting point; it is highly refractory and has a high specific resistance.

TEST QUESTIONS

1. *What are heating units?*
2. *Upon what does the choice of material for heating units depend?*
3. *Give classification of heating units.*

4. *Give calculation for heating units for electric irons, toasters, etc.*
5. *Describe an immersion heater.*
6. *How much electric energy is required to heat an ordinary sized room in freezing weather?*
7. *Give calculation for house heating.*
8. *What name is given to heating units used for house heating?*
9. *How is the watt rating of a heater determined?*
10. *What is the maximum safe operating temperature of a space heater?*
11. *Give building heating thumb rules.*
12. *Describe the regulation of heat.*

CHAPTER 211

Electro-Plating

Briefly, electro-plating is *the act or process of depositing metal by electric means.*

This process consists in obtaining *an electro-deposit of one metal, used as an anode, upon some metallic article which is connected to form the cathode in an electrolytic bath,* that is the object upon which it is desired to deposit the metal is connected with the negative pole of the source of current, and the metal which is to be deposited is connected with the positive pole.

The chemical nature of the *electrolyte* employed depends upon the kind of plating. For plating with gold or with silver, the electrolyte is always alkaline, for plating with nickel or with copper, it is usually acid.

Substances other than metal can be electro-plated by first coating their surfaces with powdered graphite or plumbago, as in the case of *electrotyping.*

The principle of electro-plating is illustrated in fig. 8,242.

The Current Supply for Electro-Plating.—Low pressure direct current is used for this purpose, the pressure used being from 1 to 16 volts, depending upon the nature of the electrolyte employed, and the rate at which the plating is accomplished.

The current density is important and varies with different metals.

With a high current density the deposit may be crystalline or powdery, and will not adhere well to the cathode. What is required is to regulate the current so that the deposited metal may be smooth and adherent, and capable of being burnished without being detached.

Hard and fast lines cannot be laid down, but, generally speaking, with high current densities the deposit is powdery, and of a dark color, when it is said to be "burnt." Much higher current densities can be employed if the solution be rapidly circulated by means of a pump or agitated by blowing in air.

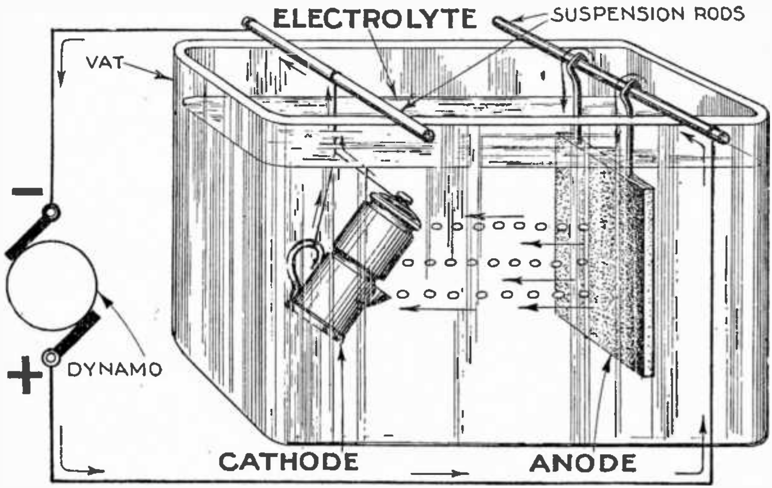


FIG. 8,242.—Process of electro-plating. ***By definition,*** electro-plating is ***the process of coating metal articles with thin films of other metals which are obtained by electrolysis from the solution of their salts.*** As here shown, the vat contains an electro-plating solution (called the ***electrolyte***) into which the article to be plated (called the ***cathode***) is immersed and connected to the negative terminal of the current source. A strip of metal (called the ***anode***) more positive than the cathode is also similarly immersed in the electrolyte and connected to the positive terminal of the current source. Current from the dynamo causes the metal of the anode to dissolve and pass over to the cathode upon which it is deposited as a thin coating.

Dynamo and Dynamo Sets for Electro-Plating.—Since it is not economical to transmit low voltage heavy amperage current a long distance, the current is usually generated in the electro-plating plant. Accordingly, a special type dynamo is used either belted to any power source or direct connected to a motor.

Both shunt and compound wound dynamos may be used either self excited or separately excited.

The so called "separately excited shunt wound dynamo" is simply a dynamo in which the entire field current is furnished from outside.

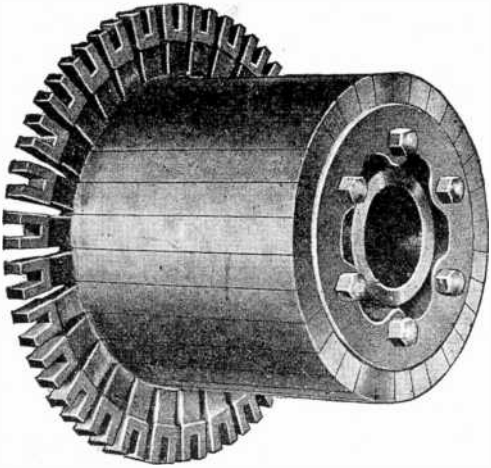


FIG. 8,243.—Reliance commutator. ***In construction,*** the segments are built on a spider type shell which is keyed to the shaft. The ears of the bars are separated so that air can circulate through winding and around commutator.

Strictly speaking, it is not shunt wound, but the above expression has come into common use, probably in contrast with the term "separately excited compound wound." Except in the smaller sizes, separate excitation produces superior plating characteristics. On account of the very heavy current output electro-plating dynamos usually have two commutators.

The choice of the type dynamo to use depends on the conditions met with in the plant.

Assume the use of a plating tank into which similar work is being placed and from which finished work is being removed continually. In order to maintain uniform current density as additional work is placed in the tank, the ampere rate must increase as the plating surface is increased. Such a condition calls for one design. Then assume the use of a tank filled with chromium plated automobile parts which require 8 or 9 volts for a few seconds and 5 volts for approximately 25 minutes before removal of the work. This calls for an entirely different design.

Whether the plating dynamo should have a flat, a drooping, or a rising characteristic depends entirely upon the work to be performed.

Fit the dynamo to the job and not the job to the dynamo.

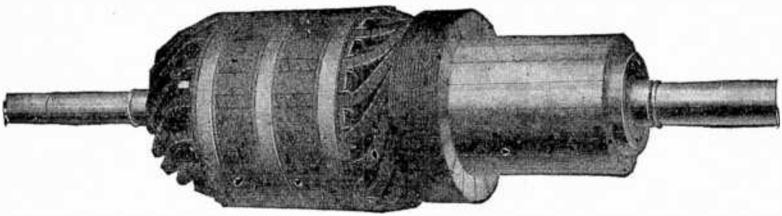


FIG. 8,244.—Reliance armature with double commutator

Scientifically metered control of deposit is becoming more and more customary and scientific regulation of the plating dynamo must be equally exact.

Series rheostats have therefore become largely antiquated for modern production work; besides, they are wasteful of current. unnecessarily costly, and have so few points of regulation that they are of little value.

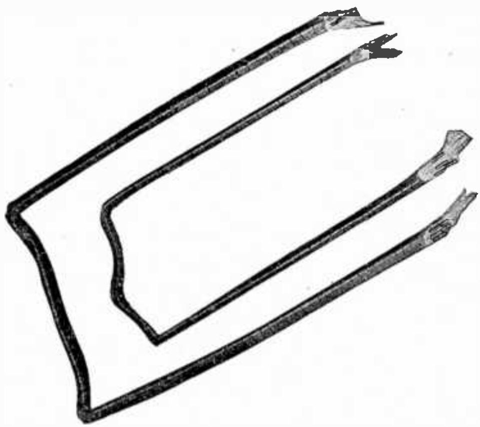
Individual tank dynamos, with voltage control, are in most cases the most economical and most satisfactory equipment.

Construction details of electro-plating dynamos and dynamo sets are shown in figs. 8,243 and 8,244.

Note in figs. 8,243 and 8,244 the large commutator and very heavy inductors necessary to carry the large current.

Electrolyte or Plating Solutions.—These may contain the necessary constituents in various percentages. The following solutions are considered the best in general practice.

A good 14 carat gold plating solution is composed of water, 1 gallon; potassium cyanide, 10 ounces; gold chloride, 10 pennyweights; and a sufficient amount of carbonate of copper to give the desired shade. A 14 carat gold anode should be employed.



FIGS. 8,245 and 8,246.—Reliance armature coils. *They are made* of strands of insulated copper wire, formed and taped together and further insulated with a coat of varnish. After winding the entire armature is painted with a special high temperature, non-flowing black finish, and baked. Each coil is then carefully tested.

The best solution for silver plating is the double cyanide of silver and potassium solution.

The single cyanide of silver is prepared by adding a solution of cyanide of potassium to a solution of nitrate of silver until a precipitate ceases to form.

The double cyanide of silver and potassium is prepared by dissolving an equivalent of silver cyanide (134 parts) in a solution containing an equivalent of cyanide of potassium (65 parts). The silver plating solution is made up with distilled water, the proportion by weight of silver per gallon of water varying from ½ ounce to 5 ounces or more.

The best nickel plating solution is that which is made up of the double sulphate of nickel and ammonium, in the proportion of 12 ounces to one pound of the double salt to each gallon of solution.. The crystals should be dissolved in boiling water in a wooden tub, frequently stirred and cold water added to make up the desired quantity. After the solution has become cool it should be filtered through a large volume, 1,000 gallons or more, held in large lead lined tanks.

Electro-plating with copper is employed chiefly to form a coating on iron, steel, tin, zinc, lead, britannia metal and pewter articles preparatory to silver plating the same, for the reason that silver will not adhere perfectly to those metals, while on the other hand, silver will adhere perfectly to copper and copper to the soft metals.

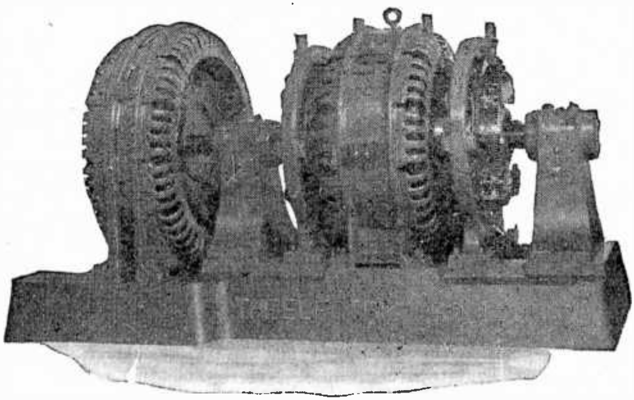


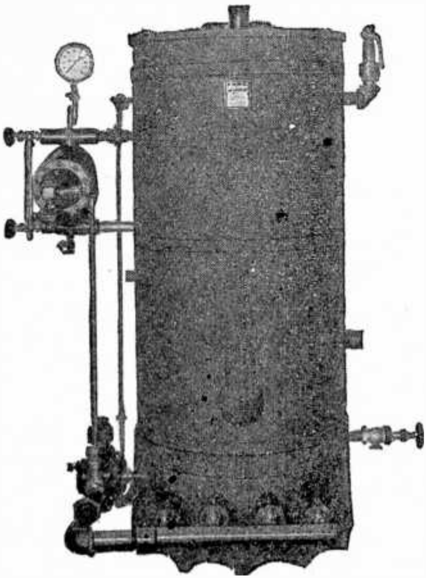
FIG. 8,247.—Electric Products 1500–3000 ampere, 6–12 volt double commutator type motor dynamo set. Dynamo is driven by synchronous motor.

The copper plating solutions employed for this purpose, and for electrotyping are acid solutions of copper sulphate.

An alkaline formula which yields a solution producing a fine grained deposit of copper is:

Water, 1 gal.; sodium cyanide, 3½ ozs.; copper cyanide, 3 ozs.; sodium carbonate, 2 ozs.; sodium hyposulphite, ¼ oz.

A very simple acid copper plating bath may be compounded as follows:



Water, 1 gal.; copper sulphate, 5 ozs.; sulphuric acid, 1 oz.

For brass plating a solution prepared as follows is excellent:

Water, 1 gal.; sodium cyanide, 9 ozs.; copper cyanide, 5 ozs.; zinc cyanide, 2 ozs.; sodium carbonate, 4 ozs.; ammonium chloride, ⅓ oz.

Brass may be colored with proper solutions. The following produces black:

Ammonia, 1 gal.; copper carbonate, 14 ozs.; sodium carbonate, 8 ozs

For brown color:

Water, 1 gal.; caustic soda, 3½ ozs.; antimony sulphide, ½ oz.

FIG. 8,248.—Reliance steam boiler. A boiler is necessary in large plating rooms where hot water is not available, or where close temperature regulation of hot solutions is desired. In general practice, one boiler *h.p.* will heat 25 gals. of water or its equivalent from 60° (boiling) Fahr. in one hour, to a temperature rise of 150°. Using this as a basis gives the following formula for determining the *h.p.* required for a given job:

$$\frac{\text{Temperature rise} \times \text{gallons of solution to be heated}}{25 \times 150 \times \text{time in hours}} = h.p.$$

Temperature rise in this formula is the difference between 60° Fahr. and the temperature to which solution is to be heated. Time in hours is the time allowed to bring the solution to the required temperature. It is usually not practical to figure more than 3 hrs. to heat a solution.

A good bronze plating solution may be prepared as follows:

Water, 1 gal.; sodium cyanide, 6 ozs.; sodium bisulphate, 2 ozs.; copper cyanide, 4 ozs.; tin chloride, ½ oz.

Plating solutions should be adapted to the particular object to be plated.

They are best made chemically but can be made by passing a current through a plate of the required metal into the solvent. Therefore, there are different anodes, so if the object is to be copper plated, a copper anode must be used.

Anodes for the respective solutions should be alloyed as follows:

Copper plate	99% copper	1% zinc
Bronze "	90% "	10% "
Brass "	80% "	20% "

Properties of Electro-Plating Elements.—The accompanying table* shows the elements used in electro-plating, arranged in accordance with their accepted standing in the voltage series.

Each element in this series is positive to the elements standing below it in the table, and negative to those coming before it. The difference in voltage is roughly indicated by the spacing between the elements under consideration.

For a minimum of electrolytic action, under conditions favorable to such action, only metals standing near together in the series should be placed in physical contact.

Reference to this table will indicate at a glance the advisable metal coatings from a permanent or protective standpoint.

*NOTE.—*In the table* is listed for convenience, chemical symbol, specific gravity, atomic weight, common valences, electro-chemical equivalent in grams per ampere per second and the ampere hours required to deposit one gram of these elements.

Cast Anodes Give Best Results.—As an example, a good solution for plating objects with copper, is made by dissolving in a gallon of water, 10 ozs. of potassium cyanide, 5 ozs. of copper carbonate, and 2 ozs. of potassium carbonate.

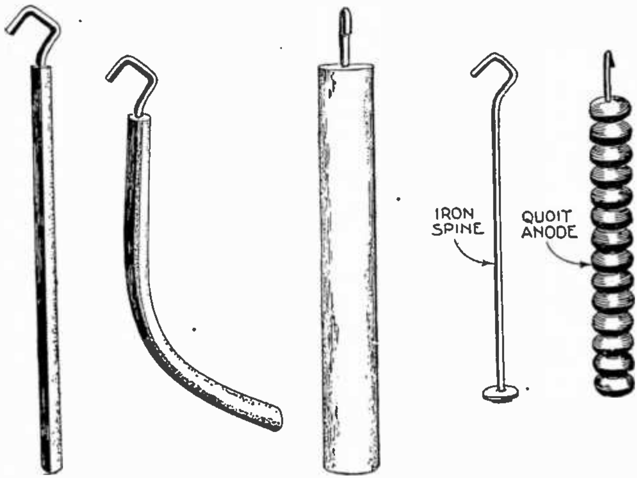
Properties of Electro-Plating Elements

Element	Symbol		Specific Gravity	Atomic Weight	Common Valences	Electro-Chemical Equivalent Grams Per Ampere Second	Ampere Hours Per Grams Deposited
Potassium		K.	0.870	39.10	1	.000406	0.685
Sodium		NA.	0.971	23.00	1	.000239	1.163
Barium		BA.	3.80	137.37	2	.000713	0.390
Calcium		CA.	1.54	40.07	2	.000208	1.338
Magnesium		MG.	1.74	24.32	2	.000126	2.202
Aluminum		AL.	2.70	27.1	3	.000094	2.969
Chromium	IC	CR.	6.92	52.0	3	.000180	1.544
	OUS	CR.	6.92	52.0	2	.000270	1.030
Manganese	IC	MN.	7.42	54.93	3	.000189	1.463
	OUS	MN.	7.42	54.93	2	.000284	0.975
Zinc		ZN.	7.00	65.37	2	.000339	0.820
Cadmium		CD.	8.65	112.4	2	.000582	0.477
Iron	IC	FE.	7.28	55.9	3	.000193	1.439
	OUS	FE.	7.28	55.9	2	.000289	0.196
Cobalt	IC	CO.	8.72	58.97	3	.000203	1.365
	OUS	CO.	8.72	58.97	2	.000305	0.909
Nickel	IC	NI.	8.80	58.68	3	.000202	1.371
	OUS	NI.	8.80	58.68	2	.000304	0.914
Tin	IC	SN.	7.30	118.7	4	.000308	0.901
	OUS	SN.	7.30	118.7	2	.000616	0.451
Lead	IC	PB.	11.4	207.2	4	.000535	0.518
	OUS	PB.	11.4	207.2	2	.001070	0.259
Hydrogen		H.	0.0695 Compared to air	1.008	1	.00001044	26 60
Antimony	IC	SB.	6.70	120.2	5	.000249	1 115
	OUS	SB.	6.70	120.2	3	.000415	0.669
Bismuth	IC	BI.	9.78	208.0	5	.000430	0.645
	OUS	BI.	9.78	208 0	3	.0007185	0.387
Arsenic	IC	AS.	5.73	74.96	5	.000155	1.790
	OUS	AS.	5.73	74.96	3	.000259	1.073
Copper	IC	CU.	8.90	63.57	2	.000329	0.843
	OUS	CU.	8.90	63.57	1	.000659	0.422
Mercury	IC	HG.	13.595	200.6	2	.001039	0.268
	OUS	HG.	13.595	200.6	1	.002079	0.134
Silver		AG.	10.5	107.88	1	.001118	0.249
Platinum	IC	PT.	21.37	94.8	4	.000505	0.550
	OUS	PT.	21.37	94.8	2	.001010	0.275
Gold	IC	AU.	19.3	197.2	3	000681	0.408
	OUS	AU.	19.3	197.2	1	.002040	0.136

Pickles and Dips.—While the best polish is secured by grinding and wheel polishing, many articles are best cleaned chemically by *immersing them in solutions which dissolve the scale, grease, etc., adhering to them, leaving a clean but rough surface which must be polished afterwards:*

Black Pickle for Iron.—Sulphuric acid 66° Baume, 1 part; water, 15 parts. Used chiefly for removing scale from castings and forgings.

Bright Pickle for Iron.—Water, 10 quarts; concentrated sulphuric acid, 28 ozs.; zinc, 2 ozs.; nitric acid, 12 ozs. Mix in the order named. The pickle leaves the metal bright.



Figs. 8,249 to 8,253.—Various types of anode. *Anodes serve two purposes*, 1, to electrify the solution; 2, maintain the metal content. The solution can be electrified by any anode which will conduct a current. In general practice this usually means an anode made from the metal to be deposited, such as, nickel, copper, brass, etc., although in some cases, as in chromium plating, an insoluble anode is used. As regards the second purpose, maintaining the metal content of the solution, it is important to note that in most plating operations it is far more expensive to add metal in the form of salts (sulphate, carbonate, cyanide, etc.) than to achieve the purpose by the corrosion of metallic anodes.

Dip for Copper, Brass, etc.—Sulphuric acid, 66° Baume, 50 parts by weight; nitric acid, 36° Baume, 100 parts by weight; common salt, 1 part by weight; lamp black, 1 part by weight.

Forgings, punchings, etc., are pickled in dilute sulphuric acid to remove scale, and then cleaned and brightened by dipping in the above solution.

Cyanide Dip for Brass.—Potassium cyanide in ten times its weight of water is used as a preliminary dip when plating articles that would have the polish injured by the acid dips. The work must be allowed to remain longer in this than in the acid solutions.

Pickle for German Silver.—German silver may be cleaned in the bright dip for brass, or in a preliminary pickle of dilute nitric acid and water (12 to 1), followed by a dip of equal parts of sulphuric and nitric acids, and then by rinsing in boiling water and drying in sawdust. Use sawdust that contains no tannin.

Tanks.—These vessels (sometimes called *vats*) are for holding the electrolyte or plating solution. There are four general types.

1. Wood;
2. Steel;
3. Cast iron;
4. Earthenware.

Wood tanks may be obtained either unlined, or with an asphaltum lining or lead lined.

Unlined wood tanks are used for cold rinses and sometimes for hot rinses.

Asphalt lined tanks are used principally for acid plating solutions, such as nickel, copper sulphate and zinc sulphate baths.

Lead lined wood tanks are used for the same type of solutions as the asphaltum lined tank and must be used where heated solutions are employed.

Steel tanks are recommended for all kinds of alkaline solutions, such as cadmium, brass, cyanide copper, etc., and for cleaning solutions and hot water rinses. Unlined tanks are used for such solutions.

For chromium plating solutions, lead lined steel tanks are used. Rubber lined steel tanks are now favored by many for nickel solutions, and for various acid dips where only earthenware was formerly considered suitable.

FIG. 8,254.—Reliance wood tank for holding plating solutions.

Cast iron tanks have to a large extent been superseded by steel, but are still used quite extensively with enamel linings in the jewelry trade as containers for silver and gold solutions.

Unlined, they are used for containing cleaning solutions and for water rinses.

Earthenware tanks can be used for all kinds of plating solutions and acid dips with the exception of solutions and dips containing hydrofluoric acid.

Being impervious to other acids, they are used extensively for pickling, metal etching and similar acid processes.

Rate of Deposit.—It has been found that *a current of one ampere will deposit* .017253 *grain, or* .001118 *gramme, of silver per second* on one of the plates of a silver voltameter, the liquid employed being a solution of silver nitrate containing from 15 to 20% of the salt. The rate of hydrogen similarly set free by a current of one ampere is .00001044 gramme per second.

Therefore, knowing the amount of hydrogen thus set free, and the chemical equivalents of the constituents of other substances, the weight of their elements that will be set free or deposited in a given time by a given current, can be calculated.

The rate of deposit is proportional to current.

However, since there is a certain amount of hydrogen liberated in the plating process, there is also a partial solution of the metal, so that there is always a deduction to be made from the theoretical value. Thus:

Gold	gives	about	80 to 90%
Nickel	"	"	80 to 95%
Silver	"	"	90 to 95%
Copper	"	"	98%

An ampere of current maintained for one hour, which serves as a unit of quantity called the "ampere hour" represents:

Gramme	.0376	Grain	.58
Ounce Troy	.00121	Ounce Avoirdupois	.00132

which multiplied by the chemical equivalent will furnish the weight of any substance deposited.

The rate of deposit should be varied to suit the nature and form of the surface of the object.

Large smooth surfaces take the greatest rate of deposit, while other more rough and irregular surfaces require a slower rate.

The length of time for plating depends on the current rate.

Upon this depends the rapidity of the ions being deposited on the objects to be plated, and the thickness of the particular plates desired.

Although the average materials are plated at from 6 to 12 volts the following table gives the voltage for various metals:

Copper in sulphate	1.5 to 2.5 volts
Copper in cyanide	4 " 6 "
Silver in cyanide	1 " 2 "
Gold in cyanide	.5 " 3 "
Nickel in sulphate	2.5 " 5.5 "

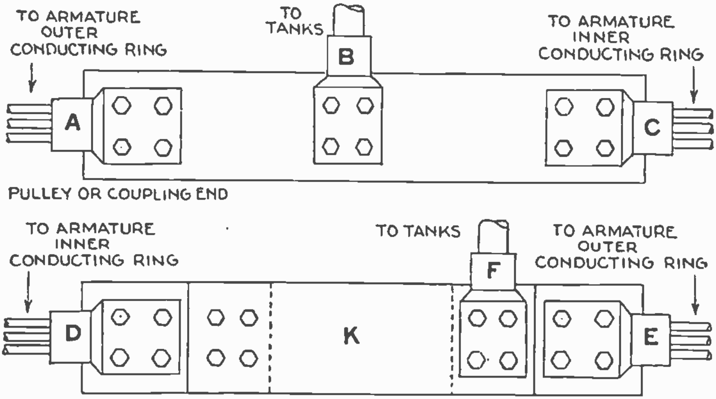
Amperes Required.—The amount of current required for plating articles of various materials are given in the table following:

Amperes required to plate one square foot.

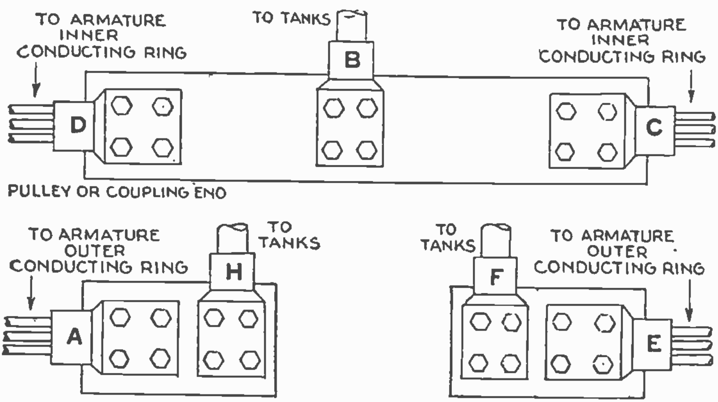
Solution of Metal.	Average amperes
Nickel	4
Brass	6 to 8
Bronze	6 to 8
Copper	6 to 8
Acid copper	10 to 12
Silver	2
Gold	1½
Zinc	10
Cadmium	6 to 8
Chromium	1 per sq. in.

Example. If the plater figure on plating with nickel, about 20 sq. ft. of surface, by referring to the table, it will be seen that each sq. ft. requires about four amperes, which would make it necessary to use approximately 80 amperes.

Again, to plate about 10 sq. ft. with copper, note each sq. ft. requires between six and eight amperes, which would mean about 70 additional amperes, or the total for the two would approximate 150. If this be the maximum output, a 150 ampere dynamo would be sufficient.



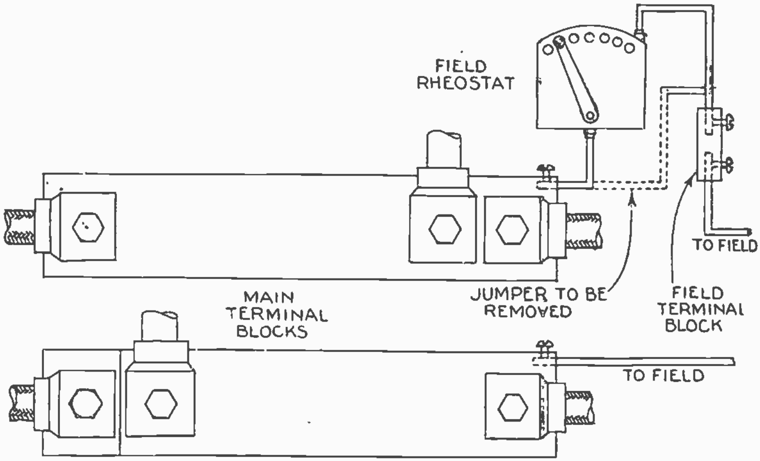
FIGS. 8,255 and 8,256.—Connecticut terminals connected for *two wire system*. The bar **K** connects the two short blocks. Also note that on the pulley end the cables from the upper block lead to the outer conducting ring, while on the end opposite the pulley it is the lower block that is connected to the outer conducting ring. The two lugs **B** and **F**, should be connected to the main conductors leading direct to the work.



FIGS. 8,257 to 8,259.—Connecticut terminals connected for *three wire system*. Note that the bar **K**, has been removed, also it will be seen that the cable lugs **A** and **D**, on the pulley end have been interchanged. That is the cable from the inner conducting ring is now connected to the upper block while the cable from the outer ring is connected to the lower block. The side from the pulley remains unchanged. A separate lug **H**, is now added and the three wires are thus obtained. Single voltage is obtained between lines **H** and **B**, and between **B** and **F**, while double voltage is obtained between lines **H** and **F**.

Electrolyte Required.—Ten gallons of solution to one sq. ft. of work surface are average figures for calculation. A gallon contains 231 cubic ins.

Dynamo Connections.—If possible the dynamo should be installed in a clean, light place, where it will be easily accessible for inspection and care. It should be located as near the plating tanks as other conditions in the plant will permit.



FIGS. 8,260 and 8,261.—Connecticut self-excited dynamo field connections. When the machine is shipped from the factory a short jumper connects the small terminal block to the main block to complete the field circuit. In installing the dynamo this jumper should be removed and the field rheostat connected between the points from which the jumper was removed, using two separate wires for the purpose.

Dynamos of 200 amperes and less are not usually equipped with field rheostats. These have the fields excited direct from the main terminal blocks.

Dynamos of sizes 300 to 1,500 amperes inclusive are regularly made self excited and are equipped with field rheostats. One side of the field winding is connected to the main terminal block and the other side is connected to a small terminal block on the side of the frame. Fig. 8,260 shows field rheostat connection

The accompanying illustrations show connections for Connecticut dynamos and illustrate in general the method of connecting dynamos.

Line Connections.—In general the line connections should be made as here directed.

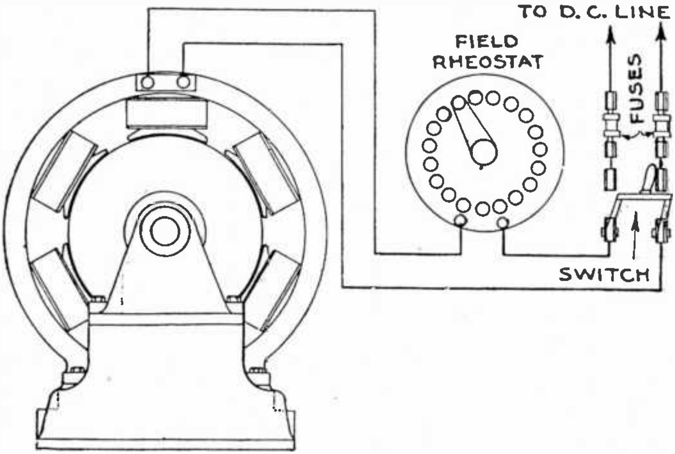


FIG. 8,262.—Connecticut separately excited dynamo. In this machine the field is excited from a separate source of *d.c.* of the same voltage as that stamped on the name plate following the word excitation. A separately excited machine is always supplied with a field rheostat and the connections should be made as here shown. By the use of the field rheostat the voltage can be lowered to a small value with stability.

Two wire connection.—For electro-plating or electro-typing, bus bars should be run from the dynamo terminal block and connected by branch conductors to the tanks. Make sure that one bus bar is connected to all the anode rods and the other to all the cathode (work) rods, through a tank rheostat if desired, as shown in fig. 8,263.

Three wire connection.—A three wire system should be connected as shown in fig. 8,264. The tanks should be divided so that approximately the same number of amperes are taken from the two upper bars as from the two lower bars.

Plating barrels and other tanks requiring a high voltage should be connected to the upper and lower bus bars. When possible, the dynamo should be located near the center of distribution and bus bars run each way.

Polarity.—If it be found that, after all the connections are made and the dynamo started, that the polarity is wrong; that

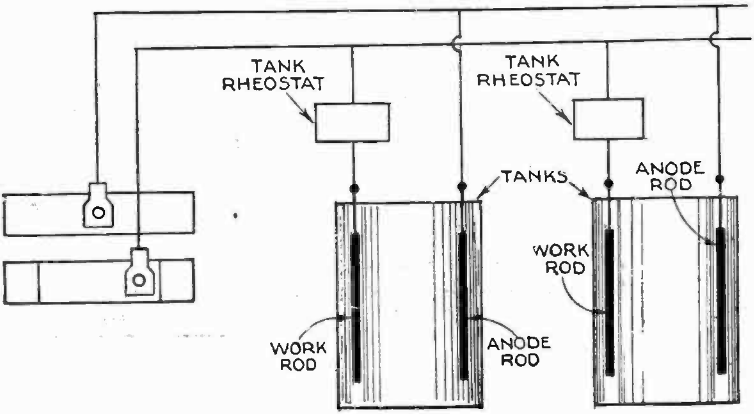


FIG. 8,263.—*Two wire* line connections.

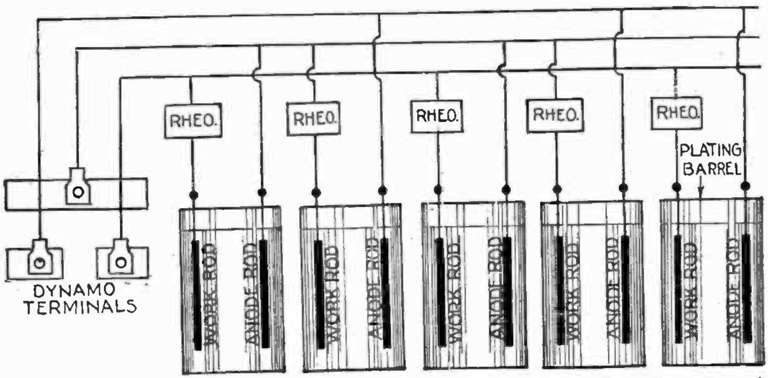


FIG. 8,264.—*Three wire* line connections for tanks requiring low voltage. The voltage in this system is one half that of the two wire system shown in fig. 8,263.

is, the positive appears on the bus bar connected to the work, which would strip the work instead of plating it, it is not necessary to change any of the main connections, but the polarity can be reversed as follows:

Self excited dynamos.—Remove one of the field leads from the main terminal block. Connect together two to six dry cells according to the size of the dynamo and touch the battery leads to the field leads of the dynamo for a few seconds.

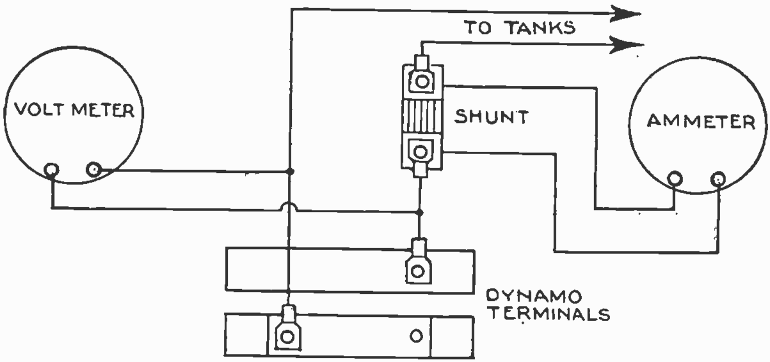


FIG. 8,265.—Volt meter and ammeter connections for *two wire* system.

Notice to which field lead the carbon pole of the battery is connected, reconnect the field lead to the dynamo and try polarity. If it be still wrong try again connecting the carbon pole of the battery to the other field lead. Upon replacing the field lead it will be found that the polarity has been reversed.

Separately excited dynamos.—To reverse polarity it is only necessary to interchange the two exciting wires connected to the small field block at the top of the dynamo.

Main Conductors.—The proper size of conductors between the dynamo and the tanks is of great importance. Trouble will be experienced if these do not have sufficient current carrying capacity.

The proper size depends not only upon the number of amperes, but upon the distance between the dynamo and the tanks. The conductors should be solid copper bar, either round or rectangular, and nothing else should be used under any circumstances.

Round bars are usually the easiest to install if smaller than 1½ in. in diameter. If larger than 1½ in., round bars are not only difficult to handle, but are not as readily secured.

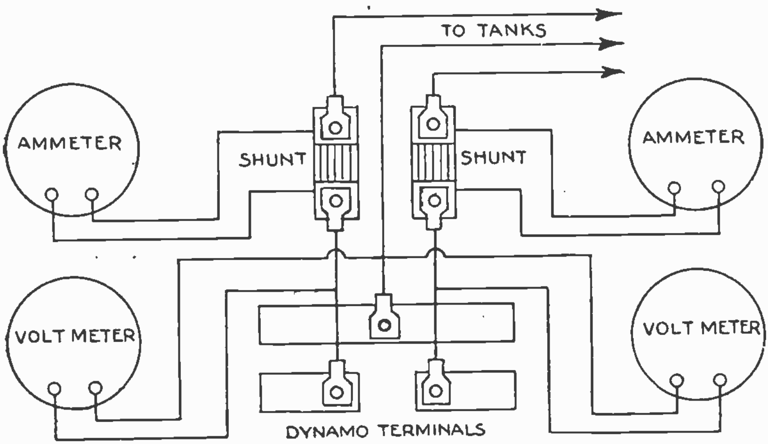


FIG. 8,266.—Volt meter and ammeter connections for *three wire* system.

The following table shows the proper size of conductors for the different size dynamos and distances between dynamo and tank.

The sizes of bars are shown in both round and flat. If flat bars be used, they need not be of the exact dimensions given, but should be of equal or greater cross section.

NOTE.—***Cadmium plating*** is the most effective means of preventing rust, having several times the resistance to corrosion that zinc, copper or nickel has. It is soft and can be easily and quickly plated, only a thin coat being required. The solution is very simple and can be kept in proper working order without difficulty.

Size of Main Conductors.

Dynamo Amperes	5 to 20 Feet		20 to 35 Feet		35 to 50 Feet		50 to 65 Feet	
	Round Bars	Flat Bars	Round Bars	Flat Bars	Round Bars	Flat Bars	Round Bars	Flat Bars
100	5/16	....	⅜	....	7/16	....	½	....
200	½	....	9/16	....	⅝	....	¾	....
300	9/16	....	11/16	....	¾	....	1	1⅝ x ½
500	¾	....	⅞	....	1	1⅝ x ½	1⅛	2 x ½
750	⅞	....	1⅛	2 x ½	1 3/16	2¼ x ½	1⅜	3 x ½
1,000	1	1⅝ x ½	1¼	2½ x ½	1⅜	3 x ½	1½	3½ x ½
1,500	1¼	2½ x ½	1½	3½ x ½	1¾	4 x ⅝	1⅞	3¾ x ¾
2,000	1½	3½ x ½	1¾	4 x ⅝	2	4¼ x ¾	2⅛	4 x ⅞
2,500	1 9/16	3 x ⅝	1⅞	3¾ x ¾	2 3/16	5 x ¾	2⅜	4½ x 1
3,000	1¾	4 x ⅝	2⅛	4 x ⅞	2⅜	4½ x 1	2⅝	4⅜ x 1¼
4,000	2	4¼ x ¾	2½	5 x 1	2¾	4¾ x 1¼	3	4¾ x 1½
5,000	2¼	4½ x ⅞	2¾	4¾ x 1¼	......	5¼ x 1¾	3¾	5½ x 2
7,500	2¾	4¾ x 1¼	...	5½ x 1¾	.....	5½ x 2	4¼	7 x 2

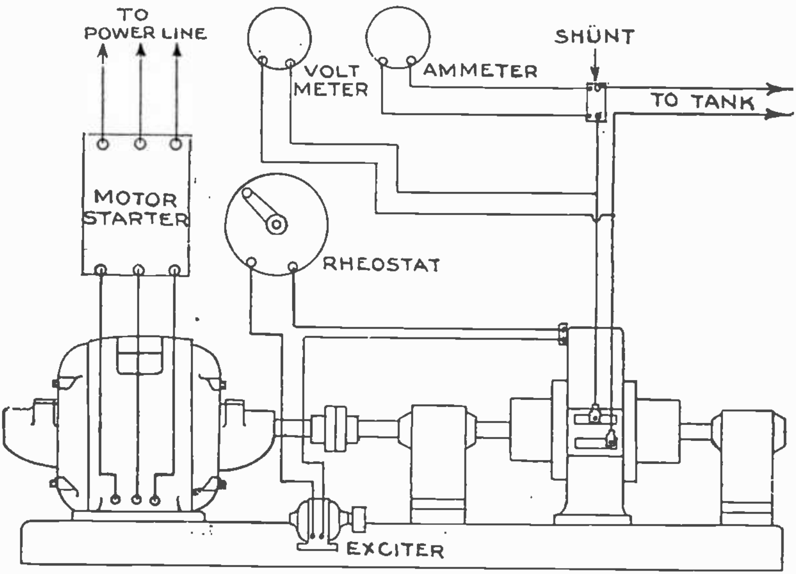


FIG. 8,267.—Method of connecting a motor dynamo set, consisting of a *separately excited* dynamo with separate exciter and *a.c.* motor.

Volt Meter and Ammeter.—One volt meter and one ammeter should be used in connection with every two wire dynamo and two volt meters and two ammeters with every three wire dynamo, the connections are as shown in figs. 8,265 and 8,266.

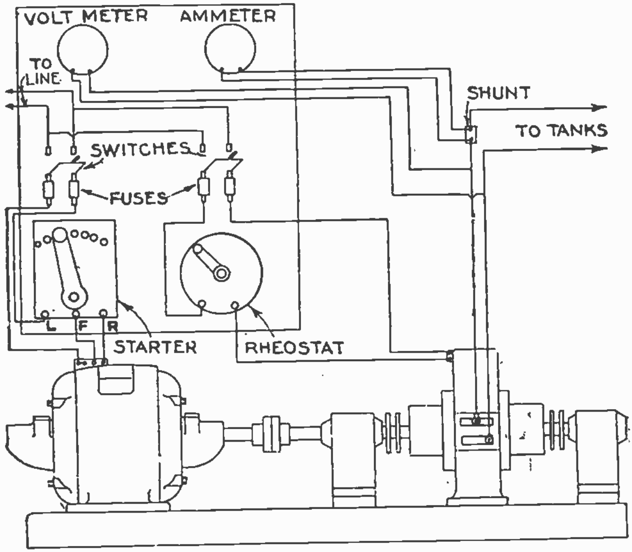


FIG. 8,268.—Method of connecting motor dynamo set, consisting of a ***separately excited*** dynamo and *d.c.* motor.

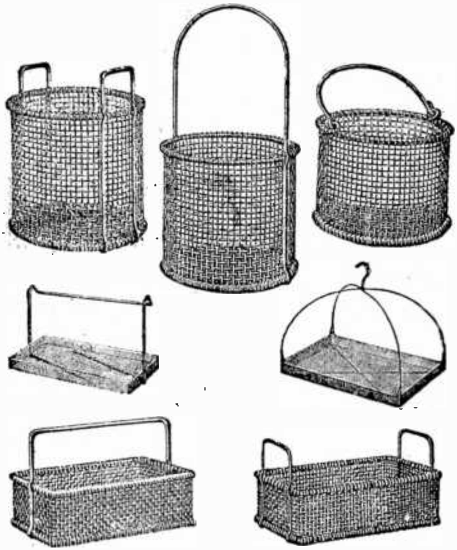
Motor Dynamo Connections.—It is very convenient especially in small plants to drive the dynamo by a direct connected motor, thus saving space required by belt and steam or gas engine, as well as the attention required to operate same.

Figs. 8,267 and 8,268 show connections for motor dynamo sets.

Dipping Vessels.—These are employed for holding the articles and dipping them into the various solutions used in cleaning the articles preparatory to the plating.

All dipping vessels used in acid solutions should be made of vitrified or glazed stoneware or glass.

Wire dipping baskets are fast superseding the earthenware type for plating room use. These baskets are light and, therefore, easy to handle. They are strong and durable, thus eliminating frequent and troublesome replacements. They drain quickly and completely, saving time and acid.



FIGS. 8,269 to 8,275.—Various dipping baskets.

Wire baskets are made of steel, brass, copper, aluminum, monel metal, and nickel chromium. The metal to be used is determined by the cleaning and pickling cycle.

As a guide to selection, the actions of various acids and alkalis on the several metals used for baskets are here given.

Steel.—Suitable for use in all alkali solutions, attacked by sulphuric, muriatic, and nitric acids.

Brass.—Suitable for use in alkali solutions except cyanide, but lacks the strength of steel, not attacked by hydrofluoric acid and can also be used in dilute solutions of sulphuric or muriatic acid. Attacked by hot concentrated sulphuric or muriatic acids and by nitric in any concentration.

Aluminum.—Nitric and sulphuric acids act very slowly on aluminum. Attacked by all alkalis and by muriatic and hydrofluoric acids in any concentration. Excellent for bright dipping.

Monel Metal.—This is a natural alloy of nickel and copper. It is not attacked to any appreciable extent by alkalis and is resistant to all the common acids except nitric, for which it is entirely unsuitable. Monel has the added advantage of great strength.

Nickel Chromium.—This alloy is used principally in cycles embodying both an alkali process and a bright dip containing nitric acid. It is not attacked by alkalis and is resistant to all the common acids. Has exceptional strength and is not affected by ordinary high heat.

Where the word "resistant" is used in referring to monel and nickel chromium, this does not mean that these metals are not attacked but that the action is comparatively slow.

NOTE.—*Tripoli composition.* Tripoli is the most widely used of all cutting compositions. It is used on brass, copper, aluminum, zinc, silver, gold, platinum, nickel-silver and, to some extent, on nickel and steel. It is also used extensively on celluloid, bone, pearl, wood, ivory, rubber and moulded products.

NOTE.—*White finish.*—This is a lime finish; a standard coloring composition for producing the highest lustre on nickel, copper, brass and other metals; also on celluloid, pyralin, bakelite and other moulded products.

NOTE.—*Bobbing composition.*—For brush wheel work, wood lapping, on flat surfaces and for cutting down with small diameter buffs where the peripheral or surface speed is necessarily low. Bobbing composition is economical and efficient. It clings tenaciously to the brush, lap or buff and cuts rapidly. It is used extensively by manufacturing jewelers, silversmiths and novelty manufacturers. Due to the fact that it cuts sharply and rapidly at low speeds, it is also being used to advantage by manufacturers of fountain pen barrels and other small rubber goods. Unexcelled for cutting down celluloid.

NOTE.—*Chromium coloring composition.*—The coloring of chromium offers a distinct problem. Chromium is extremely hard and the plated finish may be rough and frosted. Chromium rouge is designed to cut rapidly, to smooth up the rough frosted surface and, at the same time, to bring up the desirable high lustre. On bright chromium plate a mere wiping or fanning operation with chromium rouge is sufficient to produce a mirror finish.

Although the first cost of baskets made from these alloys is necessarily high as compared with baskets made from the common metals, they invariably prove more economical. This is particularly true where the baskets are carried through a cycle embodying both alkalis and acids.

Scouring, Swilling and Rinsing Troughs.—These are usually made of wood, lined with lead and divided in the middle by a partition, one part being used for scouring and the other

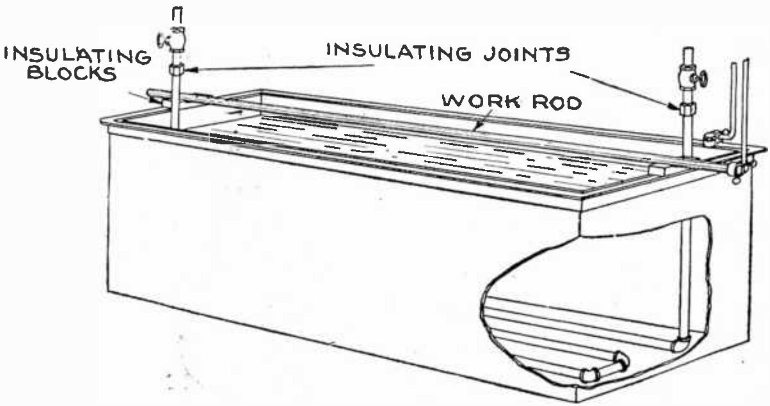


FIG. 8,276.—Cleaning tank. Typical installation of steam heating coils for heating plating solutions and cleaners. Approximate length of pipe needed for each 10 gals. of solution: ¾ stranded pipe, 4 lineal ft.; 1 in. stranded pipe, 3 lineal ft.; 1¼ in. stranded pipe, 2½ lineal ft.; 1½ in. stranded pipe, 2 lineal ft.

NOTE.—***Hard rouge for coloring gold, silver, platinum, nickel and brass.***—This is used principally for producing the final high color or lustre on gold and silver. Rouge differs from all other buffing compositions in that it works by burnishing or flowing the metal instead of by abrasion.

NOTE.—***Stainless steel rouge.***—To secure a mirror finish on stainless steel articles requires the use of a green rouge on a buff or felt wheel.

NOTE.—***Polishing tallow.***—The principal use of this material is as a lubricant on polishing wheels which are set up with emery or other abrasives, to prevent burning or glazing and for grease wheel work. It is also used for die lubrication, drawing, etc.

NOTE.—***Emery paste.***—This is used as a lubricant on emery coated wheels and as a brush composition on circular tampico brushes. The grease binder is properly proportioned to prevent crumbling and to provide ample lubrication.

for holding clean water for rinsing the articles after they have been scoured clean.

Tumbling or Rattling Barrels.—Small objects, such as small castings, stampings, etc., that are not required to have square edges, are best cleaned by tumbling, or rattling, as it is called in foundries.

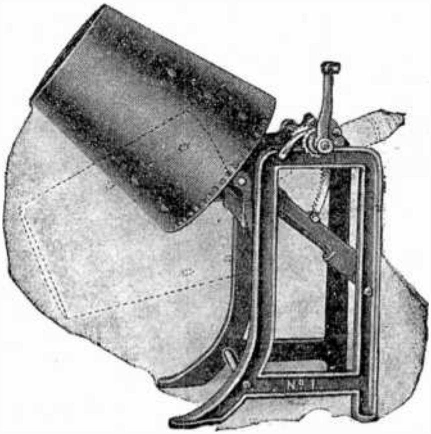


FIG. 8,277.—Hanson-Munning *tilting* tumbling barrel. Almost any work which is being barrel plated can be polished and burnished in barrels. The finish obtained through this medium compares favorably with hand finished work.

Large quantities of work are thus easily and cheaply cleaned without much manual labor, which is the expensive item in polishing. If rough castings are being worked, the sand, scale, etc., adhering to them are allowed to remain in the barrel, where it acts as a polishing powder, brightening the parts which are not reached by the metal of other castings; but when tumbling for a bright finish, the sand, dirt, etc., are exhausted by means of the blower, so that the surfaces are finely polished by friction only—burnished, as it were, by rubbing against other metal of the same kind.

A strong exhaust should be kept up when polishing in this way or the finish will be dead instead of bright.

Bright work can only be obtained by long continued tumbling, and the bright finish comes rather quickly after all the pieces in the barrel become smooth; accordingly, it is necessary not to add any pieces once the barrel is charged, or the work will not finish evenly.

Ball Burnishing Barrels.—This machine is used for producing a final color finish on metal and other parts after they have been properly surfaced in an oblique or horizontal tumbling barrel. It is also used for finishing after plating.

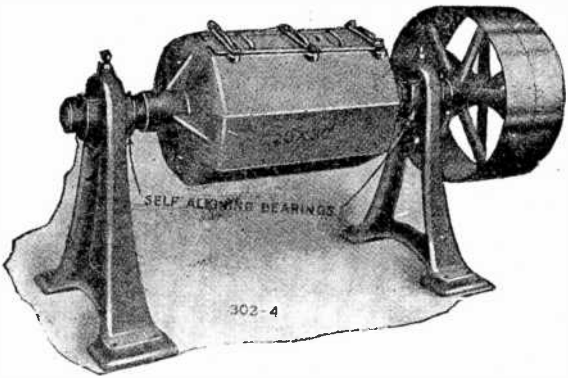


FIG. 8,278.—Hanson-Munning *horizontal* tumbling barrel. This type of barrel is to be preferred for large or long articles. The roll is nearer even and results nearer uniform. The horizontal barrel also has a larger capacity. The principal use of the horizontal type of barrel is for what the trade terms "rough work," such as grinding or smoothing up.

The barrel is of comparatively small diameter, but of greater proportionate length. Its shape is calculated to give an efficient pressure without having the weight distort the work to be burnished. There is no falling, tumbling or bumping because the barrel is full. The action is one of continuous burnishing.

All barrels are lined with hard wood. Steel balls, pebs, cones, etc., provide the burnishing medium and these occupy from one third to one half of the barrel capacity.

Burnishing Before Plating.—Small parts are taken direct from the stamping room, placed in a horizontal rotating barrel,

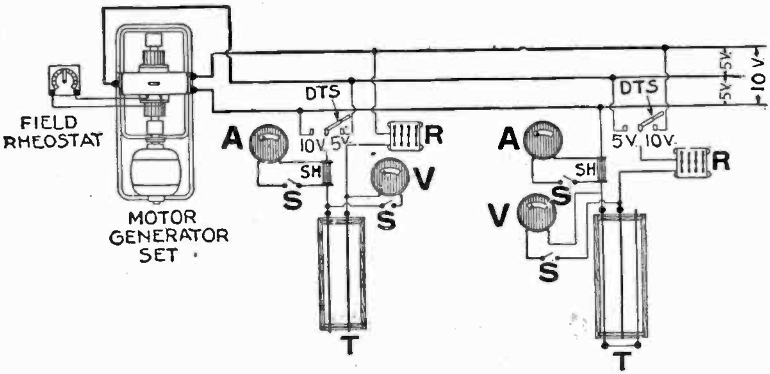


FIG. 8,279.—Diagram of three wire system with double throw tank switches for 5 or 10 volts. A, ammeter; V, volt meter; SH, ammeter shunt; R, tank rheostat; S, single pole switch; DTS, single pole double throw switch; T, plating tanks.

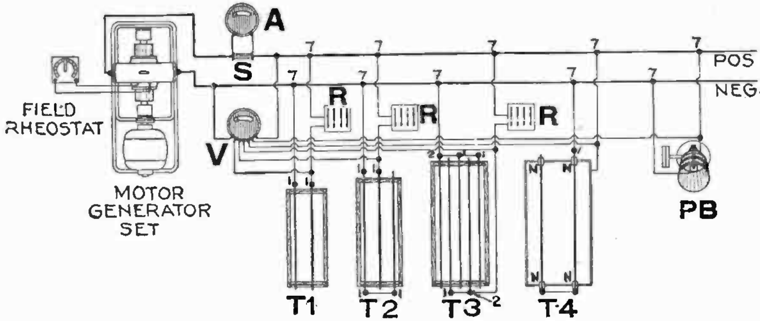


FIG. 8,280.—Diagram of two wire system showing method of connecting dynamo, tanks, plating barrel, volt meter, ammeter and rheostat. A, ammeter; V, volt meter; S, ammeter shunt; R, tank rheostat; T-1, two rod tank, one row work; T-2, three rod tank, one row work; T-3, five rod tank, two row work; T-4, electric cleaner, steel tank; PB, reliance plating barrel; N, insulator; 1, No. 1 brass connections; 2, No. 2 brass connections; 7, No. 7 brass connections.

rotated at 30 *r.p.m.* being careful to use enough sawdust as a medium to clean and prevent scratching the parts.

The barrel is allowed to rotate until the parts are clean. Time required depends on the character of the parts, and the condition the parts were in when placed in the barrel.

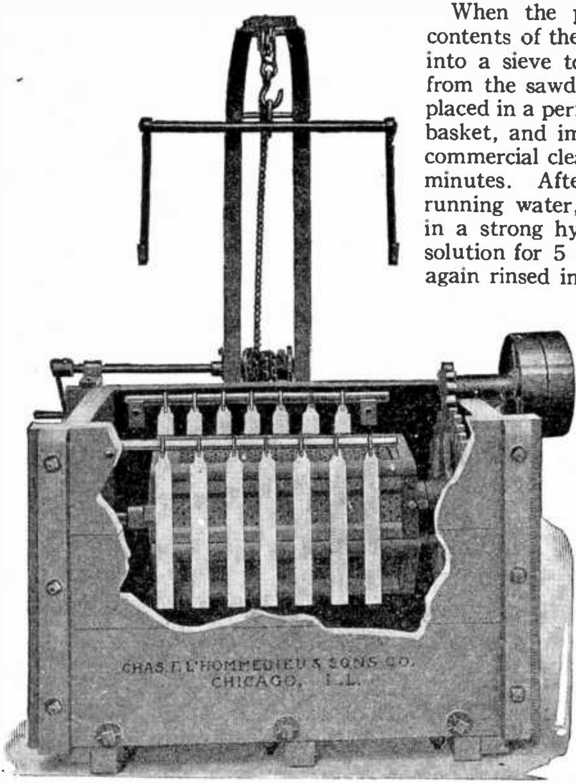


FIG. 8,281.—Reliance ***horizontal barrel*** showing anodes, drive gear, crane, etc. Almost ⅜ of the cylinder is immersed in the electrolyte. When the crane is used the barrel can be loaded while suspended above tank and then lowered by turning crank after barrel is in position. The lifting hooks are then raised and left in this position until another batch of work is plated. After the work is plated the tray which is furnished can be laid across the top of the tank so that the work can be dumped into it directly from the cylinder.

When the parts are clean the contents of the barrel are dumped into a sieve to separate the parts from the sawdust. Then they are placed in a perforated metal or wire basket, and immersed in a boiling commercial cleaning solution for 15 minutes. After rinsing with cold running water, they are immersed in a strong hydrochloric acid dip solution for 5 or 10 minutes and again rinsed in cold running water to make sure that all trace of acid is removed.

Next the contents of the basket are placed in the burnishing barrel. Parts and balls should come to within 4 to 6 ins. of the top of the barrel, depending on the character of the parts. About 200 lbs. of balls are used in a barrel 2 ft. deep by 11 in. in diameter. One half gallon of soft soap is then added, the barrel is filled with cold water, the lid is clamped on and the barrel is swung into position and rotated for 1½ to 1¾ hours.

The soap used as a medium is of the utmost importance. There are many satisfactory soaps available for the purpose.

After the burnishing barrel has rotated the proper length of time, the contents are emptied into a sieve where the balls and parts are separated. Again the parts are put into baskets, rinsed in cold running waer, then dried in sawdust and stored in a dry place if they cannot be plated immediately.

If they are to be plated immediately, the baskets with their contents are placed in a cleaning solution for 15 minutes and prepared for plating in the usual manner.

Burnishing After Plating.—After nickel plating, the parts are again put into wire mesh baskets and immersed in a storage tank containing a soap solution.

This protects the parts from staining and also neutralizes any trace of acid that may be present. The parts are then put into the burnishing barrel, balls, soap and water being added as for burnishing before plating, and the barrel rotated for from 40 minutes to one hour depending on the character of the parts and the nickel deposited.

They are then removed from the barrel, separated from the balls, rinsed in cold running water and dried in sawdust.

Polishing and Grinding Machines.—These machines, or heads consist of a stand carrying a small pulley between two bearings with shaft extended at each end to take the various buffing, polishing and grinding wheels, brushes, etc.

Polishing Wheels.—These are made of canvas, wood, felt, leather, and walrus hide. Rough heavy castings are first ground upon coarse solid emery or carborundum wheels, usually run at a slow speed, not exceeding 1,000 revolutions per minute.

Canvas wheels are used for roughing out. Felt wheels can be used for roughing, grinding, polishing and finishing. Walrine wheels are used chiefly in giving a fine polish to silverware, brass goods, etc. They can be used with crocus, emery, rouge, or rotten stone, and give a smooth fine finish to the work.

Much of the work connected with the preparation of surfaces of automobile bodies, hoods and fenders, metal furniture, metal doors and various other metal parts, which was formerly done by hand, is now accomplished mechanically by the use of various types of portable equipment.

Polishing and buffing lathes for hand and automatic operation, which have reached a high degree of perfection, are now made in many different styles and sizes. Likewise, highly satisfactory polishing and buffing compounds and wheels have been developed for practically every requirement.

To facilitate easy and rapid removal of metal from curved as well as flat surfaces, various kinds of coated abrasive discs mounted on cone shaped sanders have been developed.

For the polishing of such surfaces special circular and disc type buffs and suitable polishing compounds have also been worked out, so that this work can now be accomplished more quickly and economically than formerly and with less effort on the part of the operator.

The wheels to be used in polishing and buffing will depend partly upon the speeds used, the condition of the material and the kind of finish desired.

The lathe speeds in some shops will vary considerably from the lathe speeds in others. The materials to be finished do not always come to the polisher in the same condition.

The following are recommended by L'Hommedieu for average conditions:

Iron, steel and brass castings.—Reliance canvas wheels for flat surfaces; Rex cloth wheels for curved or irregular surfaces. Finish with Chicago wheels, walrus, bullneck, or felt wheels. Cut down with No. 201 buffs; color with No. 50 buffs.

Aluminum castings.—Rough out with Rex cloth wheels; finish with sheepskin wheels. Cut down with No. 201 buffs; color with No. 50 buffs.

Die castings.—Rex cloth wheels on all polishing operations. Cut down with No. 201 or 203 buffs; color with No. 50 buffs.

Brass stampings.—Cut down with No. 203 buffs; color with No. 50 buffs. If necessary, polish with Reliance canvas wheel on first operation.

Aluminum stampings.—Cut down with No. 201 or No. 401 buffs; color with No. 50 buffs.

White metal stampings.—Polish with sheepskin wheel. Cut down with No. 201 or 401 buffs; color with No. 50 buffs.

Nickel, copper and cadmium plate.—Color with No. 50 buffs.

Chromium, monel metal and stainless steel.—Color with No. 201 buffs.

Solid silver and gold.—Color with brown or white sheepskin discs or walrus wheel.

Silver and gold plate.—Cut down with No. 50 buffs; color with loose flannel buffs.

Hard rubber, bakelite and similar material.—Cut down with No. 401 buffs; color with No. 50 buffs.

Celluloid.—Color with No. 50 buffs.

Pewter.—Color with No. 50 buffs.

Nickel Plating.—Nickel does not adhere very well to iron or steel articles, and furthermore, if after being plated upon steel, the article becomes scratched, the steel rusts, and the rust, getting beneath the nickel film, causes it to peel off.

It is, therefore, very usual to first coat the iron with a film of copper, which, being a soft metal, is not readily removed by scratching. The nickel is then deposited upon the copper coating.

Nickel cannot be deposited from solutions containing more than a trace of acid; most nickel plating solutions consist of a solution of the double salt of ammonium sulphate and nickel sulphate, which is rendered alkaline with ammonia.

In order to obtain a thoroughly satisfactory and brilliant deposit of nickel, the articles which are to be plated must be very carefully prepared, and should have a burnished surface.

Cleaning.—The articles should be first strung upon copper wire of suitable dimension to prevent thin flat pieces of steel clinging too closely together.

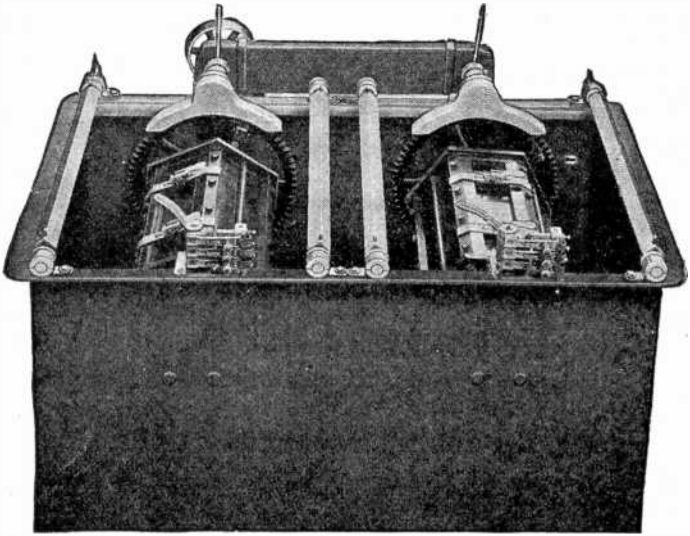


FIG. 8,282.—Hanson-Munning plating barrel. Electro-plating small metal parts in bulk eliminates racking, wiring and individual handling of pieces and thereby saves time and labor. Suitable for nickel, silver, copper, brass, cadmium, zinc, tin and lead. The type of cylinder and tank is determined by the solution to be used and the size and type of work to be plated.

Small glass buttons or small metal separators may be used between each piece strung upon the wire. A great many pieces can then be copperized at one time.

The articles so arranged are then ready for immersion in the cleaning bath of the following composition:

Water, 1 gal.; caustic potash, 4 ozs.; trisodium phosphate, 2 ozs.

Any good commercial metal cleaner may be used instead of the above in the same weight proportion. The cleaner should be heated to 200° Fahr. in iron kettles with steam coils made from steel or by external heat using gas, etc. An immersion in the heated cleaner for five minutes removes any grease or oils upon the metal.

The articles are then removed from the cleaner and washed in clean cold running water.

Acid Cleaning.—The previously cleaned parts should next be immersed for 10 to 30 seconds in an acid cleaner of the following composition:

Water, 1 gal.; muriatic acid, 1 gal.

This treatment removes any oxide or rust adhering to the surface. The articles should then be washed in cold running water after which they are ready for immersion in the copper plating or copperized solution.

Copper Plating Iron and Steel.—To deposit copper upon steel or iron articles by immersion in solutions composed of water, sulphuric acid and copper sulphate or copper carbonate, it is necessary that the steel or iron surface be chemically clean and free from rust or oxidation if adherent uniform coatings of copper are to be the final result.

The formula for the copper carbonate plating solution is as follows:

Water	1 gal.
Sulphuric acid	8 fluid ozs.
Dry copper carbonate	4 ozs.

The copper carbonate should be added to the acid solution very slowly to avoid an excess of carbonic acid gas evolution. The solution is stirred thoroughly afterwards.

Water	1 gal.
Sulphuric acid 60°	1½ oz.
Copper sulphate	1 oz.

No precautions are necessary in mixing the copper sulphate solution.

The steel or iron articles after cleaning should next be immersed for a few seconds in either of the copper solutions recommended until a uniform, clean copper deposit results.

The articles are now removed immediately, thoroughly washed in cold water and then in the following soap solution:

Water	1 gal.
Neutral soap chips	1 oz.

The soap chips are dissolved in a small amount of hot water before adding the balance of the cold water to make up the volume. The solution is used cold. The articles are immersed in the soap solution for a few seconds, then in boiling water for a second or two, drained thoroughly and dried by heat or preferably in hard maple wood sawdust.

If it be desired to protect the articles from atmospheric oxidation they should be finally lacquered by the aid of a water dip lacquer. They should then be dried by heat to harden the lacquer.

The copper carbonate solution should be preferably used although the copper sulphate solution is cheaper and can be discarded more frequently and replaced with new solution.

Silvering Glass Mirrors.—The glass must be perfectly clean prior to silvering. Old silver should be removed by immersing the glass in nitric acid and water, 2 parts nitric to 1 part water.

Silvering Stock Solution

Pure silver nitrate crystals	3 ozs.
Distilled water	20 ozs.
Aqua ammonia	2 ozs.

The silver nitrate is dissolved in part of water heated to 120° Fahr. then the balance of the water and the ammonia are added. Any undissolved material is then removed.

Reducing Solution

Distilled water	5 ozs.
Tartaric acid crystals	1 oz.

Silvering Solution

Stock solution	1½ ozs.
Distilled water	16 ozs.
Reducing solution	⅛ oz.

Sensitizing Solution

Distilled water	10 ozs.
Stannous chloride	⅛ oz.

Gold Plating.—Maintain the plating solution at 125° Fahr. In plating a faint film of gold is first deposited and the article lightly scratch brushed, to lay down the grain.

The work is then thoroughly washed in hot water, dipped in cold water and immersed again in the plating solution for the final coating. It is a good plan to keep the work in motion by swinging it slightly on its slinging wire.

Regarding the color of the deposit, gold is sensitive to changes in the current density, the temperature of the bath and the composition of the plating solution. Many beautiful tints, such as rose, red, green and the like may be secured by using special solutions.

Galvanizing.—A bath containing zinc sulphate, which must only be slightly acid, is employed; as the electrolysis proceeds the solution becomes acid by the zinc being deposited out, and in order to keep the strength of the solution constant, it is circulated through a filter bed containing zinc dust.

NOTE.—*Crown galvanizing salts.* These are a prepared zinc sulphate base salt which has been popular for many years. With the proper proportions of No. 1 and No. 2 zinc toning salts, crown makes a solution which will produce a rapid, frosty white deposit good for general purposes. 2½ lbs. are required to the gallon.

NOTE.—*No. 1 zinc toning salt.* This salt when added to a crown galvanizing solution eliminates treeing and produces a smooth deposit. 1 oz. per gal. should be added when making up a new solution of crown galvanizing salts, and small additions made from time to time as roughness is noted in the deposit.

NOTE.—*No. 2 zinc toning salt.* This salt is used to increase the conductivity of acid zinc solutions. Its regular use results in clean anodes and heavy deposits. 2 ozs. per gal. should be added to new solutions made from crown galvanizing salts and further additions made to the solution from time to time as fouling of the anodes is noted.

Zinc anodes are not generally used because they are apt to disintegrate; the anodes usually employed are of lead, but iron is sometimes used. In fact, the presence of a trace of iron in the bath improves the deposit.

Electrotyping.—In preparing electrotypes *a wax impression is taken of the form, which is made up usually of type, or illustrations, or both.*

In order to do this a metal plate is evenly coated with a wax composition, and this is placed with the wax face downward upon the form. The form with the wax upon it is then placed in a hydraulic press and subjected to a steady pressure of about two tons to the square inch. To prevent the type adhering to the wax, it is dusted over with finely powdered graphite. After being taken out of the press, the wax is carefully removed from the form. The mould is next coated with black lead to give it a metallic surface, as the wax is a non-conductor; the mould is then subjected to the process of electro-deposition, resulting in the formation of a film of copper on the prepared surface.

A battery or dynamo is used to generate the current. The positive terminal of the source of current is connected to a rod extending across a trough or tank containing the plating bath. Suspended from the rod are anodes of copper, from which a deposit is desired. The other terminal of the source is connected with another rod across the trough, to which are suspended the articles to be plated.

The copper shell is removed from the mould by applying hot water; the shell is then backed up with electrotype metal to render it strong enough for use.

Chromium Plating

Chromium Plating.—Electro-plating in general is accomplished by passing an electric current from one electrode to another through a bath containing in solution the metal which it is desired to deposit.

For example, in nickel plating, a nickel rod is used as the positive electrode, while the object to be plated becomes the negative electrode. These two poles are immersed in a bath of nickel sulphate or other suitable salt of nickel and an electric current is passed through the solution.

The current causes the nickel rod to dissolve gradually and replenish the bath from which nickel is simultaneously being deposited upon the surface to be plated.

In this manner a cycle is set up; nickel rods, called anodes and current are constantly supplied to the process, and in return nickel is obtained as a coating upon the objects hung in the bath.

Anodes.—In most plating processes new metal is supplied to the bath in the form of anodes which dissolve in the plating solution at approximately the same speed as that at which metal is being deposited from the solution.

There are only two well known exceptions to this procedure, which are found in the electro-deposition of platinum and in that of chromium. Here, insoluble anodes are made use of, and the bath is replenished by means of metallic salts.

There are important objections to the use of soluble anodes in chromic-acid baths, it having been found that the current efficiency of chromium and ferro-chromium anodes is much greater than the cathode current efficiency.

This means that during electrolysis chromium goes into solution at a more rapid rate than that at which metal is depositing out from the solution. Hence the concentration of chromium, especially the trivalent chromium, builds up rapidly and the bath becomes inoperable.

Only in solutions of divalent and trivalent salts of chromium have chromium anodes been found entirely satisfactory.

In order to avoid the difficulty encountered with soluble anodes an ingenious (patented) process was developed for using insoluble anodes of lead in conjunction with auxiliary soluble anodes of chromium.

When the chromium concentration fell below a certain predetermined figure, the auxiliary anodes were introduced into the bath and were removed when the bath composition was satisfactory.

In the majority of installations insoluble anodes are used.

The researches of Watts definitely narrowed the selection of possiblé materials to two: iron or lead. If lead anodes be used, the bath will be maintained in a very good condition because trivalent chromium formed during electrolysis is readily reoxidized by lead anodes. Some grades of lead, however, corrode in such a manner that adherent patches of lead chromate are formed which exert a detrimental effect upon the plate.

Iron anodes always remain clean.

They permit, however, a greater accumulation of trivalent chromium in the bath than lead anodes. Moreover, iron goes into solution. The nearer pure the iron, the slower will be the rate of solution. Iron in the bath increases its resistance and thereby increases both the power necessary for plating and the attendant power costs. These factors must be considered in making a choice of anode materials. If properly taken care of, lead anodes are preferable.

Tanks.—The plating bath may be contained in a lead lined wooden vat, or in a glass lined steel tank but a common procedure is to use a steel tank in which the joints are lapped and welded inside and out.

Steel and iron become passive in chromic acid and are but very slightly attacked. As has been pointed out before, sheet lead or sheet steel anodes may be hung in the bath, or, in the case of a steel tank, the tank itself may be connected anodically. Heating and cooling coils are usually installed in order that the temperature may be controlled readily.

The deposition of chromium is attended by a copious evolution of gas, hydrogen and oxygen mixed with a spray containing chromic acid.

This fume is very irritating to the mucous membranes; exposure over a long period of time leads to bad head colds, nose bleed and even ulceration in the nasal passages. For this reason fume ducts are generally installed very near the surface of the bath. Exhausting fans pull the fumes directly across the solution and downward.

The Bath.—The chromium plating bath has as its main constituent chromic acid. Its function in the bath is two-fold: to conduct the electric current, and to act as the source of supply of chromium. During the operation of plating, chromic acid must be added from time to time.

A solution of chromic acid alone will not yield commercially valuable deposits of metal. It is essential that small quantities of sulphate or its equivalent be added in amounts about 1% as great as that of the chromic acid used. The most convenient way of adding sulphate is through the use of sulphuric acid; chromium sulphate; sodium sulphate or any such material however, can be substituted.

If there be a deficiency of sulphate, the resulting deposit will contain areas of a brown hydroxide of chromium.

As the amount of sulphate is increased, the quality of the plate is improved.

When too great an amount of sulphate is present, good plate can be obtained only in a very narrow range of plating conditions.

Still more sulphate makes the bath entirely inoperable.

The plating bath is usually quite strong.

The chromic acid concentration in a recommended formula is about 250 grams per liter (32 ozs. per gal.). A stronger or weaker solution may be used, but the constituents must be in about the same relative proportions. Many baths contain other constituents either added intentionally or formed during use. Most substances of this nature, however, are detrimental rather than beneficial to the deposit.

Process of Deposition.—The cathode, the article to be plated, must be carefully cleaned of all grease, oil, and oxide. The grease and oil are removed by cleaning in a hot solution of alkalis, preferably with the aid of electric current in which case the piece to be plated is made the negative pole.

Some foreign workers do not believe cleaning to remove grease a necessary step and they depend largely upon the detergent effect of the chromic acid plating solution. Oxide is removed by pickling in acid; in the case of copper and brass, a solution of sodium cyanide works admirably. After it is rinsed, the piece is immersed in the chromic acid plating bath, connected to the negative side of the circuit and the current is applied.

In plating with nickel, silver, copper, or almost any other metal, if a small current be applied, deposition takes place slowly; if a large current be applied, deposition is rapid. The amount of plate formed is dependent upon the total amount of current supplied. Chromium deposition is a much more complicated process.

If a very low current density be used, the current merely reduces the chromic acid to trivalent chromium without any deposition of metal whatever.

Current density is current per unit area and is usually expressed as amperes per sq. ft. or amperes per square decimeter. As the current density is increased, a point is reached where suddenly an evolution of hydrogen is noticed at the cathode. Upon examination it will be found that, in addition to reducing chromic acid as before and liberating hydrogen, the current also has brought about the deposition of chromium. Only a very small fraction, under 5% of the current at this stage actually is used in metal deposition. The plate is generally milky in appearance.

Increasing the current density increases the current efficiency and the resulting deposit is brilliant.

If put on a buffed surface, the plate will be so bright that no subsequent buffing is necessary. Increasing the current density still farther so that the current efficiency rises about 20% results in a gray, matte deposit which in thick layers may crack and peel badly. There is therefore, a range of current densities which will produce good plate. Certain metals, such as copper and brass, when used as cathode exhibit a comparatively wide range; other metals such as nickel and iron a narrower one.

Changing the temperature of deposition shifts this range. For example, at room temperature with a given solution good deposits can be obtained on copper between 20 and 80 amperes per sq. ft. (2.2 and 8.8 amperes per sq. decimeter); at 60° C., between 70 and 600 amperes per sq. ft. (7.7 and 66 amperes per sq. decimeter).

It will be found that, although the range of current densities producing good deposits increases with the temperature, the current efficiencies of the deposition remains nearly the same. That is, good plate for decorative purposes will be obtained between 5 and 20% efficiency regardless of the temperature.

If thick deposits be desired a current density and temperature combination to give about 13% current efficiency will form a bright, smooth plate with the minimum tendency toward treeing.

If the bath contain other things in addition to the essential chromic acid and sulphate or its equivalent, unfavorable conditions will result. For example, the formation and accumulation of trivalent chromium leads to increased resistivity in the bath. It also greatly contracts the plating range already described. Dissolved iron also increases the resistivity of the solution. Other effects are not yet fully known.

Bright chromium surfaces are obtained by plating on bright under coatings.

It is easier to obtain fine finishes by plating on a buffed undercoat of a metal like nickel than upon buffed copper. Dull chromium can, however, be buffed by using a special buffing compound although this procedure is generally uneconomical and is unnecessary.

The necessity for control is very great in chromium plating.

In best installations there will be found thermostatic temperature control, recording thermometers, accurate ammeters, good fume exhausters, and there will be some provision made for a periodic chemical analysis of the bath. There is, however, no great measure of uniformity in the quality and extent of the control methods at the present time.

TEST QUESTIONS

1. *What is electro-plating?*
2. *Describe the process of electro-plating.*
3. *What voltage is used for the current supply?*
4. *Describe dynamo and dynamo sets used for electro-plating.*
5. *Upon what does the choice of the type of dynamo depend?*
6. *How is the rate of deposit controlled?*
7. *What governs the choice of plating solutions?*
8. *Give the properties of electro-plating elements.*
9. *What are pickles and dips?*
10. *What kinds of pickle are used for iron?*
11. *Describe the various tanks used.*
12. *What is the rate of deposit of one ampere?*
13. *How many amperes are required for plating various materials?*
14. *How many gallons of electrolyte are required for each square foot of work surface?*
15. *Describe the dynamo and line connections.*
16. *What is the effect on the work of wrong polarity?*
17. *How many volt meters and ammeters should be used?*
18. *How should a motor dynamo set be connected?*
19. *What are dipping vessels used for?*
20. *What is the construction of scouring, swilling and rinsing troughs?*

21. *What is a tumbling or rattling barrel used for?*
22. *How are articles burnished?*
23. *Describe the process of 1, nickel; 2, copper; 3, chromium; 4, gold plating; 5, galvanizing, and 6, electrotyping.*

CHAPTER 212

Electrolysis

By definition electrolysis is *decomposition of a chemical compound in solution, called the* **electrolyte,** *into its constituent elements*, called **ions**, by the *passage of an electric current through it.*

There are two kinds of ions

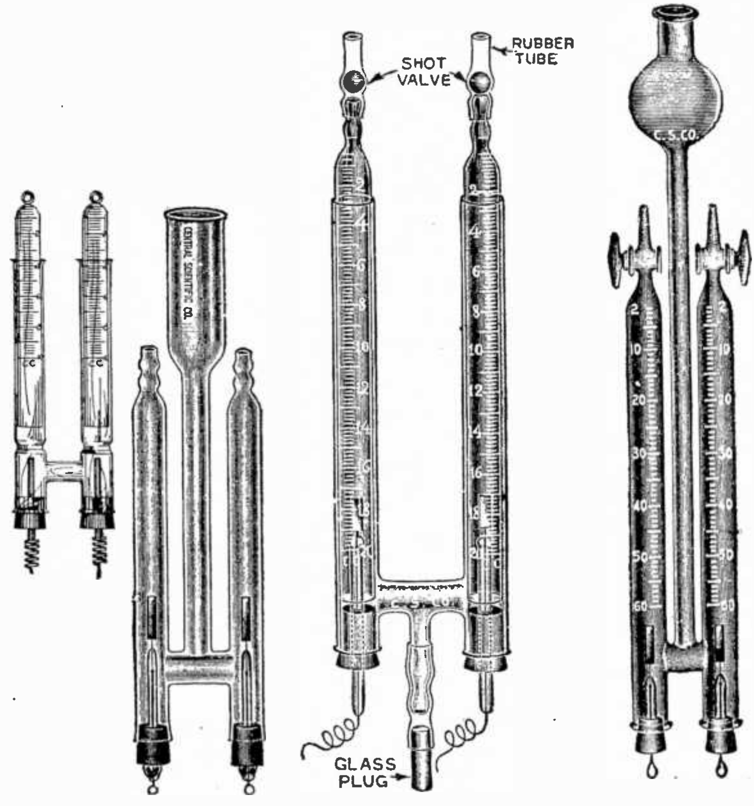
1. Cations;
2. Anions.

Cations are *electro-positive* and anions are *electro-negative.*

The cations appear at the cathode and the anions at the anode.

Path of the Current.—The current may be regarded as being carried through the electrolyte by the ions; since an ion is capable of carrying a fixed charge only of + or − electricity, any increase in the current strength necessitates an increase in the number of ions.

Oxygen and Hydrogen.—Dilute sulphuric acid is employed in one form of apparatus as electrolyte, namely, that patented by Schoop, the more customary electrolyte being a solution of caustic soda.



FIGS. 8,283 to 8,286.—Electrolysis apparatus. Fig. 8,283, electrolysis of water, simple form with sliding graduated tubes and platinum electrodes. Fig. 8,284, electrolysis of water, improved form with platinum electrodes that may be easily replaced by copper electrodes or by carbon electrodes for electrolysis of hydrochloric acid. Fig. 8,285, electrolysis apparatus (Osborne form), for study of conductivity of liquids, ionization, electro-plating, electrolysis of water, and principles involved in the theory of electrolytic dissociation. ***It consists of*** an outer U tube with graduated sliding tubes, shot valves, glass plug and platinum electrodes which are easily replaced by carbon or copper electrodes. Fig. 8,286, Hoffman's improved form of electrolysis of water apparatus with graduated tubes, glass stop cocks and removable platinum electrodes.

The primary products of electrolysis in this case are hydroxyl (OH) and the metal sodium (Na) but these immediately enter into secondary chemical changes which produce oxygen gas at the anode and hydrogen gas at the cathode. The gases obtained in this way are not quite free from impurity, but for industrial requirements they are sufficiently pure, and this method of manufacture is much cheaper and more cleanly than the usual chemical methods of production.

Chlorates.—Chlorate of potash or of soda is produced electrolytically by the electrolysis of the corresponding chloride.

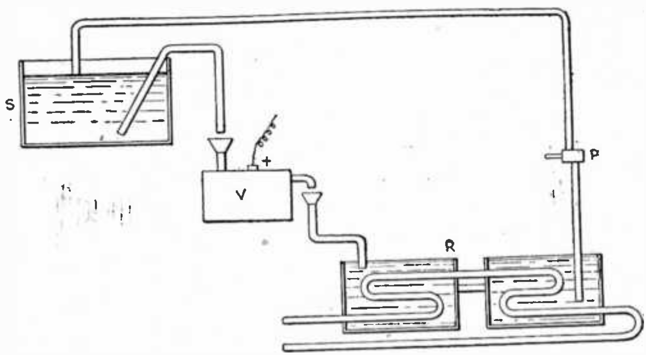


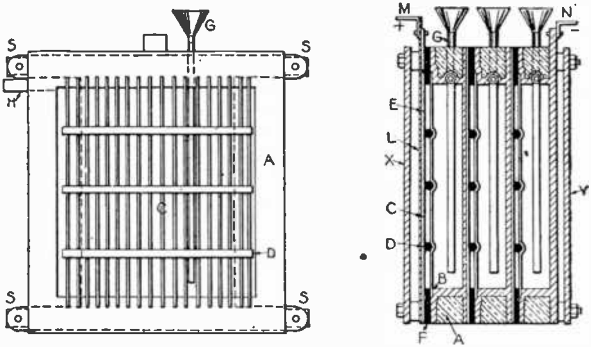
FIG. 8,287.—Arrangement of Gibb's process. The process *consists in* the electrolysis of potassium chloride solutions, using a copper or iron cathode and a platinum anode. S is the supply tank; V, the electrolytic cell; R, the refrigerators; and P, the pump by means of which the exhausted electrolyte is returned to the supply tank, while the chlorate precipitates out as crystals.

The electrolytic and chemical changes which first occur when a solution of sodium or potassium chloride is electrolyzed by the aid of electrodes not acted on by the products of the electrolytic decomposition is described under *Alkali and Bleach*.

Hypochlorite.—If the cell designed for chlorate productions be worked with a low current density, and at a temperature which does not rise above 68° Fahr., little chlorate will be produced and sodium hypochlorite will be formed in its place.

Ozone.—This can be produced by chemical methods, but it is also produced by *the sparkless discharge of electricity through dry air or oxygen from conductors charged at a high pressure and it is always formed when a frictional electric machine of the old plate type is worked with an air discharge.*

Sodium and Potassium.—It is necessary to work with *a fused electrolyte in place of an aqueous solution in this case.*



FIGS. 8,288 and 8,289.—Gibb's cell and battery of three cells. The cells *consist of* a wooden frame A, covered with some metal B, such as lead, not attacked by the electrolyte. The cathode consists of a grid of vertical copper wire C, kept in position by cross bars D, of some insulating material. The grid is placed in a vertical position against one side of the cell frame, and kept in place by the anode of the adjoining cell, from which it is insulated by the strips, F, and bars D. The opposite side of the cell from that occupied by the cathode is partially closed by the anode indicated by dotted lines. This consists of a thick lead plate L, covered with platinum foil on the outer side E, (fig. 8,289), and is held in position by the cathode and framework of the following cell. G, is a pipe, reaching to the bottom of the cell, by which the potassium chloride is continuously supplied, and it is the overflow pipe to convey the mixed solution of the chloride and chlorate as well as the liberated hydrogen gas away from the cell. S,S,S,S, are lugs projecting from the framework by means of which any number of cells can be bolted together to form a series of cells. In fig. 8,289, the heavy plates X and Y, are used to close the ends of the wooden framework and form a fully closed series of cells with only the openings at the various supply and overflow points. Current connections are made at the points M and N.

Owing to the readiness of the sodium and potassium to enter into combination with water, the difficulties of operating the process upon a commercial scale are chiefly due to this great chemical activity of the alkali metals.

Alkali and Bleach.—When an electric current is passed through a solution of sodium chloride in water, using electrodes which are not attacked by the chloride or by free chlorine, the *chloride is split up into its constituent parts, the metal sodium is separated at the cathode, while the gas chlorine forms in minute bubbles at the surface of the anode and rises to the surface of the liquid in the cell.*

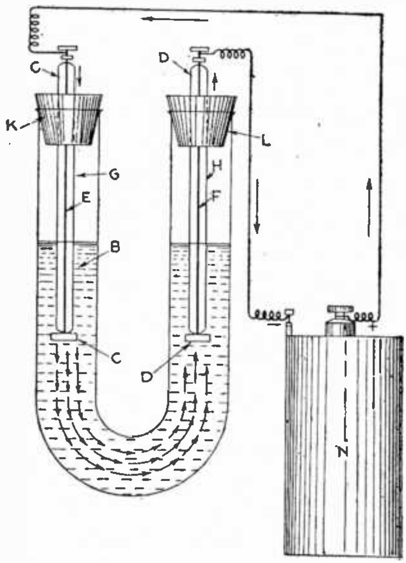


FIG. 8,290.—Electrolysis of copper. Fill the U shaped glass tube shown above, with a solution B, made by dissolving some crystals of copper sulphate or bluestone. Immerse in the solution two platinum electrodes C and D, attached to the copper wires E and F, sealed in the glass tubes G and H, which are held in the tube openings by loosely fitting rubber corks K and L. Attach the negative pole of the battery N, to the terminal of the electrode C, and the positive pole of the battery to the upper terminal of the electrode D. The electric current from the battery will then pass from the platinum *anode* C, through the copper sulphate electrolyte B, to the platinum *cathode* D, thence to the negative terminal of the battery. The passage of the current through the electrolyte will result in the liberation of the constituent ions of the latter. oxygen gas being liberated at the anode C, metallic copper deposited on the cathode D, and the copper sulphate solution B, changed to sulphuric acid.

The metal sodium, however, has a great affinity for the hydroxyl constituent of water, and it at once enters into union with this, and produces sodium hydrate and hydrogen gas at the surface of the cathode. These changes are the basis of all the patented processes and cells for the production of alkalies and chlorine products by electrolysis.

Aluminum.—The process of aluminum manufacture consists in the *electrolysis of a fused mixture of the fluorides of sodium, calcium and aluminum, in which alumina (aluminum oxide) is dissolved.*

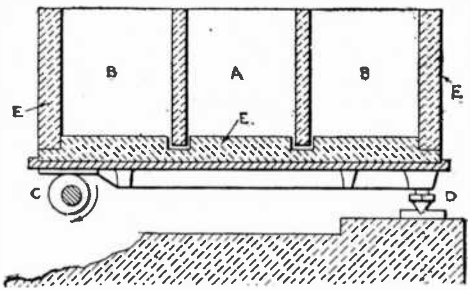


FIG. 8,291.—Castner cell. ***The parts are*** A, cathode chamber; BB, anode chambers; C, eccentric for producing a rocking movement of cell; D, pivot support for framework of cell; E, slate walls of cell. The Castner cell is of the mercury type in which advantage is taken of the property possessed by mercury of forming an alloy with sodium, fluid at the ordinary temperature, this alloy being known chemically as an amalgam. When the amalgam is heated with water it is decomposed, and a solution of sodium hydrate is formed, while the mercury is restored to its original condition of purity. Hence, if a layer of mercury be employed as cathode on the floor of a cell in which a solution of sodium chloride is being decomposed by the current, the sodium liberated at the surface of the mercury will at once enter into union with it, and will be kept safe from further chemical or electrolytic changes. The layer of mercury, in fact, acts as a reservoir for the sodium atoms, or ions, brought to its surface, and stores up these until they are wanted.

When an electric current is passed through such a mixture of fused salt, using carbon electrodes, aluminum separates as drops of molten metal at the cathode, while oxygen is liberated at the anode and at once unites with it to form carbonic acid gas. The bath is kept in the fused state by the heating action of the current.

The action taking place in the electrolytic bath is therefore, virtually, a reduction of the alumina or aluminum oxide by the carbon of the anode; but this reduction would be impossible without the aid of the current to first separate the oxygen and aluminum, which have great affinity one for the other.

The aluminum separated at the cathode is in the molten state and falls to the bottom of the bath, and it is allowed to collect there, being removed at stated intervals, either by a syphon or by tilting. Fresh alumina is fed into the bath at short intervals to replace that which has been decomposed by the current; and the process is, therefore, a continuous one.

FIG. 8,292.—Electrolysis in lower New York. The figure illustrates current movements as discovered. The power house is located near the navy yard in Brooklyn. A portion of the returning currents, as shown by arrows, flows over the New York and Brooklyn bridge to Manhattan, thence north to Williamsburg bridge via underground mains, subway structures, and other metals, and passes over that bridge back to Brooklyn, thence through mains to rails and negatives, to power house. In this case damage may be expected at three points: 1, where currents leave bridge metals on the Manhattan side; 2, where they leave pipes to enter Williamsburg bridge; 3, where they leave same bridge for pipes in Brooklyn side. When the two bridge structures are connected in Manhattan as proposed, then there will be further changes in the direction of current. Before the Williamsburg bridge was built, these currents recrossed through the river bed, leaving mains all along the docks in the Manhattan side, for the river, and leaving the river for mains or other metals along the docks of the Brooklyn side. Traces of these currents have been found as far north as 23rd St., a distance of over two miles from the Brooklyn bridge. Since the Williamsburg bridge has been built, nearly all traces of these currents flowing north of it have disappeared, showing that the mass of metal composing the structure acts as a short circuit or path of lower resistance which carries practically all of the returning currents flowing from Manhattan back to Brooklyn.

Bullion Refining.—The general principle of electrolytic bullion refining is *to use the alloy of precious metals, or bullion, as an anode in an electrolyte which dissolves only one of the two metals to be separated, and to use a sheet of the pure metal that is being deposited, as cathode.*

For silver deposition an acid solution of nitrate is employed as the electrolyte (the Moebius process), while for gold an acid solution of gold chloride is found to yield the best results (the Wohlwill process).

Wet Extraction Process for Metals.—Copper, nickel, tin and zinc have all been extracted from their ores or slags by the use of electrolytic processes, and in many cases these processes are still being worked upon an industrial scale.

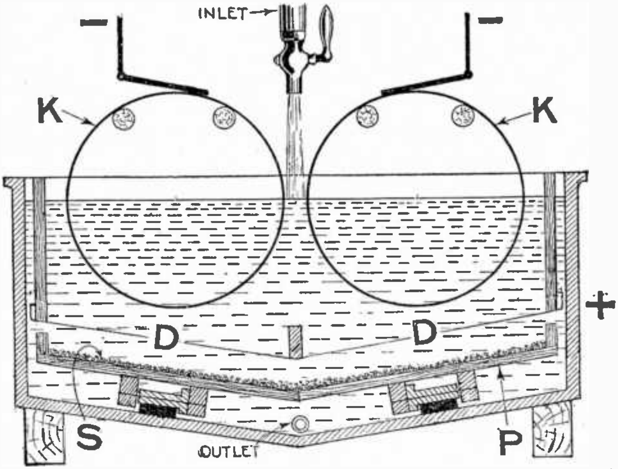


FIG. 8,293.—Electrolyzing tank used in the Dietzel process for silver refining. The rotary cylindrical cathodes K are coated with a thin layer of grease or graphite, on which copper is deposited electrolytically. As soon as it becomes dendritic, it is knocked off and melted. The cylinders are suspended on flanged contact rollers and are caused to rotate by the friction between them and the rollers. Contacts between the rollers and the electric machine are made at the bearings of the rollers outside the tank. A loose bottom P, supports the material S, to be treated, and is constructed of hard rubber, celluloid or glass plates set in wooden frames. Electrical contact is made with the material S, by platinum wires or by plates of carbon. The anodes, cast in plates about from ⅛ to ¼ in. thick, are placed on the plates P. The linen filter cloths D, catch any dendritic copper falling from the cathodes and prevent the anodic silver from rising to the copper cathodes. *In operation:* on the passage of the current, the silver and the copper are dissolved in the electrolyte, which contains from 2 to 5% of copper and from .05 to .4% of free nitric acid; the gold is not dissolved. The solution flows through the bottom of the tank into a series of vessels filled with metallic copper, on which the silver deposits, dissolving an equivalent amount of copper. The desilverized solution then flows into the tank from above, and part of the copper is deposited on the cathodes. The average current density is 14 amperes per sq. ft. at from 2½ to 3 volts. As late as 1905, the sulphuric method of separation was extensively used in copper refineries, but it is being displaced by the electrolytic method.

Copper.—The principle of the wet copper extraction process is as follows: The ore is roasted to drive off the sulphur, and then bleached in suitable vats with a solution which will dissolve the copper and leave the other metals and impurities undissolved. This solution is then electrolyzed in order to recover the copper as a cathode deposit.

Nickel.—The roasted ore is leached with a solution containing both copper and calcium salts as chlorides, and the copper is first deposited by electrolysis. The last traces of copper are then removed from the electrolyte by chemical means, and the nickel is in turn deposited by use of a higher voltage from the remaining solution.

Tin.—The Böhne process depends upon the use of sulphuric acid as a leaching agent and upon electrolytic deposition of the tin, from the sulphate solution so obtained. In the recovery of tin from old tin cans and tin scrap by electrolysis, sodium hydrate is used as the electrolyte.

Zinc.—A great amount of investigation and large sums of money have been spent upon processes for extracting zinc from its ores, by aid of electrolysis, but only two of these have achieved any industrial success. The Hoepfner process depends upon the use of the waste calcium chloride solution from ammonia soda works, and was worked out chiefly as a process for recovery and utilization of the chlorine from this waste product; zinc, testing 99.96 per cent purity, and bleach being the products finally obtained.

The Swinburne-Ashcroft method (the other successful process) is not a wet extraction process, but depends upon the electrolytic separation of zinc from fused zinc chloride.

TEST QUESTIONS

1. *What is electrolysis?*
2. *Name the two kinds of ions.*
3. *Describe the path of the current.*
4. *Describe the electrolysis of water.*
5. *How is chlorate of potash or of soda produced electrolytically?*
6. *Describe the Gibb's process.*

7. *How is ozone produced?*
8. *What kind of electrolyte is used for sodium and potassium?*
9. *What happens when an electric current is passed through a solution of sodium chloride and water?*
10. *Describe the electrolysis of copper.*
11. *How is aluminum produced?*
12. *Describe the method of bullion refining.*

CHAPTER 213

Electric Lighting

Electric lighting broadly speaking is a large subject and covers several branches of engineering. A full treatment of the subject would accordingly include

1. Generation;
2. Transmission;
3. Utilization.

The first two divisions of the subject have been so thoroughly presented by the author in other volumes of this Series and in Audel's Engineers and Mechanics Guides that to consider them here would only be repetition of matter contained in the volumes just mentioned, and would leave no space to present the various kinds of apparatus used and methods employed.*

Sources of Electric Light.—There are various means of producing light by electricity. The devices used are

1. Incandescent lamps;
2. Vacuum tubes;
3. Arc lamps.

Incandescent Electric Lamps.—This form of lighting device is the most widely used source of electric light and lends itself

*NOTE.—***It is to be supposed** that when a reader procures a book on a certain subject, he wishes to concentrate on that particular subject. With this idea in view the author believes that the necessarily limited number of pages at his disposal should be confined strictly to the main subject, without any lengthy discussion of items foreign thereto, it being assumed that if the reader desire to post himself on related subjects as for instance, steam engines, he will get a book on that subject. The earnest student will adopt this method of study.

to the greatest variety of uses. It operates on the principle of *heating a wire to a white heat by sending an electric current through it.*

In construction, a slender filament of some conducting refractory material is enclosed in a glass chamber and connected to lead wires fused through the base of the chamber or "bulb." The bulb is exhausted of air as completely as possible and the exhaustion duct sealed. The object of placing the filament in a vacuum is to prevent oxidation.

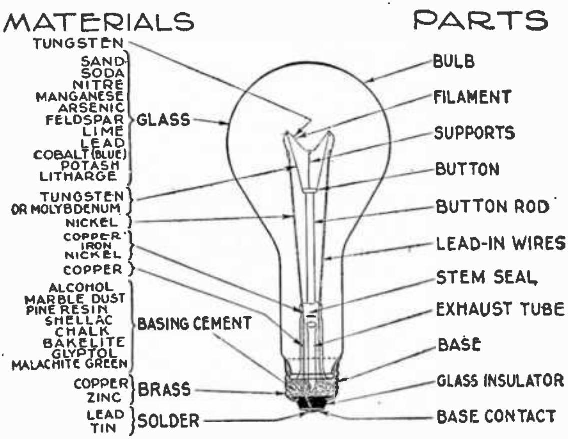


FIG. 8,294.—Materials and parts of an incandescent lamp.

Ques. Why is an incandescent lamp so called?

Ans. Because a wire or filament is heated to incandescence by the passage of an electric current, thus producing light.

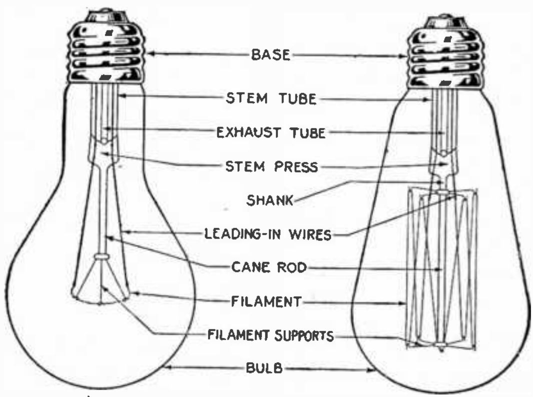
Ques. What materials are incandescent lamp filaments made of?

Ans. Mainly tungsten.

In the older forms of lamps, carbon, platinum, tantalum, and other materials were used but they have been superseded because of their shortcomings, such as short life, unsuitability to alternating current and high cost for commercial purposes.

Ques. What is tungsten?

Ans. A metal extracted from minerals known as Wolframite (a tungstate of iron and manganese) and *sheelite* (a tungstate of calcium).



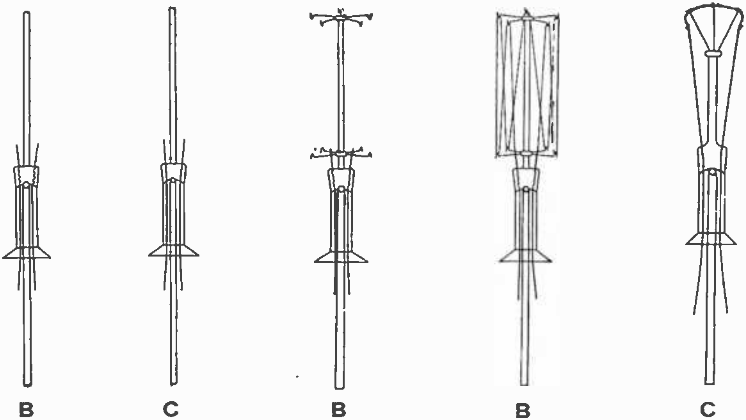
FIGS. 8,295 and 8,296.—Principal parts of an Edison Mazda lamp.

These are found in China, Korea, Colorado, California, New Mexico and several other places. The ore is purified to the oxide which later is reduced to pure tungsten appearing as a grayish-black powder. This is compressed into a solid under hydraulic pressure and intense heat, and is then drawn into wire.

NOTE.—*Edison,* in 1879 invented the incandescent lamp of the form and principle which is in use at the present day; he employed a carbon filament. Later a metalized carbon filament was produced which was more efficient and came under the name of the Gem lamp Still later the tantalum lamp was produced which was still more efficient and, in 1907, the tungsten lamp was produced which is about three times as efficient as the original carbon lamp.

Ques. What is inserted into the bulbs of large lamps and why?

Ans. A gas is inserted after the air has been drawn out, to permit the filament being operated at a higher temperature and to modify the conduction of the heat, keeping it concentrated or neutralizing it.



FIGS. 8,297 and 8,298.—Assembly of tubes, cane rods, leading-in wires, etc., of an incandescent lamp. ***In construction,*** a glass tube is blown and the lower end flared to fit the bulb and seal with it; this serves as the support for all the elements. A glass rod is inserted near the top for holding the filament, a tube through the bottom to serve as the exhaust tube for drawing out the air, and two leading-in wires for connecting the filament with the base. These are all heated and when sufficiently soft are pressed together to bind all the elements and seal in the leading-in wires. A blast of air retains the opening in the exhaust tube.

FIG. 8,299.—Supports for the incandescent lamp filament. The filament being as thin as a hair, it is necessary to anchor it or have a firm means of holding it in place. It is nearly two feet long in a 50 watt lamp and is therefore coiled or draped over supporting wires which hold it in place. These wires are inserted in the glass rod or stem while hot and bent into hooks as shown in the illustration.

FIGS. 8,300 and 8,301.—Lamp filaments in place over anchors of vacuum and gas filled lamps. The regular or vacuum lamp has the filament supported vertically or draped over the anchors and gives off light all around, while the gas filled lamp has the filament coiled and supported near the top and concentrates the light in one direction. The leading-in wires are either pinched or welded to the filaments.

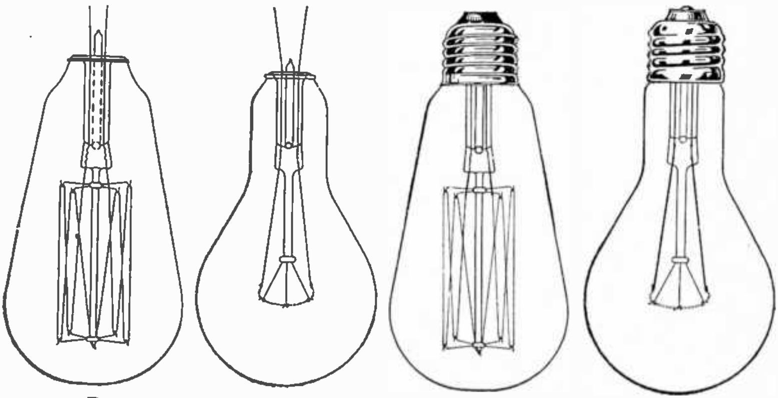
NOTE.—In the above illustrations the designations B and C, indicate Mazda type B and type C lamps respectively.

Methods Employed in Making Incandescent Lamps.—By the aid of automatic machinery incandescent lamps are turned out at a rapid rate.

The following description briefly explains the various steps:

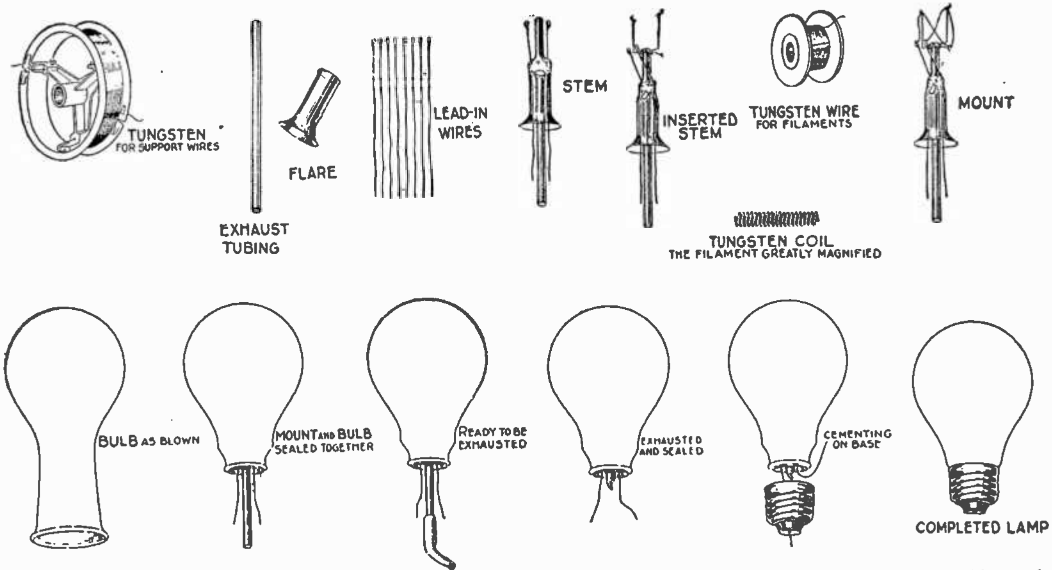
The glass bulbs are blown from molten glass coming from a furnace, and by successive puffs of air are shaped to almost the form required and then surrounded by moulds which put them into exact shape, the excess glass or stem is cut off by gas flame.

A tube, known as the stem, is blown which afterwards is welded to the bulb and contains the leading-in wires and tubes for supporting the



FIGS. 8,302 and 8,303.—Exhausted lamps showing the filament set in the glass bulb and the base and the exhaust tube sealed. The opening in the base is sufficiently large to take the element as shown and is then placed against the flange or flared part of the large tube and rotated in gas flames and sealed. A rubber tube coming from the air pump is placed over the exhaust tube at the bottom of the lamp and after the air is exhausted it is sealed. In the gas filled lamp gas is admitted after the air has been drawn out.

FIGS. 8,304 and 8,305.—Completed incandescent and gas filled lamps. A base is punched from a ribbon of brass, a thread rolled into it and an opening left for a bottom contact piece; this is to serve as the center contact piece of the lamp. The shell and this piece or disc are held in proper position and molten glass poured in to bind them and at the same time insulate them. Holes are left for the leading-in wires to be soldered to the contact piece and the shell. Cement is then put around the inside of the shell, the lamp placed in it and when hardened is complete. During the processes tests are made for the continuity of the filament, the extent of the vacuum, the burning qualities and the rigidity of the parts. They are then packed and ready for shipment.



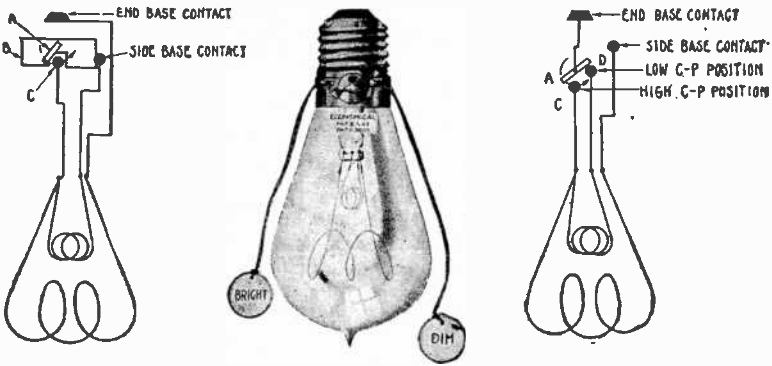
FIGS. 8,306 to 8,320.—Making an incandescent lamp. The stem and inserting machine bring together the flare, exhaust tubing, rod, lead-in wires, assembling all in one complete stem, and finally inserting the support wires ready for mounting the filament. These stems are then transferred by a conveyor to operators who mount the filament on the supports. The sealing in and exhaust machine seals the mount in the bulb after which it exhausts the air, and, in the case of gas filled lamps, fills the bulb with inert gas. The operator inserts a mount and places a bulb over it as each successive loading position passes. The bulbs are rotated with a gas flame playing on the bulb where the bulb and flare are to be welded together, and at each successive stage in their travel, are heated just the right temperature by tonguelike flames to make a perfect seal. When the seal has been made, air pumps cut in to exhaust the bulb. On the basing machine the lamp is capped with a brass base having a lining of plastic cement; one lead wire makes contact with the shell and the other is threaded through to the contact to the end. As the lamps pass through a heated oven the cement hardens and mechanical fingers drop a touch of solder on the lead wires and the excess length is cut off. As the lamp nears the end of its final circle in a lamp making machine, it is lighted for inspection.

filament and exhausting the air. The tip is not visible on the bulb as the air is exhausted from the bottom and the sealed end concealed in the base.

Leading in wires are made of special metal so that the rate of expansion and contraction will be similar to that of the glass and thereby form a solid connection between the wires and the glass. Supports are set in the glass tube in the bulb for holding the filament and serve as anchors for the filament.

The entire element is then set into the bulb, the botton sealed and the exhaust tube placed on the exhaust pump. When the desired vacuum is obtained the tube is sealed, the end broken off and the lamp is ready for the base.

In gas filled lamps, gas is inserted before the stem is sealed.



FIGS. 8,321 to 8,323.—Hylo turn down incandescent lamps. Owing to the difficulty of manufacturing a mechanically strong one or one-half candle power filament for direct operation on voltages as high as 110, the two filaments are connected in series for the dim light. The full candle power of the lamp is obtained by operating a switching device which either short cir cuits or open circuits the small filament. In type No. 1 lamp, figs. 8,321 and 8,322, the switch consists of a pivoted metal segment A (attached to the base B), which may be rotated slightly by means of the cords so as to touch an auxiliary contact C, thus short circuiting the small filament and lighting the high candle power filament. By shifting the segment off the contact C both filaments are in series, but only the small filament is lighted. The cords operate only to change the candle power from high to low, or vice-versa, and in order to put out the lamp the key or switch should be used. In type No. 7 lamp, shown in diagram only, fig. 8,323, there is a switch A concealed in the base, which provides three changes in candle power; namely, 16, 1, and out, all obtained by operating the string alone. This switch is pivoted at its center B, and the lamp circuit is completed when connection is made at either of the contacts C or D. The switch makes contact at only one of these points at a time. When connection is made at D both filaments operate in series and the small filament is lighted. When the switch is pulled over to C the small filament is open circuited and the high candle power filament burns alone. By pulling the switch clear of both C and D, the lamp is put out.

The base is made of brass with the thread formed into it and is fastened to the bulb by cement.

Ques. What determines the size of the filament of an incandescent lamp?

Ans. The size must be such as to offer a resistance which will allow the proper current to give the desired candle power at the voltage for which the lamp is designed.

The Use of Gas in Incandescent Lamps.—By deliberately filling the bulb with an inert gas which will not chemically combine with the filament, the presence of the gas retards *the rate at which the filament material evaporates*.

In practice the pressure of the gas in the bulb, when the filament is lighted, is about that of the atmosphere.

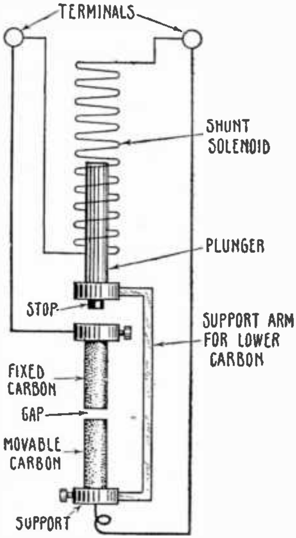
The use of gas increases the loss of energy put into the lamp owing to the conduction and convection of heat by the gas from the filament, which does not happen in a vacuum lamp.

In order to reduce the amount lost by conduction, the gas used should have as poor a heat conductivity as possible. Originally nitrogen was used, but argon with a small percentage of nitrogen is now used. Substantially pure argon will conduct current (ionize) at the voltage ordinarily used for lamps. Thus current would flow through the gas between the filament terminals, the resistance of this path decreasing as the current increases, thus causing the lamp to "arc" or short circuit.

The gas, when heated by the hot filament, rises to the upper part of the bulb where it becomes cooled. It then falls, this cycle being repeated so that the gas circulates in the bulb as long as the lamp is lighted. The smaller the diameter of the filament the greater *relatively* are the heat losses produced by the circulating gas.

NOTE.—*In the earlier lamps* made by Edison the conductor consisted of platinum in the form of a filament or loop of wire. On account of the high cost of platinum, carbon was substituted in the form of filament of carbonated bamboo. After this came the *squirted filament* produced by dissolving cotton in a solution of zinc chloride. The gelatinous material thus obtained was forced or "squirted" through a small orifice into a vessel containing alcohol, which caused it to set and harden sufficiently for subsequent handling and washing. After washing, this product was wound upon a large drum and dried; it then possessed considerable strength. In this form it was cut up into lengths suitable for filaments and carbonized at a high temperature.

How an Arc Lamp Works.—If two carbon rods be connected electrically to the terminals of a dynamo and the free ends of the



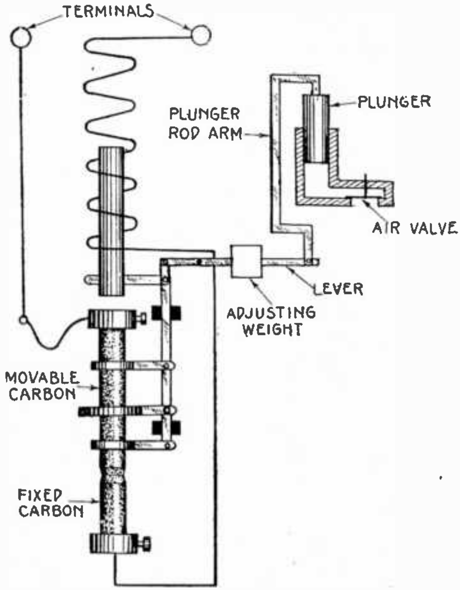
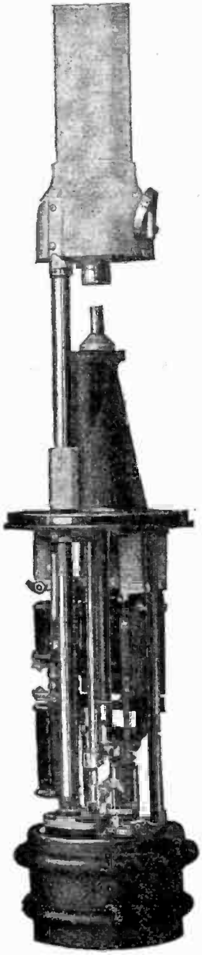
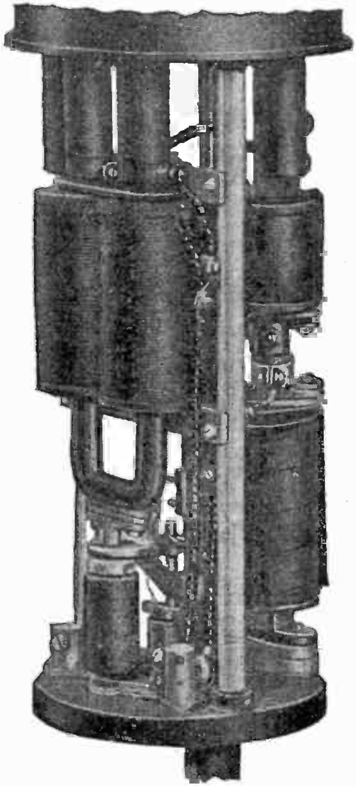


FIG. 8,324.—Elementary shunt control lamp. *In operation* most of the current flows through the heavy wire connected in series with the carbon, the balance flowing through the shunt solenoid. Normally, when the current is off, gravity causes the plunger to drop against the stop, thus separating the carbons. When current is turned on it flows through the shunt solenoid and pulls up the plunger, and with it the lower carbon opposed by gravity. On contact, the current is short circuited around the shunt coil, the solenoid, thus weakened, allowing the plunger to recede and break contact of the carbons, lengthening the gap until equilibrium is established.

FIG. 8,325.—Elementary series control arc lamp with dash pot and adjusting weight. *In operation,* before the carbons get hot, the sudden motion of the magnet draws them apart, breaking the circuit, and they fall together again, the result being a vibrating action exactly like that of a vibrating bell. To secure equilibrium, it is necessary to retard the upward motion of the movable carbon, and this is what the dash pot accomplishes. Thus as the solenoid separates the carbons, the dash pot plunger, which is connected to the adjusting weight lever, moves downward, compressing the air which slowly leaks past the plunger, thus retarding the upward movement of the carbon. The function of the air valve is to admit air on the up stroke of the dash pot plunger, otherwise a partial vacuum would be formed which would retard the upward movement. It must be evident to any one that refinement in adjustment may be obtained by the addition of an adjusting weight by which gravity can be conteracted to any desirable extent, regulating the arc voltage to a desirable working value.





Figs. 8,326 and 8,327.—Views of mechanism of General Electric luminous arc lamp. The arc is struck between a stationary copper upper electrode and a movable magnetite lower electrode and burns under normal updraft conditions. *In construction:* The lower electrode is carried on a rod actuated by the standard type of shoe clutch mechanism. The current is carried to the electrode by means of a flexible spiral connection contained in a tube which is

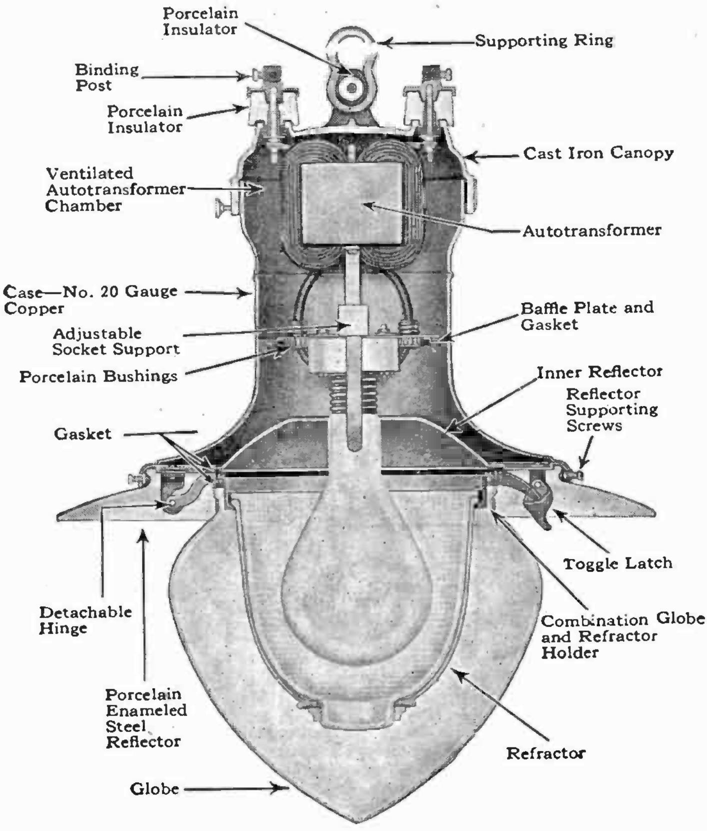


FIG. 8,328 and 8,329.—Westinghouse dust proof Luxsolite pendant; sectional view showing parts.

FIGS. 8,326 and 8,327.—*Text continued.*

telescoped by the electrode rod. This tube projects down inside the pole for a distance of about 18 ins. A single side rod, telescoping the supporting tube supports and carries the electrode, dome and chimney so that no shadows are visible when the lamp is properly placed, with the side rod toward the sidewalk. Should any non-conducting slag form on the upper surface of the lower electrode, it would be effectually broken because two weld breaking devices are provided, namely, the hinged upper electrode, and the slot in the top of the dash-pot stem. If the voltage become excessive, or if, for any reason, the lamp should fail, it is immediately cut out of circuit by a cut out which is part of the lamp mechanism.

rods brought together, the current from the dynamo will flow through the closed circuit thus established.

Now, if the carbon rods be drawn apart so as to form a slight break of one-eighth of an inch or less in the circuit, the current will jump from one rod to the other and the arc thus formed will be maintained across the gap in the circuit.

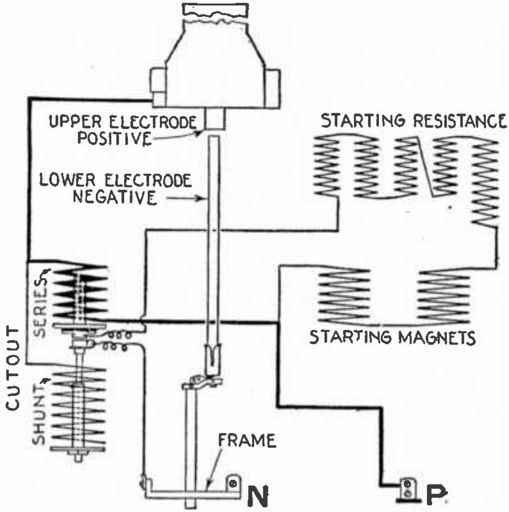


FIG. 8,330.—Elementary diagram of General Electric luminous arc lamp. *Cycle of operation:* The current enters terminal P, passing through the starting magnets, starting resistance and the cut out contacts to the negative terminal. The starting coils are thus energized and the lower electrode is brought into contact with the positive, establishing the arc and the circuit through the series cut out coil. This coil, on becoming energized, separates the contacts and opens the circuit through the starting coils, thus allowing the lower electrode to fall back to its normal position, retarded by the dashpots. The electrodes remain in this position until for some reason the voltage at the arc momentarily reaches a point sufficiently high to actuate the shunt magnet, when the contacts are once more closed and the cycle of operation is repeated.

In any practical arc lamp, not only must the carbons be properly secured to supports but suitable mechanism must be provided to meet certain conditions essential in operation.

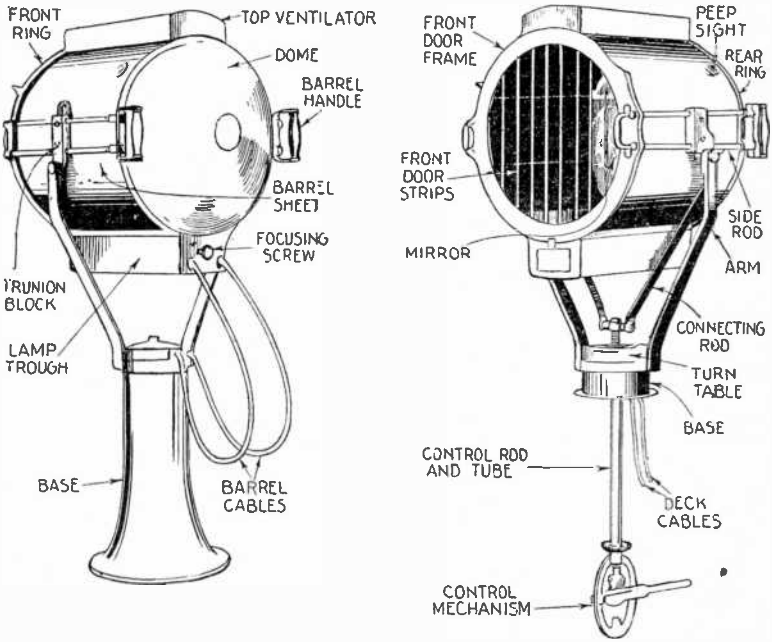
This mechanism should be of such nature that:

1. The carbons are brought into contact when the current is turned off;

2. The carbons are separated a proper distance so that an arc may be formed when the current is turned on;

3. The carbons are fed to the arc as they are consumed;

4. The circuit is made or broken when the carbons are consumed.



FIGS. 8,331 and 8,332 —General Electric carbon arc searchlights. Views showing general construction

The control of the carbons is effected by various feed mechanisms as shown in the accompanying illustrations.

Luminous Arcs.—In the case of an electric arc maintained between ordinary carbon electrodes, almost all of the light comes from the *tips of the electrodes and comparatively little from the arc stream itself.*

In the development of arc lamps various attempts have been made to increase the luminosity of the arc stream by introducing some substance not carried by the ordinary carbon electrodes.

In the latest types of arc lamp this is accomplished in one of two ways: by using in direct current lamps, negative electrodes of a material the incandescent vapor of which gives a highly luminous spectrum; or by employing electrodes of such refractory material as will give a very high arc temperature, by the effects of which certain materials carried by the positive electrode will be converted into incandescent vapor of a high light giving power.

Lamps operating on the first method are variously called *metallic*, *magnetite*, or in general *luminous arc* lamps.

The mechanism and operation of a luminous arc lamp is shown in figs. 8,326 to 8,330.

Vacuum Tube Lamps.—Practical lamps of this type employing long vacuum tubes have been commercially available since 1903.

The accompanying illustrations and explanation of the Cooper-Hewitt and Neon lamps will show their characteristics and operation. They are extensively used in various industrial and commercial plants where large candle power, a low operating cost, and a tubular form with low intrinsic brilliancy and good diffusion are more important than the natural color value of illumination.

It has been observed that those who have never worked under the light of this lamp are the strongest objectors to its *green* color, but those who have used it for various purposes assert that the eyes apparently are less fatigued by it when applied to fine work than by those illuminants which yield more of the red rays.

The lamps are of very high efficiency, the watts consumed per candle power being about one-half that of open arcs, one-third that of enclosed arcs, and one-sixth of the ordinary carbon filament incandescent lamps. The life of the tubes is about 5,000 hours.

The first cost of the tubes is high, varying from one-half to twice that of other forms of electric lighting, but it is claimed by the makers that the economy attained in the reduced operating cost will be sufficient to counterbalance the entire cost of installation of considerable size.

The direct current Cooper-Hewitt lamp is shown in fig. 8,333.

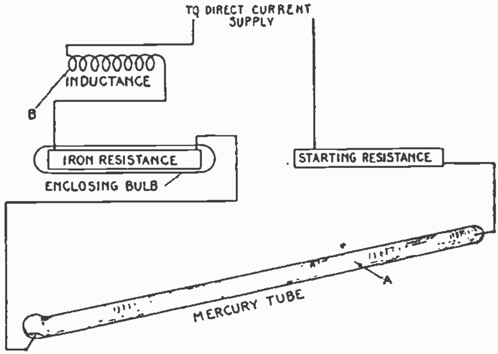


FIG. 8,333.—Connections of Cooper-Hewitt direct current mercury vapor lamp.

It consists of a glass tube A, and a small set of inductance and resistance coils B, connected in series with the tube. The latter is made of special glass, and carries an iron electrode at its upper or positive end, and a mercury electrode at its negative or bulb end. These electrodes are connected with the outside by platinum wires sealed in the glass.

The tubes for all lamps have a uniform diameter of 1 inch, but vary in length for different candle powers. At the present time they are made in lengths of 21 and 45 inches for candle powers of 300 and 700 respectively for the general groups of voltages around 110 and 220 volts respectively. Tubes can be adopted, however, for any commercial voltage, but the candle power will change slightly for different voltages.

These tubes are exhausted and sealed, and only a small quantity of mercury is placed in the bulb at the negative end. The

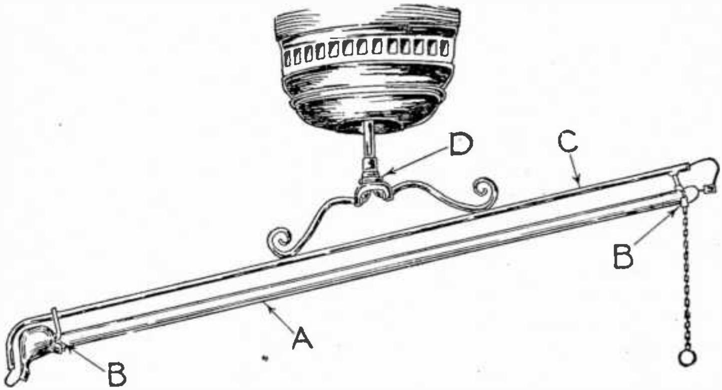


FIG. 8,334.—Cooper-Hewitt direct current lamp. ***In construction,*** the tube A is supported by two clamps B, B, attached to a *lamp rod* C fixed parallel with the tube and pivoted at D to the main stem which is screwed into the ceiling crowfoot. The inductance and resistance coils, etc., are also supported by the stem and covered by a metal canopy. In some cases a suitable reflector is attached to the lamp rod. ***To light the tube,*** it is tilted downward by means of the chain attached to its positive end and the mercury allowed to flow in a small stream between the electrodes. The tube is then returned to its normal position, thereby breaking the circuit and starting the arc which puts the lamp in operation. In some forms of the lamp the act of tilting is accomplished by means of a solenoid attached to the stem at the pivot joint of the lamp rod. Since mercury is an electrode material with which the voltage required to maintain an arc is much less than the sparking voltage at the temperature of the arc, the direct current tube lamp cannot be used with alternating current.

mercury tube has the peculiar characteristic that it experiences momentary increases of resistance which are of sufficient magnitude to break the continuity of the vapor arc. This peculiarity disappears, however, when the current strength is over 4 amperes, and with weaker currents when the negative electrode becomes heated.

In the case of 3.5 ampere commercial lamp it has been found necessary to introduce inductance in series with the tube for the.

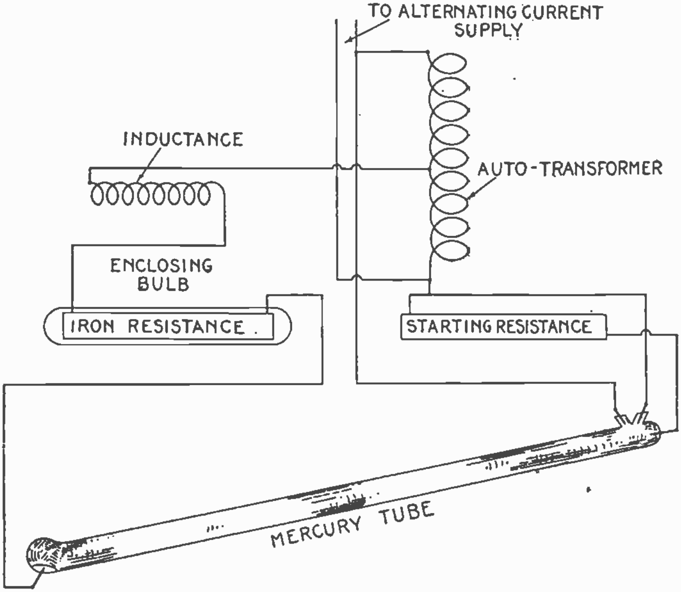


FIG. 8,335.—Connections of Cooper-Hewitt alternating current mercury vapor lamp. *In operation* the lamp is lighted by tilting the tube as described in fig. 8,334, and the mercury allowed to flow out of the bulb toward the positive end of the tube until it strikes the starting electrode. It will be noted that the arrangement of the positive electrodes in pockets on the upper side of the tube prevents the mercury coming in contact with them. Now, since the flow of mercury around the starting electrode is quite irregular, it makes and breaks the circuit, and if the resulting arc be started at such a point in the alternations of the current that the mercury column becomes the negative electrode, the arc will continue, alternately, between the mercury when the starting electrode is not connected. When the lamp has been restored to its normal position the resistance connected between the starting electrode and the temporarily inactive positive electrode will not permit the arc to be maintained on the former, but alternately on both of the positive electrodes. The candle power of the mercury vapor arc varies considerably with variations of voltage. This difficulty is overcome by including in the circuit a *ballast* or resistance quite similar to that employed with the Nernst lamp. It consists of an iron wire wound on a porcelain pencil, and the whole sealed in a glass tube through which the terminals are brought out. The resistance of iron is greatly increased by the passage through it of a relatively small current; the ballast is worked at temperature of at least 900 degrees Fahr. This resistance coil is placed in series with the arc and is so designed that a slight decrease of current causes such a decrease in the volts drop across the terminals of the coil that the remainder of the voltage impressed on the lamp remains more nearly constant.

purpose of storing sufficient magnetic energy to oppose and overcome the tendency to reduce the current. It has been found that this effect of increasing resistance has a tendency to become cumulative, or in other words, if an inductance of a certain size be required to maintain the vapor arc or stream for a few sec-

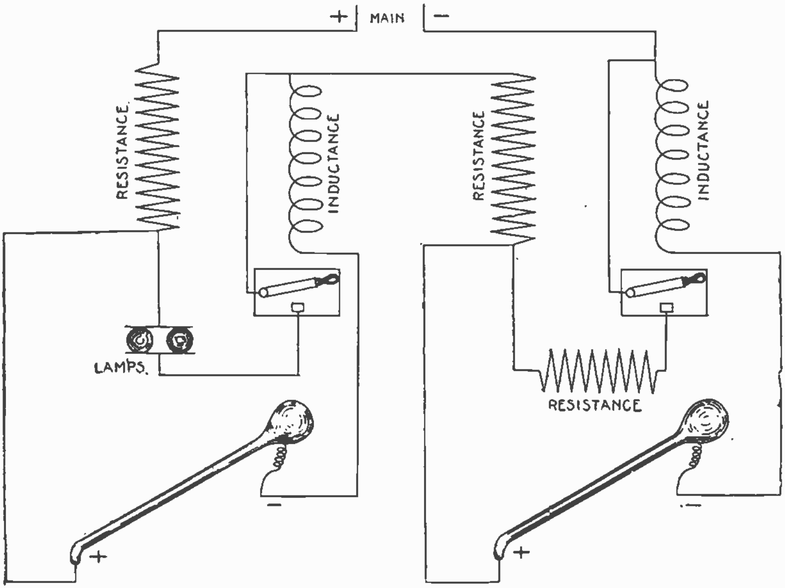


FIG. 8,336.—Diagram illustrating the method of operating Cooper-Hewitt lamps in series.

onds, a larger inductance would be necessary to maintain it for a few minutes or hours, and a still larger one to maintain it continuously. Approximately, a tenfold increase of inductance in the circuit increases the continuity of action about 1,800 times.

The Cooper-Hewitt lamp designed for alternating current is shown in fig. 8,335.

It is similar in all respects to that of the direct current lamp with the exception that the upper end carries two positive electrodes and one small starting electrode, the latter being connected to the starting resistance to one of the positive electrodes.

Neon Luminous Tube Lights.—Neon gas is one of the natural gases in the air prevalent in the proportion of one part of neon to every 66,000 parts of air. Helium, argon, xenon and krypton are the other rare gases which are found in the air. When these rare gases are excited by passing electric current through them they glow with a characteristic color.

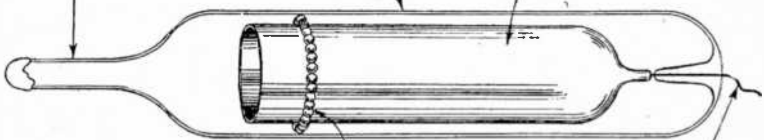


FIG. 8,337.—Neon luminous tube. View showing construction.

Georges Claude experimented for seven or eight years before arriving at a satisfactory method of securing a light which would have sufficiently long life to be practical commercially. He found that unless the neon gas (neon was the first rare gas experimented with) was in practically a pure state the light dimmed and finally died. The proportion of neon in the air was so small that it was impossible to introduce more gas through breather valves as had been done with nitrogen tubes. He next found that the electric current passing through the electrodes at the ends of each tube caused a sputtering or a flying off of small particles of the metal which combined with the neon atoms until there was insufficient gas remaining in the tube and it dimmed and went out.

Claude patented a process which called for electrodes of sufficient size to prevent sputtering; the driving of the occluded gases from these electrodes, and the fine purification of the neon gas. By this method of manufacture tube lights have been secured which have operated more than 20,000 hours. This compares with approximately 1,000 hours for the incandescent lamp.

The procedure in making a luminous tube display is as follows: The sketch is increased to actual size and pounced upon asbestos. Straight lengths of glass tubing of the desired diameter are then heated and blown to the shape of the sketch, electrodes are then sealed in at each end of the glass tubes. then the air is pumped out and neon gas pumped in and the tubes sealed.

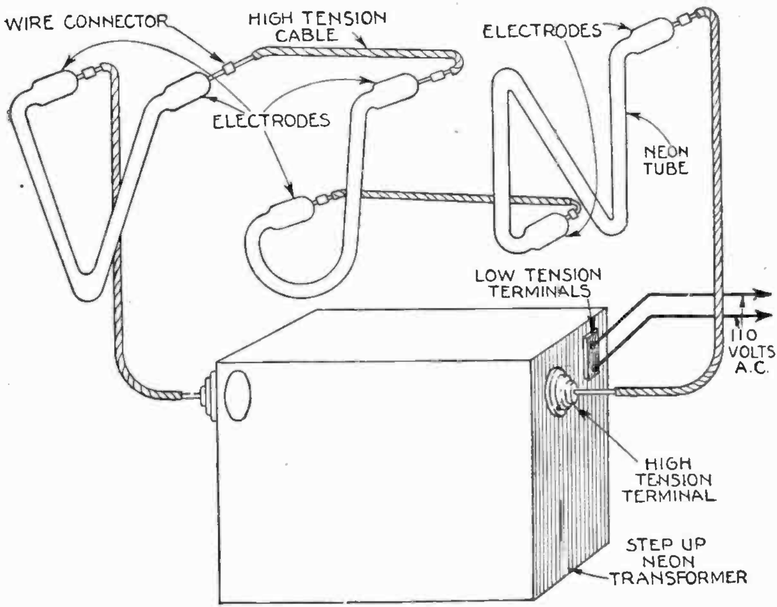


FIG. 8,338.—Neon tubes showing wiring connections.

After an aging process which further purifies the gas, this part of the sign is ready to be attached to the metal frame work or box and lighted.

In the luminous tube signs it is necessary to use high tension current to send it through a sufficient length of glass tubing.

In this country the current averages about 8,000 volts but it is low amperage and not dangerous to life.

When neon gas is contained in a transparent glass tube and agitated with electricity, it glows with an orange red color. Various other gases alone and in combination are used to secure other colors.

For a blue light, mercury is introduced into the tube which vaporizes.

For a green light, the contents of the tube are the same as for a blue light, and an amber colored glass is used instead of the transparent glass.

Several shades of blue, green, yellow and red are obtainable as well as the new white tube light recently perfected by the Claude Laboratories.

When a sign is completed the ordinary 110-volt current is connected with the sign, from there it goes through a step-up transformer and then through the glass tubes.

As a rule all the high tension wiring is properly insulated and contained within the sign. About 50 feet of glass tubing can be operated from one transformer, but usually about five foot lengths of glass tube are used for convenience in handling, installing and repairing.

Wire jump overs connect the five foot lengths to get the maximum amount of tubing operating on each transformer. The amount of tubing which can be operated from one transformer depends on the diameter of the tube and the gaseous content of the tube which regulates the color.

In operation the glass tube containing the gas *is part of the electric circuit and it is the action of the electric current on the gas in the tube which causes the light.*

Neon light is a cold light as there is no filament in the tube to become heated. Accordingly since energy is not wasted through the generation of heat the current consumption is low.

Engineers are working at present on adapting luminous tube lighting for interior illumination, both because it generates little heat and also because it does not glare and irritate the eye. Progress is being made along these lines and in fact installations have already been made.

Constant Current Series System.—The application here described is for street lighting with explanation of the various types of load and control used with the series system.*

Figs. 8,339 to 8,345 is a chart in four sections (**A,B,C,D**). The four classes of constant current street lighting transformers which may be used to supply *a. c.* series lighting systems, are illustrated in section **A.** At the top the oil immersed automatic pole type R. O.; next, the air cooled automatic sub-station type R. F.; the station type R. V. constant current non-automatic regulating transformer; and at the lower left a typical installation of the oil immersed subway type R. O. transformer.

The operation of three of the classes of transformers just mentioned is entirely automatic, and does not require the attendance of a station operator. Requiring the attention of a station operator but functioning at a considerably higher primary power factor is the non-automatic station type R.V. constant current transformer supplying the main series system.

The transformer and load control consists of an FK-41 oil circuit breaker panel equipped with watt hour meter and horn gap lightning arrester. Mounted in the base of the Form 18 Novalux ornamental lantern unit is a single lamp type ILC series transformer. This unit embodies a type M, cut out with type IL series transformer. A film cut out at the lamp base may be used if desired.

Carrying the series circuit underground necessitated the use of very heavily insulated armored cable.

The copper conductor is protected by successive layers of insulation, lead sheath, asphalted jute, two overlapping layers of band steel and a final wrap of asphalted jute.

Having the desirable feature of being easily replaced in the series circuit is the single light type IL with detachable coupling supplying the form 9 unit (*section* **A**). It will be noticed that the schematic diagram adjacent to this unit shows the use of multiple socket and no film cut out (*section* **B**). This practice is permissible for single lamp transformers supplying up to, but not including, 25,000 lumen lamps.

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*NOTE.—*The series system* here described represents the practice of the General Electric Co., the system being known under the trade name Novalux series system.

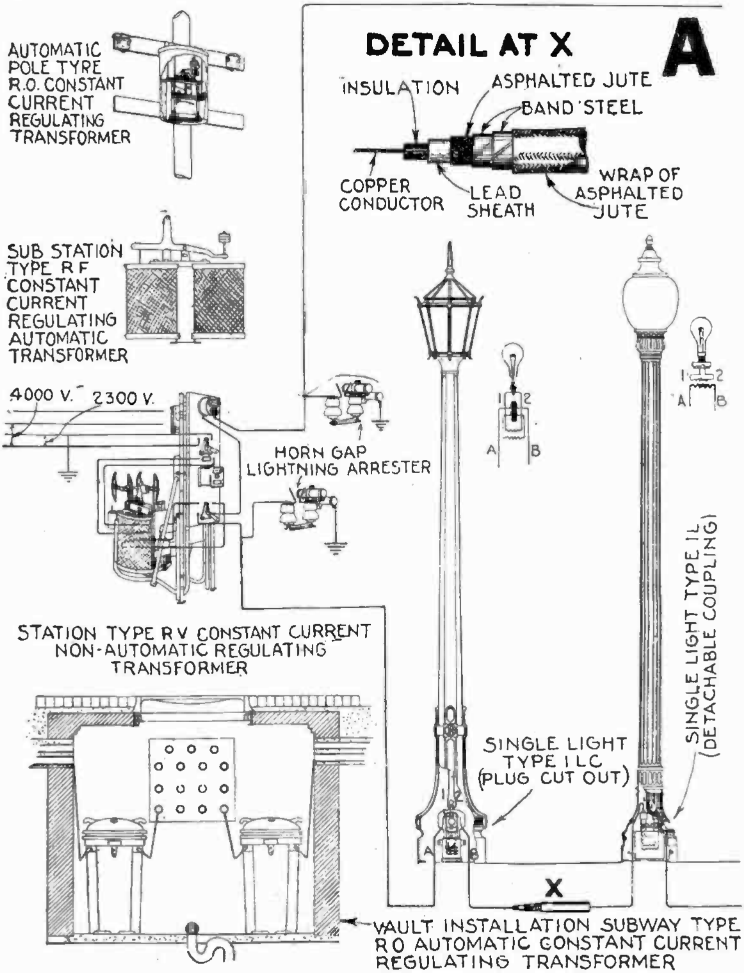


FIG. 8,339 to 8,345.—General Electric Novalux series street lighting system. *Section* **A.**

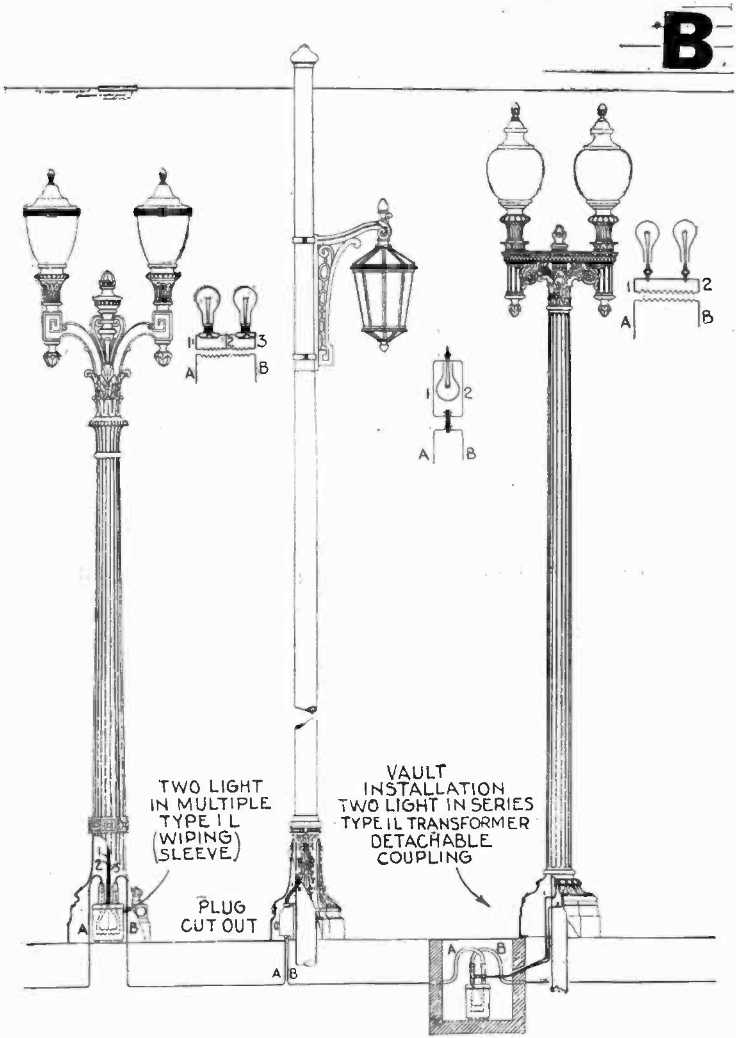


FIG. 8,346 to 8,349.—General Electric Novalux series street lighting system. *Section* B.

The two lamps mounted in Form 12 ornamental units on a single pole are connected in multiple on the secondary of the two light in multiple type IL transformer, cable joints being made through wiping sleeves. This does not require film cut outs and is best for a two light installation. A type M, plug cut out in the base of pole and a film cut out at the lamp supply are shown in the pendant lantern.

Next is a vault installation of a two light in series type IL, transformer (*section* **B**). The transformer requires film cut outs so that in case of the failure of one lamp the other will continue to operate. The Form 32, bracket unit is connected directly into the series circuit with film cut out at the lamp base.

A means of disconnecting individual lamps without breaking main circuit is available in the type R, pot head cut out used with the lamp in the Form 12 unit (*section* **C**).

A concrete post installation is next shown equipped with Form 9, unit and Form E, casing which is designed to permit the use of an auto-transformer, commonly called, compensator. The auto-transformer is a very efficient means of obtaining the 15 and 20 ampere currents necessary for the satisfactory operation of the Mazda series lamps of 400 candle power or over.

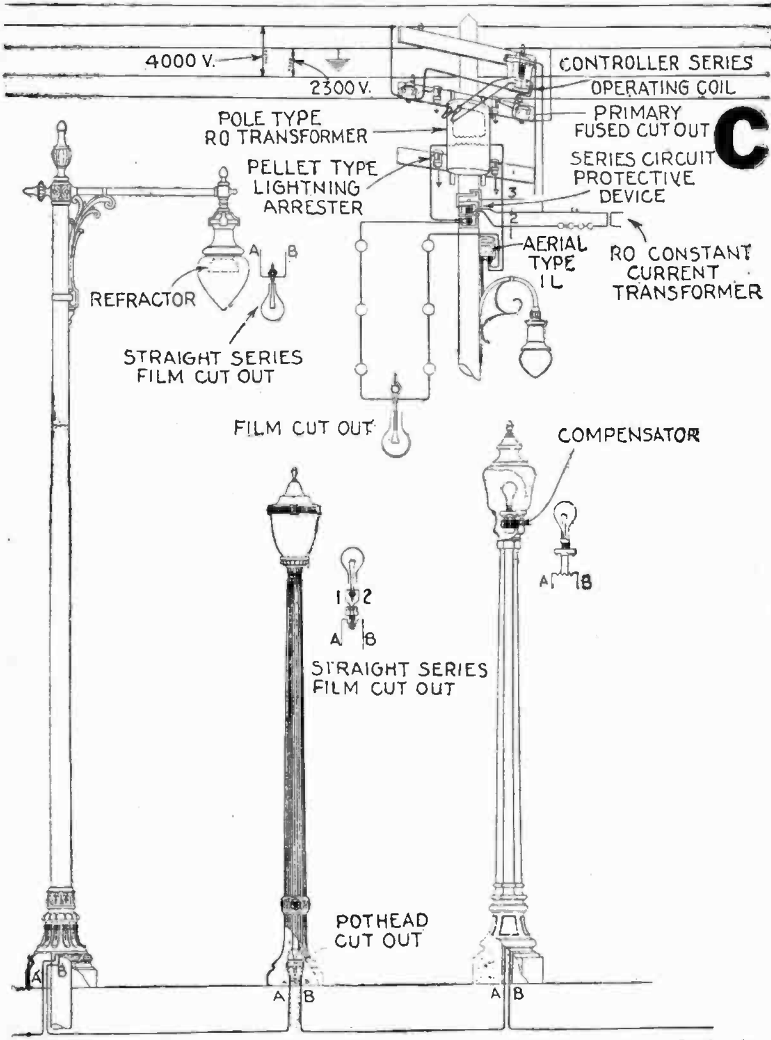
The operation of apparatus such as flood lights, flashing beacons, etc. (commonly designed for use on 115 volt multiple lighting circuits) from a series circuit. is accomplished by means of a series multiple type IL transformer.

For the effective insulation of a small group of series lamps from the main high voltage series circuit a type SL, series transformer is used. To guard against the probability of an open circuited secondary, all sizes of type SL, transformers above 100 watts capacity must be provided with a protective device. The film cut out being shown here.

The next apparatus group shown on the chart is not connected into the main series circuit but illustrates the control of a remote series lighting system and, subsequently multiple lighting system by means of a time switch. The energy for both series and multiple sub-systems is supplied from 2300 V. feeders.

Comprising primary protection between the power line and time switch are pellet type oxide film lightning arresters, and fused cut outs. The series circuit is supplied from the secondary of the pole type R. O. constant current transformer, secondary being protected by pellet type arresters and a standard Novalux series circuit protective device. The right angle bracket attached to the pole holds a Novalux eternalite unit.

Operated by this smaller series circuit is a remote control switch having a series operating coil and multiple contact. Energizing the operating



FIGS. 8,350 to 8,353.—General Electric Novalux series street lighting system. *Section* C.

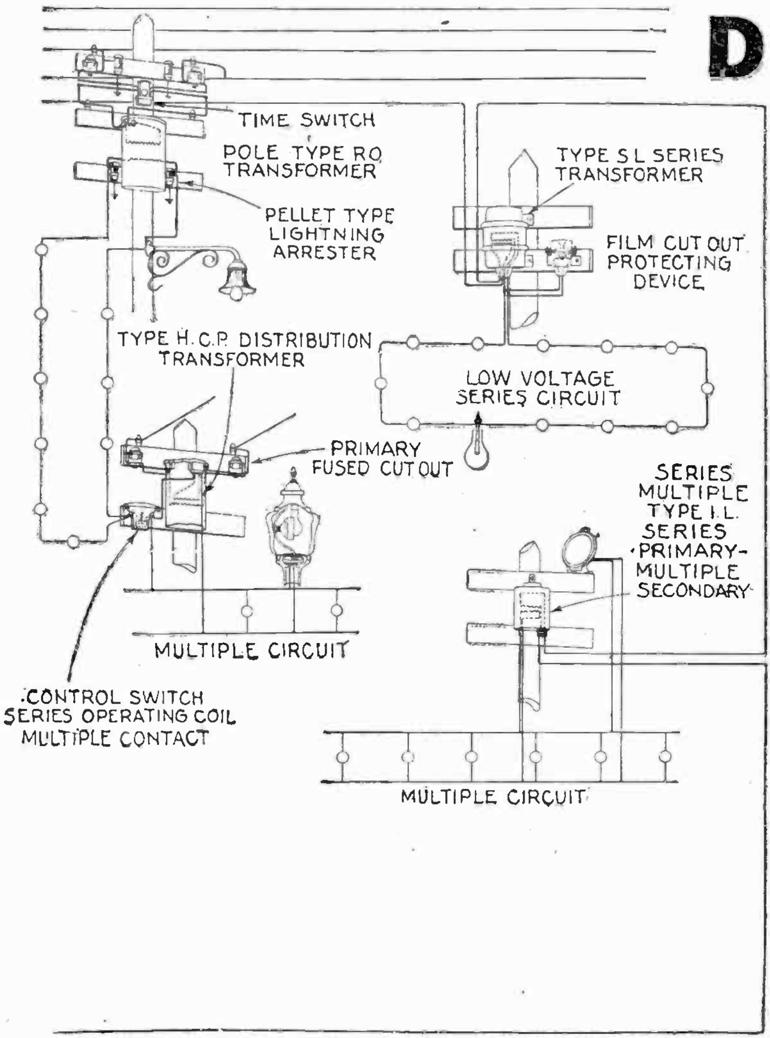


FIG. 8,354.—General Electric Novalux series street lighting system. *Section* D.

coil closes the circuit through the secondary of the multiple transformer and multiple circuit.

In the next apparatus group the original series circuit is used for the remote control of a separate series circuit supplied from 2300 volt feeders by means of a pole type R. O. constant current transformer. Auxiliary apparatus for this installation is similar to that in the group just described except that the Form 6, bracket type unit is supplied from an aerial type IL, series transformer.

Where the series circuit is carried overhead on poles the conductor requires only the standard weatherproof insulation.

TEST QUESTIONS

1. *What are the three sources of electric light?*
2. *How does an incandescent lamp work?*
3. *Describe the construction of incandescent lamps.*
4. *How are incandescent lamps made?*
5. *Describe a turn down incandescent lamp.*
6. *What determines the size of the filament?*
7. *Why is gas used in incandescent lamps?*
8. *What is the construction of an arc lamp?*
9. *What are the different types of arc lamp?*
10. *How does a simple arc lamp work?*
11. *What is a luminous arc?*
12. *What is a vacuum tube lamp?*
13. *Describe the Cooper-Hewitt vacuum tube lamp.*
14. *Draw a diagram of a Cooper-Hewitt* a.c. *lamp.*
15. *Describe the Neon lamp.*
16. *Draw a circuit diagram for a Neon light.*
17. *Describe the operation of a Neon light.*
18. *What are the features of the constant current series system as applied to street lighting?*

CHAPTER 213A

NEON

and Other Discharge Lamps

The difference between the ***incandescent lamp*** and the ***discharge lamp*** is mainly that while the incandescent type produces a continuous spectra dependent almost entirely upon the temperature of the filament, the electric discharge lamps produce lines of discontinuous spectra which are characteristic of the particular gas or vapor used.

An additional difference is, that generally the electric discharge group requires a current limiting device, consisting of an impedance coil, transformer or resistor, depending upon the particular lamp or circuit used.

The electric discharge group includes:

1. Neon lamps
2. Mercury vapor lamps
3. Sodium vapor lamps
4. Ultra-violet lamps
5. Fluorescent lamps

Neon Lamps.—The neon lamp, well known due to its employment in neon signs, contains a small amount of neon gas and an electrode at each end of the sealed glass tube.

From 2,000 to 15,000 volts is applied across the electrodes from its transformer.

Color Effect.—To obtain the brilliant orange-red color effect generated by the gas, the gas must be extremely pure, since a mixture of as little as 1% of nitrogen, for example, will result in a radiation completely dominated by the latter gas.

Various other gases such as *argon* or *helium* alone or in combination, are used to obtain a variety of colors. For a blue light, for example, mercury is introduced into the tube. Color effects can be further modified by the use of various colored glass to obtain the wide variety needed for decorative lighting and sign advertising.

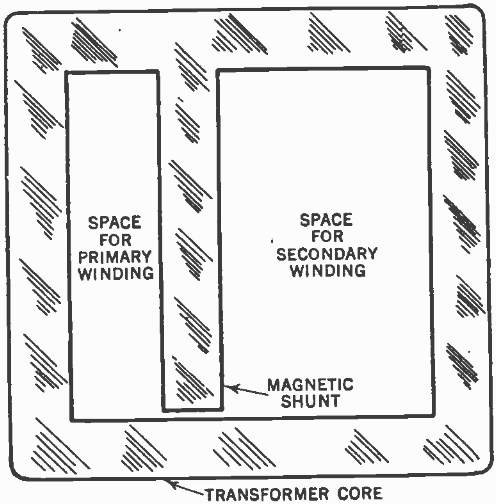
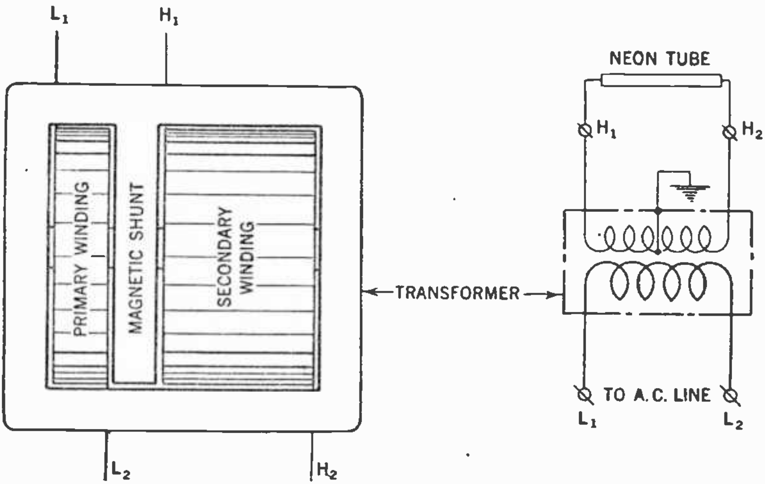


FIG 1.—Outline of neon sign transformer core.

Neon Tube Auxiliaries.—When the neon tube is utilized for sign service, the important auxiliaries besides switches, high-voltage cable and insulators, is the ***step-up potential transformer.***

This transformer differs in certain respects from the well known light and power type, in that it generally has:

1. A large ratio of transformation
2. Small power requirement
3. A special magnetic shunt



FIGS. 2 and 3.—View of neon sign transformer with windings in place, and schematic wiring diagram.

The secondary voltage usually varies of from 2,000 to 15,000 volts, which if transformed from the usual 110 volt lighting current, gives a ratio of transformation of from 18.2 to 136. That is, the secondary winding of the transformer must have from 18.2 to 136 times the number of the primary turns.

Power requirements vary with the amount of tubing to be made luminous and may be from 40 up to 900 volt-amperes.

The function of the special magnetic shunt, fig. 1, is to act as a current regulator for the transformer. It is necessary as a current limiting feature because of the fact that the higher the current through the tube the lower its resistance becomes.

If a neon tube be connected to a transformer of the light and power type (i.e., without the special magnetic shunt) then as the tube is heated up the current would increase. As the current increased, the resistance of the gas would decrease, in turn increasing the current until either the transformer or the tubing would burn out.

Because of the previously mentioned current limiting feature, when the current in the secondary increases, more and more of the magnetic lines are by-passed by the magnetic shunt and as a result, less of the lines connect the secondary winding, until the neon tube reaches a state of equilibrium at which point the secondary current reaches a constant value.

In common with all inductive circuits the transformer has a lagging power factor. The equipment needed for power factor improvement is usually supplied with the transformer..

Neon Glass Tubing.—The fundamental requirements for neon glass tubing are:

1. It must have considerable physical strength
2. It must melt at a convenient temperature, so that it may be worked easily in ordinary gas flames
3. It must be able to withstand sudden and extreme temperature changes without breaking.

There are two general kinds of glass used in neon tubing, namely: *Lead* and *pyrex glass*.

Lead glass tubing contains a considerable amount of lead oxide as the name implies. It is made from silicon oxide and lead oxide melted together with potash and other substances and carefully cooled.

The glass tubing can be bent and shaped with ease over any ordinary illuminating gas flame, the bending sequence depending upon the design of the letters or any other particular geometrical features.

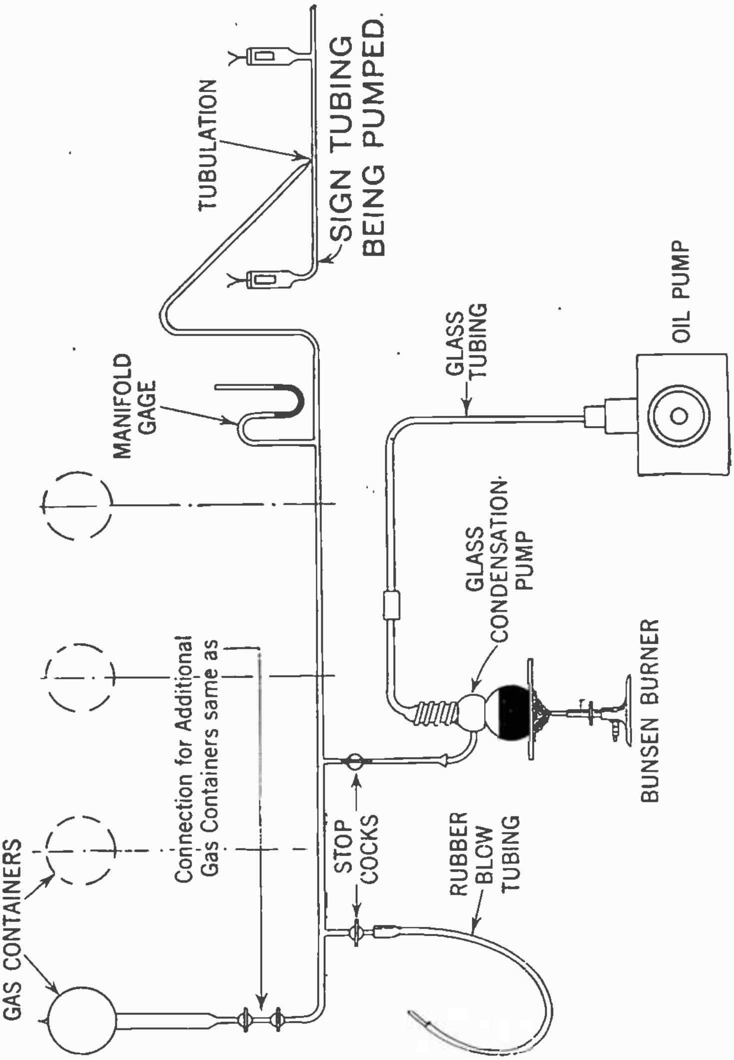


FIG. 4.—Diagram of manifold system showing principal connections.

Pyrex glass can not be bent as easily as lead glass, and requires an oxygen-fed flame. In its physical properties it differs considerably from lead glass, in that it can easily withstand the most extreme temperature changes, and is also mechanically stronger than the former.

Neon Sign Construction.—The first part in the construction of a neon sign is the design of the letters, after which the glass is heated, bent to shape, spliced together, and then a continuous complete tube open at each end is formed.

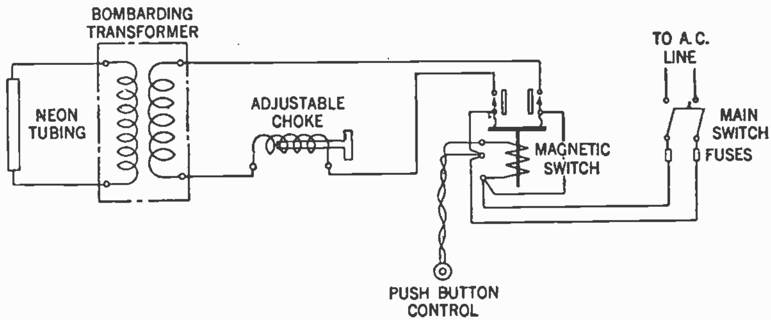


FIG. 5.—Schematic wiring diagram of bombarding transformer with auxiliary equipment.

Next, a hole is made in the center of the tubing and a small tube is attached for the purpose of connecting it to the pump. The electrodes with their glass jackets, are then inserted at each end of the tube, and the pump attached to the entire tubing.

After the pressure in the tube has been reduced slightly as indicated by the vacuum gauge, the stop cock leading to the pump is turned off, so that the pump is disconnected from the tube.

The bombarding operation, to remove the chemical impurities, next takes place. This operation consists in connecting of a high potential current across the electrodes of the tube. This bombardment is kept up for a length of time depending upon the size of the tube and other particulars.

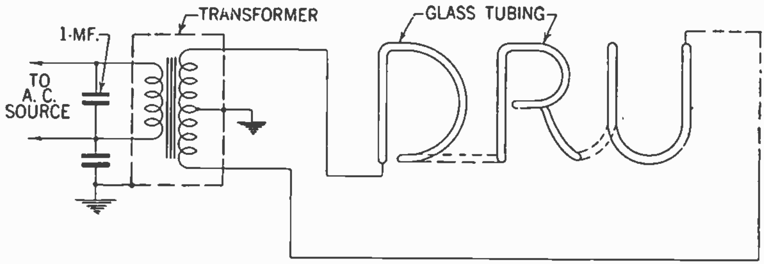


FIG. 6.—Typical wiring diagram showing radio interference suppressor in transformer primary.

At the completion of this process the pump stop-cock is again opened, and the pump again reduces the pressure and removes the impurities being loosened by the bombarding process.

The pump stop-cock is now turned off, and the stop-cock leading to the rare gas flask is opened slowly to admit gas to the tubing.

When the proper pressure as indicated by the vacuum gauge is reached, the stop-cock is turned off, the tubulations leading from the pumps are sealed, thus completing the process.

Other Classes of Neon Lamps.—The more recent types of neon vapor devices are the *hot cathode tube* and the *glow lamp*. In the former device one of the terminals is heated to incandescence. This allows the lamp to be operated at a considerable lower voltage and provides a considerable higher efficiency than normally obtained by discharge through neon.

The *glow lamp* has found an extensive use on pilot lights, current indicators, signal lamps and for stroboscopic work. Its main characteristics are: 1, *low current consumption;* 2, *long life;* 3, *low brilliancy;* 4, *ability to withstand shocks and vibration.*

Both of these lamps may be used on either *a.c.* or *d.c.* current. When used on *d.c.* current only one electrode glows, thus indicating polarity, which factor extends its use for various testing purposes.

With most lamps of this type a current limiting resistance is built into the base and external auxiliaries such as are associated with other discharge lamps are not required.

The Mercury Vapor Lamp.—The extensive use of the mercury vapor lamp depends entirely upon the versatility of the mercury vapor as regards pressure, temperature, voltage and other characteristics, each change resulting in a lamp of different spectral quality and efficiency.

The lamps of the group utilized for general lighting service are usually described as the high intensity mercury lamp. The pressure within the enclosure varies from one atmosphere up to as much as 80 atmospheres for special lamps.

Operating Features.—The mercury vapor lamp usually contains a small amount of argon gas to facilitate starting, since mercury is normally a liquid at room temperature, and even in partial vacuum has very little vapor pressure.

After a few minutes of electrode heating the arc vaporizes enough mercury to reach the point of stabilization. The exact point is dependent on each particular lamp, and is controlled by the design of the auxiliaries.

As the mercury pressure increases, the arc becomes concentrated at the center of the bulb, usually tubular in shape. Under certain conditions the lamp can be burned only in a vertical position as otherwise the concentrated arc will bow, touching the glass and causing its breakage.

The intense heat of the arc in some of the mercury lamps requires the use of a quartz envelope rather than glass.

When the current of any high pressure lamp is interrupted, a few minutes of cooling is required.

The consequent lowering of internal pressure allows the arc to again strike and normal operation is resumed.

Color Effect.—The light produced by high intensity vapor lamps shows three main lines—*yellow, yellow-green and violet.* Due to the energy concentration in the yellow-green area of the spectrum, the luminous efficiency is very high—the human eye being most responsive to color in this area.

Sodium Vapor Lamps.—Scientists have long been familiar with the fact that high luminous efficiencies could be obtained by the use of sodium vapor as a light source.

The development of a practical lamp of this type, however, was delayed since ordinary glass cannot withstand the chemical action of hot sodium.

With the development of special resistant glass, the sodium vapor lamp has now reached the practical stage.

Operation.—Principally the sodium vapor lamp consists of a bulb containing a small amount of metallic sodium, neon gas, and two sets of electrodes connected to a pin type base.

In order to conserve the heat generated and assure the lamp operating at normal air temperatures, it must be enclosed in a special vacuum envelope designed for this purpose.

The presence of neon gas serves to start the discharge and to develop enough heat to vaporize the sodium. This condition accounts for the red-orange glow during the first few minutes of operation.

The metallic sodium gradually vaporizes and then ionizes, thereby producing the characteristic monochromatic yellow light. The lamp will come up to its rated light output in approximately 15 to 20 minutes. It will restart immediately should the power supply be momentarily interrupted since the presence of vapor is quite low and the voltage applied sufficient to restrike the arc. The major application of this type of lamp is for *highway* and general *outdoor lighting* where color discrimination is not required.

Ultra-Violet Lamps.—The increasing application of ultra-violet radiation has resulted in the development of a number of different sources which produce this short-wave energy.

Ultra-violet radiations are commonly produced by carbon and tungsten arcs and also in various gaseous discharge lamps. The term *ultra-violet radiation* in general, refers to that part of the electro-magnetic spectrum adjacent to the visible spectrum and extending roughly from 1000 to 3800 Angstrom units.

This band may be divided into four narrower bands each with distinct characteristics, thus:

(A) 3,200 to 3,800 Angstrom is useful in certain types of photography and fluorescent displays.

(B) 2,800 to 3,200 Angstrom known as the *biologically* effective band which produces sunburn and tan.

(C) 2,000 to 2,800 Angstrom, the bacterial band which is lethal to most micro-organisms.

(D) 1,000 to 2,000 Angstrom, the ozone producing band about which very little is hitherto known.

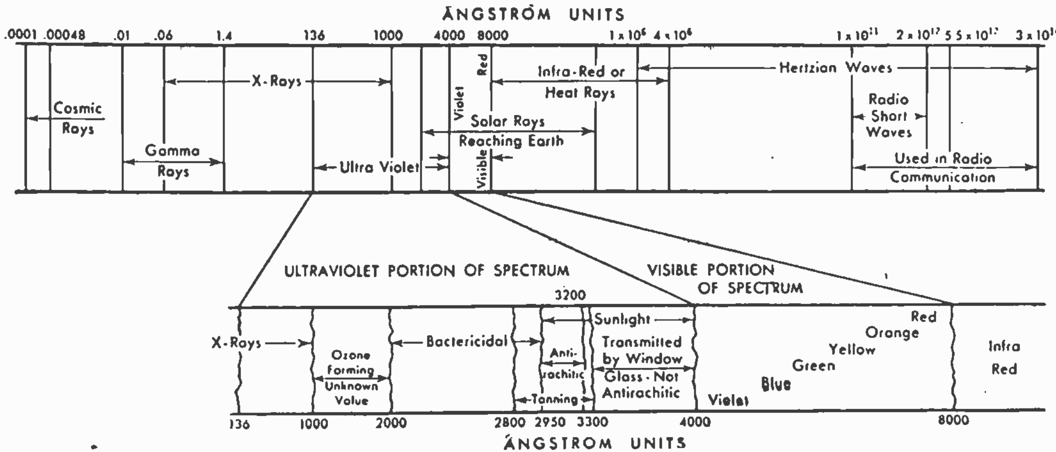


FIG. 7.—The spectrum. The angstrom unit is used to express the wave length of light and ultra-violet radiations. One angstrom unit is equal to 1/10,000,000 of a millimeter or approximately 1/250,000,000 of an inch.

Steri-Lamps.—The fact that ultra-violet radiation destroys micro-organisms has made this type a most useful tool for all sorts of sterilizing purposes.

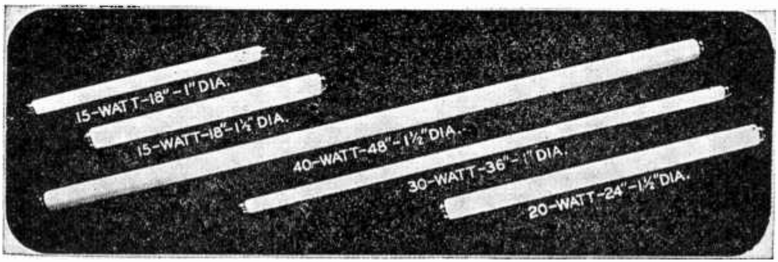
They are being used successfully for sterilizing air in ducts of air-conditioning equipment, for prevention of the formation of mould in food industries, such as walk-in meat coolers, domestic refrigerators, bakeries, dairies, and in hospitals, etc.

Just what the ultimate fields of application for these lamps will be, no one can predict. One use leads to another, and unquestionably many applications will develop as time goes on. It is, however, already apparent that there are now available new tools in the form of light sources that will contribute much to human welfare and industrial progress.

CHAPTER 213B

Fluorescent Lamps

In contrast to the well known filament lamp in which electricity flows from one lead wire to another through the solid tungsten wire, thus heating it to incandescence, the fluorescent lamp in common with other electric discharge devices makes use of ultra-violet energy to activate a **fluorescent material** coated on the inside of the bulb's surface.



Figs. 1 to 5.—Various size fluorescent lamps.

The coating material used depends upon the color effect desired and may consist of ***zinc silicate, cadmium silicate*** or ***calcium tungstate.*** These organic chemicals are known as ***phosphors,*** which powder transforms short-wave invisible radiation into visible light.

Construction of Fluorescent Lamps.—The lamp in its present form consists of a tubular glass-bulb with two external contacts at each end, which are connected to filament-type electrodes made of coiled tungsten wire (See fig. 6). These filament electrodes are coated with an active electron emissive material.

Within the bulb there is a small drop of mercury and also a low pressure (a few millimeters) of pure argon gas to facilitate the starting.

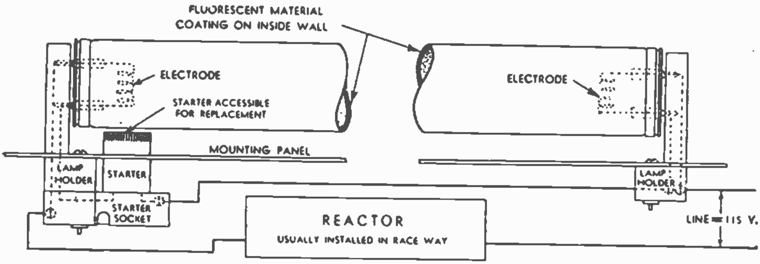


Fig. 6.—Assembly of typical fluorescent lamp showing auxiliaries and connections.

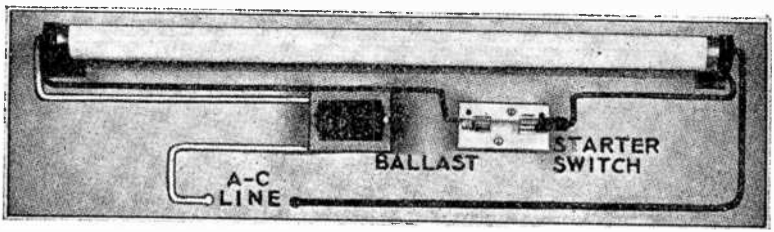


Fig. 7.—Simplified diagram of fluorescent lamp and auxiliaries. The ballast choke coil performs the function of limiting the current to the designed value required by the lamp. The starter switch (shown as a simple knife switch for the sake of clearity) momentarily closes the heating circuit through the filament electrodes to facilitate starting.

Starting Auxiliaries.—Fluorescent lamps in common with all electric discharge apparatus requires *auxiliary control equipment*. The function of the starting auxiliaries is to create *a momentarily high-voltage impulse* in order to establish an arc between the electrodes at the opposite ends of the tubular lamp.

The auxiliary consists of two principal elements: 1, an iron core choke coil (ballast) which limits the arc current, and 2, a starting switch which momentarily closes and then opens the electrode heating circuit. See figs. 7 and 8.

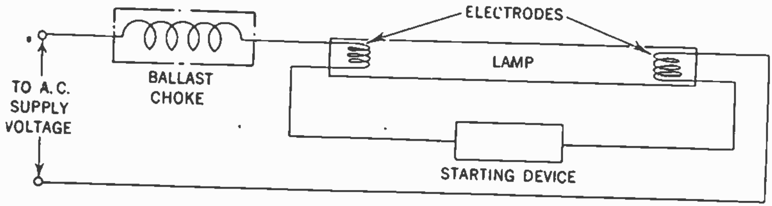


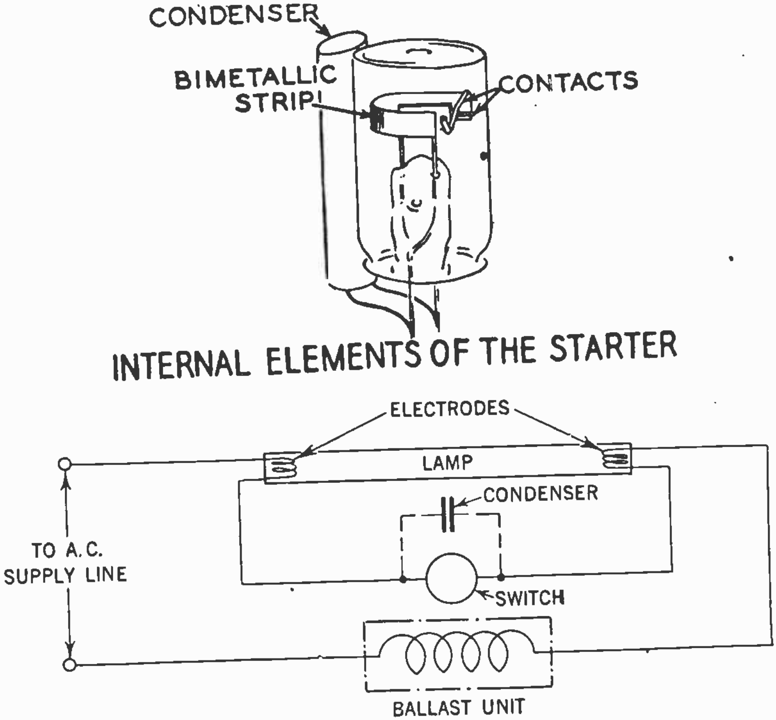
FIG. 8.—Schematic diagram showing connection of fluorescent lamp.

Each lamp requires a separate auxiliary, although the elements for two or more lamps may be contained in a single unit. Specifically designed ballast equipments are required *for each wattage size*, *for each frequency* and *for each voltage range*.

When the lamp was first introduced a number of starting methods such as the thermal switch, resonant and magnetic switch type were exclusively utilized. Recently, however, a switch known as the *glow switch* operating on the thermal principle has been manufactured.

Operation of Glow Switch.—This new starting device is about 1 in. long and about ⅜ in. in diameter and resembles a miniature electric lamp, but contains an easily ionized gas and two bi-metallic electrodes which serve as the switch contacts.

The switch is connected in series with the fluorescent lamp electrodes; when the current is turned on a glow discharge is created between the normally open switch contacts on the bi-metallic electrodes.



Figs. 9 and 10.—Glow switch starter and connection to lamp unit.

The heat of the glow causes the contacts to close. At this point the lamp electrodes are heated to a bright red color. When the contacts close the glow discharge automatically ceases, allowing the bi-metal elements to cool and separate, opening the switch and striking the arc.

The whole operation from the time the current is applied and until the arc is established requires only one or two seconds.

As used in the new fluorescent lamp starter, the glow switch and a tiny condenser to eliminate radio interferenece are housed in a small aluminum shell equipped with a bayonet-type end and inserted in a special socket attached to the standard fluorescent lamp holder. Thus the starting unit is readily accessible and replaceable. Since it is now separate from the starting unit and need not be accessible after installation, choke or ballast device (necessary to limit the operating current) is made more compact and may be mounted in any convenient place.

Need for Power Factor Correction.—It is a well known fact that power consuming apparatus of the *inductive class* such as coils and other current limiting devices has a *lagging power factor* i.e., the current is lagging the voltage by a certain amount depending upon the size of the coil or device in question. Thus, for example, the equation for power in all direct current circuits and in alternating current circuits containing only pure ohmic resistance is,

$$\text{watts} = \text{volts} \times \text{amperes}.$$

If, however, other circuit elements be present, as in the case of the fluorescent lamp circuit, with the inductive choke coil in series with it, the equation for true power becomes

$$\text{watts} = \text{volts} \times \text{amperes} \times \text{power factor}.$$

The power factor of the average fluorescent lamp itself is approximately 90%, practically, however due to the ballast choke the power factor for the complete unit is reduced to from 50% to 60%.

It is evident from the above, that especially where a large number of lamps be required, certain corrective equipment is required to increase the power factor and thus increase the economy of operation. An effective method of *improving* the *power factor* to unity (or nearly so) is to connect a suitable condenser across the choke coil in the case of single lamp ballast and in case of two lamps ballast to use the "split phase" principle with one of the lamps ballasted by inductive reactance only and the other by inductance and capacitance in series, as shown in figs. 11 to 14.

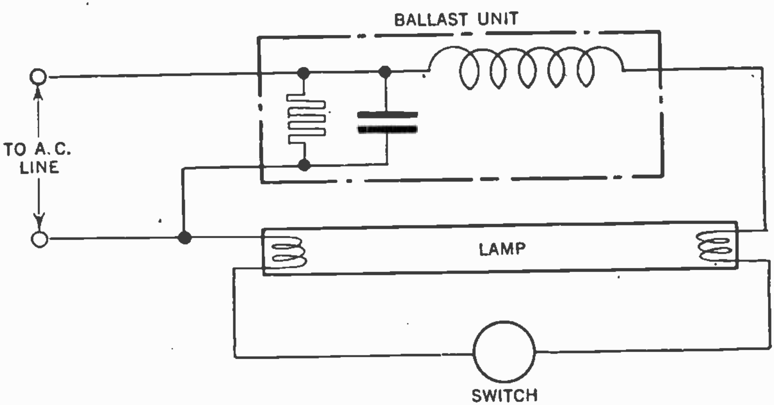


FIG. 11.—Method of connection for single unit fluorescent lamp, with corrected power factor.

Useful Lamp Life.—In general, fluorescent lamps lose their usefulness because of decrease in light output before they fail to operate. Darkening of the bulb occurs because of the effect of mercury on the fluorescent coating and because of the material given off by the electrodes. The latter especially causes darkening at the ends of the bulb late in life. The rate of depreciation in light output diminishes throughout life; the first hundred hours produce about as much darkening as the following 1000 hours. Rated output is based on conditions at 100 hours.

Frequent starting of lamps may take more life out of the electrodes than long hours of burning because momentarily there is a higher than normal voltage drop at the electrodes which causes the active material to sputter or evaporate off. If a lamp be started once a minute, for example, the hours of burning will be shorter than normal, but if it be turned on and burned continuously, its life will be longer than normal. When the active material on the electrodes is nearly exhausted, the voltage required for starting will rise and may equal or exceed the available supply. This may occur after the lamp has been started thousands of times or burned beyond its rated life. Sometimes the end of life is indicated by the lamp flashing momentarily and then going out.

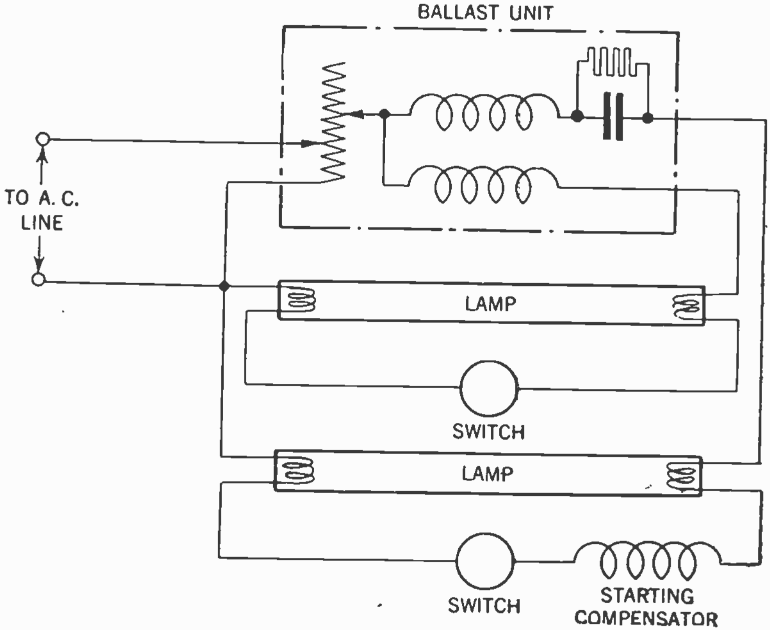


FIG. 12.—Method of connection for two unit fluorescent lamps, with corrected power factor.

Lamp Quality.—Quality in a fluorescent lamp, aside from the purely mechanical features to insure sturdy base pins, end seals and electrode construction, is largely a matter of efficiency of light production and uniformity in spectral quality. Shortcomings in mechanical construction quickly manifest themselves in service and the necessary requirements in mechanical design become apparent and are easily corrected. Less obvious but of more permanent significance is the control of those elements that make for efficiency and spectral quality. On these latter factors alone rests the principal interest in this new illuminant. These permit new perspectives in artificial lighting.

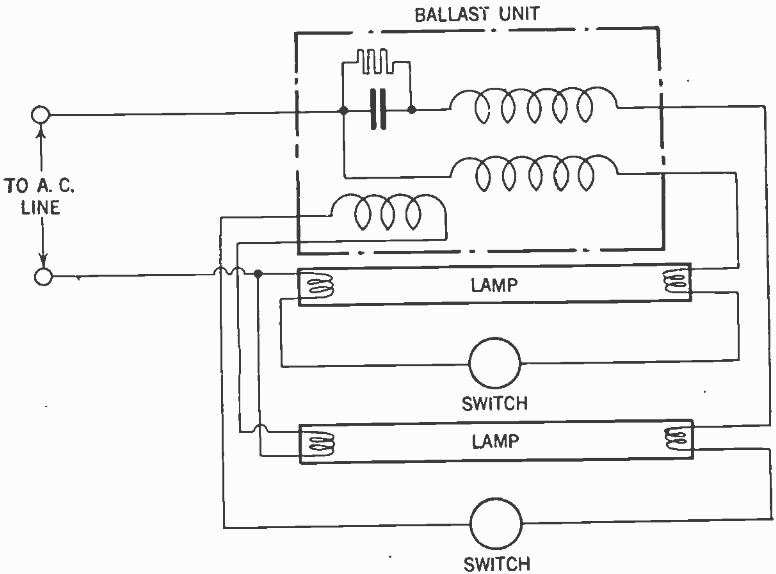


FIG. 13.—Another method of connection, for two unit fluorescent lamps, with corrected power factor.

To produce light by fluorescent principles is relatively simple, but it *takes skill* to produce the *highest efficiency* and integrity of spectral color quality. This involves the utmost in purity of materials and timing of chemical processing of the *phosphors* used. It involves, also, precise blending of basic *fluorescent chemicals* and invariable competent engineering to furnish high quality, dependable lamps.

Fluorescent lamps will burn in any position, although when burned in a vertical position the condensing mercury may cause a slight streaking of the powders upon condensation. Like filament lamps the larger sizes as represented by length are more efficient than shorter length lamps. This is because there is a fairly constant wattage loss at the electrodes regardless of length of lamp. Efficiency is also dependent upon fine relationship of current density and vapor pressure. These are in turn affected by operating temperature.

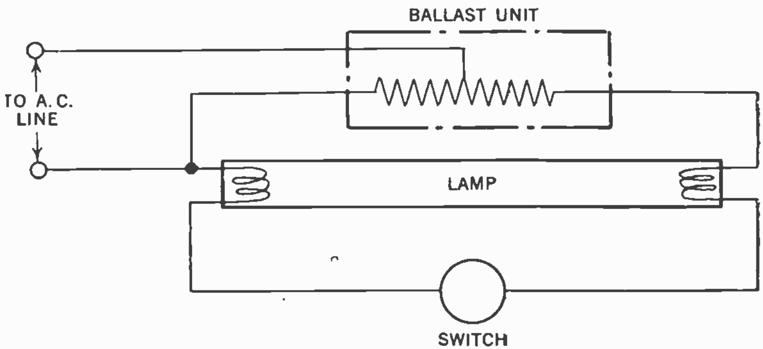


Fig. 14.—Method of connection for single unit fluorescent lamp, with uncorrected power factor.

Radiant Heating Effects.—Confusion is sometimes expressed at the assertion that fluorescent lamps produce cooler foot-candles than do incandescent lamps. While a kilowatt-hour represents over all a heating effect of 3,414 B.t.u.'s regardless of how consumed, the lesser sensation of heat from fluorescent lamps lies in the fact that only about 35 or 45% of the energy is radiated as compared to 75 to 85% for the filament lamp.

Because the efficiency of light production by fluorescent lamps is about double that of filament lamps, and also because the radiant heat is only half that of filament lamps, this is the basis of the statement that the sensation of heat from fluorescent lamps is, roughly, only one-fourth that from filament lamps for the same amount of light delivered.

Stroboscopic Effect.—As the line frequency of the alternating current in most localities is 60 *cycles per second*, the standard line of fluorescent equipment is manufactured for that frequency.

This in practical terms means that the light output will be passing from its maximum to its minimum value 120 times per second. It is possible that this may, in some instances, give rise to a *stroboscopic effect*, that is moving objects such as *rotating parts of machinery*, illuminated by this light, may appear to be moving in disunity or jerks, or rotating more slowly than their actual speed.

In actual application, however, where this effect might cause annoyance, it can be practically eliminated in a three lamp unit by connecting each lamp on a separate phase of a three phase system, and it can be greatly reduced in a two lamp unit by the use of a two lamp control unit, which employs a condenser in the ballast of one of the lamps as shown in figs. 12 and 13.

The current through the lamps is thrown almost 90° out of phase and under these conditions the light output of one of the lamps is at a maximum. This method has an additional advantage of producing a combined power factor of nearly unity for tne two lamps.

Radio Interference.—The fluorescent lamp in common with most electrical devices may cause a certain amount of radio interference. This interference may be caused by one of the following factors:

1. Direct radiation from the bulb to the antenna. This effect diminishes rapidly as the radio is separated from the lamp. Thus, for example, at a radius of 9 ft. interference from this cause is negligible.

2. Line radiation from the electric supply line to the antenna.

3. Line feed-back from the lamp through the line to the radio.

Interference from line radiation and line feed-back can be minimized by proper application of line filters.

The latter two causes of radio interference effects may be reduced to a minimum by incorporation of *proper condensers* in the equipment.

Installations.—While fluorescent lamp installations may not match the simplicity associated with the incandescent lamps, the choice between the two systems should rest on both the engineering and economic consideration involved in each individual case. The following considerations should be followed in the use of fluorescent lamps:

1. That only power factor corrected auxiliaries be used
2. That only replaceable starter auxiliaries be considered for all except specialized installations.
3. That both lamp size and ballast equipment be chosen to make up the most economical installation

Like filament lamps, the **efficiency** of fluorescent lamps increases with the **increase** in *wattage sizes.*

The *replaceable starter* system makes it practical to locate the ballast at some distance from the lamps, because two wires are eliminated which were formerly needed to connect auxiliaries with built-in switches.

This is particularly advantageous for installation where lamp space is restricted, or where the application requires a special location of the ballast equipment.

Lamp Sizes.—The lamps are at present manufactured in four wattage sizes: **15, 20, 30 and 40,** with the lengths varying from **18 to 48 inches.** It should be noted that the *larger lamps are more efficient.* Hence for large illumination projects the larger lamps are more practical because of the lower lamp cost per foot, and also because of the higher efficiency.

Circuit Voltages.—With fluorescent lamps, voltage regulation depends upon the choke used and not on the starting mechanism. The voltage, unless otherwise stated, is alternating current at a *frequency of* 60 *cycles per second*, although special auxiliaries are manufactured for use on other commercial frequencies as well as on direct current.

The voltage range of the lamps including ballast is from 110 to 250 volts.

Wiring.—The assembly and wiring of the fluorescent lamp does not differ markedly from any other light wiring schemes. It is evident that the **National Electric Code** giving the regulations of the **National Board of Fire Underwriters** or additional local requirements should be strictly adhered to.

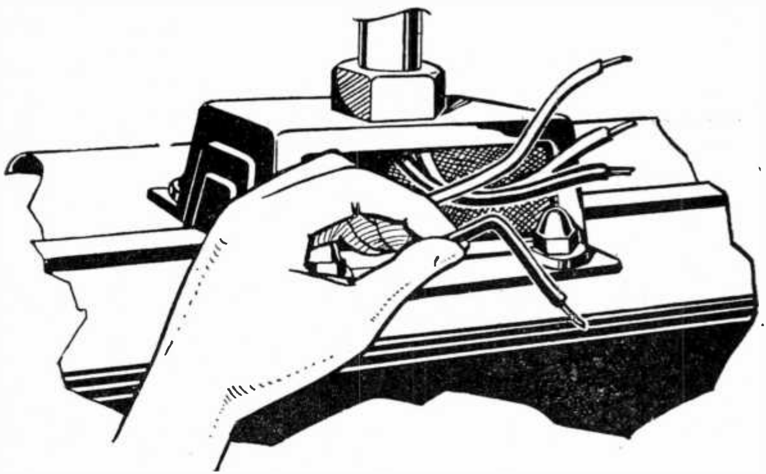


Fig. 15.—Splice box with cover removed, showing wires ready for splicing.

Particular attention should be observed in regard to installation of lamps with uncorrected power factor. Such units with their auxiliaries have an average power factor of only from 50 to 60%.

In addition to being a source of annoyance to the power supply companies, installations of such units will cause undue heating and danger due to insufficient wire capacity.

As an illustration of the effect of power factor, suppose that a load of 250 watts is connected to a 125-volt circuit. The current in this circuit will be 2 amperes if the power be unity or 100%, but if it be only 60%, for example, 3⅓ amperes will be required to supply the same power. In other words, an extra 1⅓ amperes must be circulated through the transmission system producing heating of the wires with a consequent loss of power.

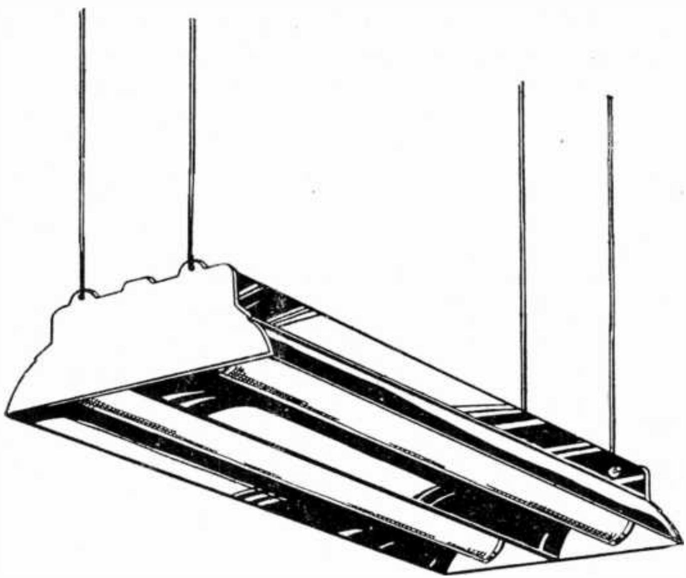


FIG. 16.—Typical two-unit fluorescent lamps assembled with reflector.

With large loads and low power factor this condition may become very serious from the point of view of the power supply company since the capacity of their entire system must be designed on the basis of the current that flows through it.

Mounting of the Lamps.—The lamps may be hung in any position desired, and may be purchased either with or without their auxiliaries. The units are usually provided with hangers for supporting from a rigid conduit and this hanger is usually supplied with a splice box as shown in fig. 15.

Reflectors are designed to provide for either direct, semi-indirect or indirect illumination. A typical two-lamp unit fully assembled is shown in fig. 16. Lamp holders are wired to auxiliaries according to manufacturers, instructions. Either thermal or magnetic type starting switches may be used, although the previously discussed glow switch, operating on the bi-metallic thermostatic principle, if used, will greatly simplify wiring and also facilitate switch trouble location.

CHAPTER 214

Illumination

By definition: *Light is a **rapid vibratory motion** which is transmitted in the form of waves on the ether;* in other words, *light is a **sensation** received through the organ of sight and is caused by waves which are transmitted on the ether.*

The term illumination is defined as *the density of light flux projected on a surface;* it denotes *the **art** of using artificial sources of light*, that is to say, the problem of illumination involves *the **selection** and **arrangement** of these artificial sources of light* so that the objects to be lighted will show up to the best advantage and with the minimum amount of artificial light.

Terms and Units Used in Illumination.—The definition of terms and units which follow should be carefully noted.

Beam.—Several parallel rays.

Candle foot.—The illumination produced by a light of one candle power at a distance of one foot.

Candle power.—The amount of light emitted by a sperm candle seven-eighths inch in diameter and burning 120 grains (7.776 grams) per hour.

Lumen.—The standard of luminous flux, being the light sent out from a unit source through a unit solid angle.

Lux.—The sectional intensity of a one candle power beam at a distance of one meter from the source of light; that is, it is a *meter candle*, since 1 meter = 3.1 foot, one meter candle $= 1 \div (3.1)^2$ candle foot.

Mean conical candle power.—The mean of the candle power in all directions making a given angle θ with the equatorial plane of a lamp; it is the mean conical candle power at the angle ϑ.

Mean spherical candle power.—If there be drawn from a source, equally in all directions, lines whose lengths are proportional to the candle power in these directions, then the mean value of the lengths of all these lines is the mean spherical candle power.

Pencil.—Several rays converging to a point.

Photometry.—The process of measuring the intensity of light. The instrument by which the candle power is determined is called a photometer.

Ray.—The direction in which a light wave is advancing.

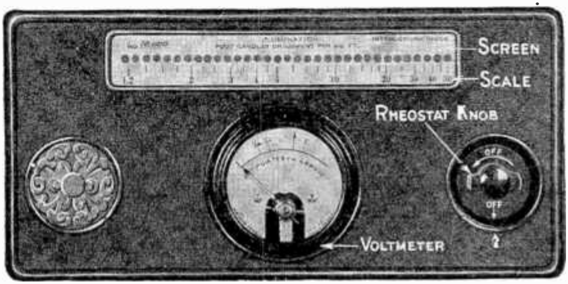
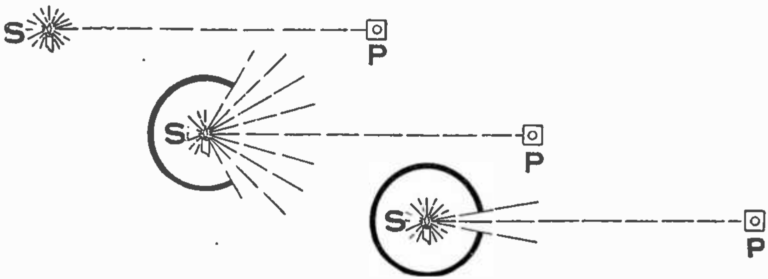
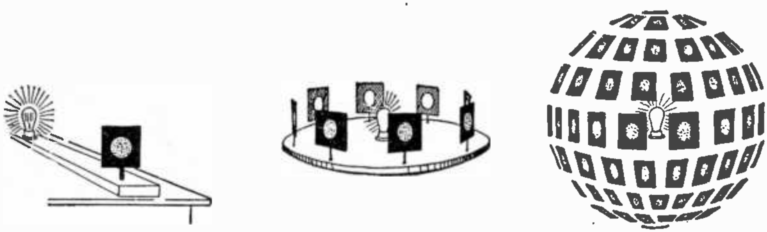


FIG. 8,355.—General Electric foot candle meter. To obtain readings, place the foot candle meter on the desk against the wall, or in any other location where it is desired to measure the illumination. *Make sure that no unusual shadows are cast on the screen.* Select on the screen the round spot which most nearly disappears, that is, appears to be of the same brightness as the white screen surface. Read the illumination directly in foot candles from the point on the scale which is beneath this spot. Foot candle readings may be obtained from any angle while viewing the meter from the side. Readings should not be taken while viewing the meter from the ends, as erroneous indications will be obtained.

Foot Candle Measurements.—An approved instrument for this purpose is the foot candle meter as shown in fig. 8,355. In operation it is placed upon or adjacent to the surface on which a measurement of the foot candle intensity is desired. A lamp within the box illuminates the under side of the screen to a much higher intensity at one end than at the other. The illumination which it is desired to measure is of course, practically uniform over the entire scale.



FIGS. 8.356 to 8.358.—Candle power as indicated by a photometer fig. 8,356 shows a standard candle and a photometer pointed toward the candle. When the photometer is balanced against a known source, it will indicate one candle power. In fig. 8,357, the same candle is surrounded by a sphere painted a dead black so that none of the rays striking it are reflected but are absorbed and cease to be light, in other words, are thrown away as far as the experiment is concerned. In this case the photometer will still indicate a luminous intensity of 1 candle in spite of the fact that a great deal of light has been thrown away. In fig. 8,358, a sphere with a much smaller opening is used and therefore still more of the light is wasted, but even in this case the photometer will indicate 1 candle power In fact, the reading will be 1 candle regardless of the size of the opening; that is, regardless of the quantity of light allowed to be emitted, provided the direct rays from the candle to the photometer are not obstructed. The proverbial light hidden under a bushel, if it is 1 candle, will give out 1 candle power if there be a small hole in the bushel for a beam to escape. As far as its general illuminating value is concerned, it is still hidden under a bushel. This leads to the important conclusion that the candle power of a source does not necessarily give an indication of the total quantity of light emitted by the source, as explained in figs. 8,359 to 8,861,



FIGS. 8.359 to 8,361.—Measurement of candle power, fig. 8,359, horizontal candle power; fig. 8,360, mean horizontal candle power, fig. 8,361, mean spherical candle power. The candle power of a source does not necessarily give an indication of the total quantity of light emitted by the source. An automobile head lamp may, for example, produce a beam with maximum candle power of 100,000 the source being a 21 c.-p. lamp. Closely related to candle power is mean spherical candle power. The mean spherical candle power of a lamp is simply the average of all the candle powers in all directions about the lamp. A source giving one candle in every direction would have a mean spherical candle power of 1, or if a source gave off various candle powers in different directions and if the average of all these candle powers were 1, the source would have a mean spherical candle power of 1. The infinite number of directions in which a source ordinarily emits light do not all lie in the same plane, but extend into space on all sides about the source, like the pricks of a chestnut burr.

Closely spaced translucent dots line the scale from end to end. If the illumination on the scale from the outside fall within the measuring limits of the meter (1.2-50 foot candles) the spots will appear brighter at one end of the scale than at the other, and at the point where the spots are neither brighter nor darker than the white paper scale, the illuminations from within and from without are equal.

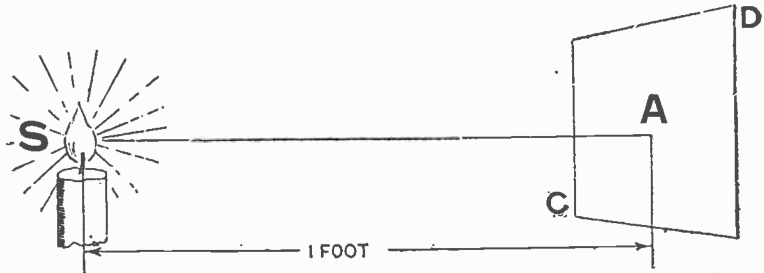


FIG. 8,362.—One foot candle. If the source S give an intensity of 1 candle along the line SA and if A is 1 foot distant from the source, the level of illumination on the plane CD at the point A is 1 foot candle. The level of illumination measured in foot candles, is the measurement most intimately associated with everyday use of light, and a measurement which the eye either consciously or unconsciously is making whenever the faculty of vision is being employed, for the number of foot candles there are on the working plane, other things being equal, determines directly whether or not there is sufficient light.

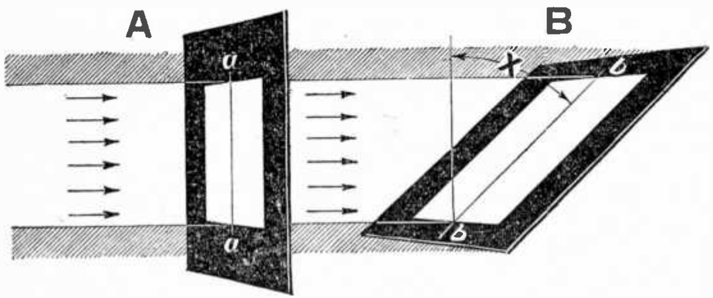


FIG. 8,363.—Illumination of perpendicular and inclined surfaces. If instead of being perpendicular to the beam of light as at A a plane is tilted at the angle X, as at B, the same amount of light is spread over a greater area. The illumination on B is to A inversely as the length bb is to aa or as cosine X. Thus if cos X = .7, and the foot candlage on A is 1, the illumination on B would be .7 foot candle.

The scale is accurately calibrated, with the lamp within the box burning at a certain definite voltage. A volt meter and rheostat enable the operator to adjust the lamp voltage to four different values, which permit the instrument to be used for intensities ranging from a minimum of .012 to 100 foot candles. The energy is supplied from small dry cells.

Candle Power Distribution Curve.—This distribution curve of a lamp or unit was at one time widely used in calculating illumination intensities, but the greater simplicity and accuracy of the lumen method of computing illumination has resulted in

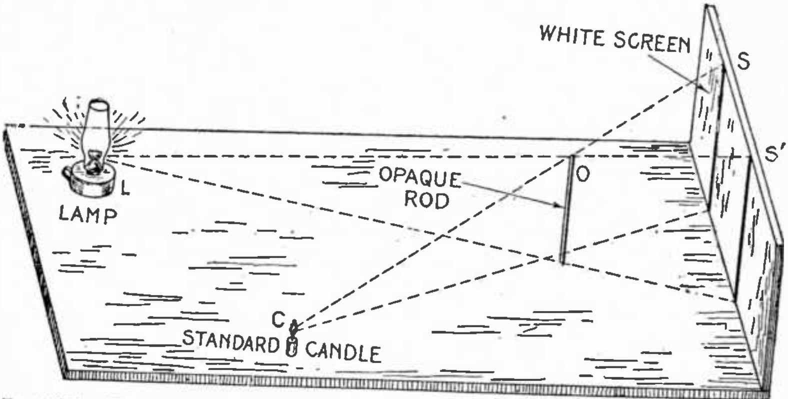


FIG. 8,364.—Principle of Rumford's photometer. *A screen is equally illuminated by each of two sources of light whenever the two shadows cast by the same object are equally illuminated*, that is, have the same depth of shadow. In the diagram L and C, are the two sources of light, L, being a lamp, and C, a standard candle. An opaque rod is placed near the white screen. Two shadows will be formed on the screen side by side. The light from the candle falls upon the shadow S′ and the light from the lamp falls upon the shadow S. The distance of L and C, from the screen may be adjusted so that the two shadows will look exactly alike. Since the intensity of any light varies inversely as the square of the distance increases, then the comparative power of two sources of light must vary directly as the squares of their distances from the screen which they illuminate equally. Thus if C, in the figure be 50 *cm.*, L, 200 cm. from the screen, and the shadows be alike, the distances are as 1 to 4. The illuminating powers are then as 1 to 16. If C, be 1 *c.p.*, then L, is 16 *c.p.*

the former method falling into disuse. Distribution curves are now used principally for comparing the suitability of reflectors for use in a given location from the standpoints, particularly, of light distribution and light absorption.

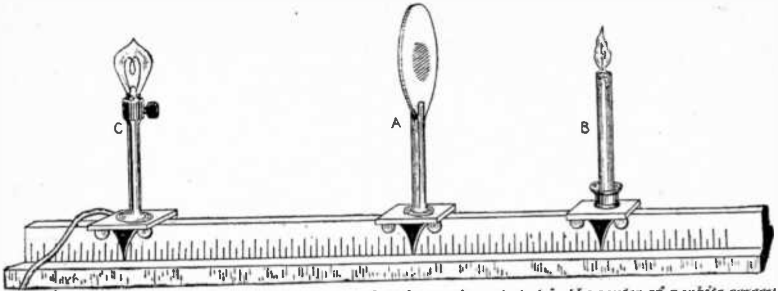
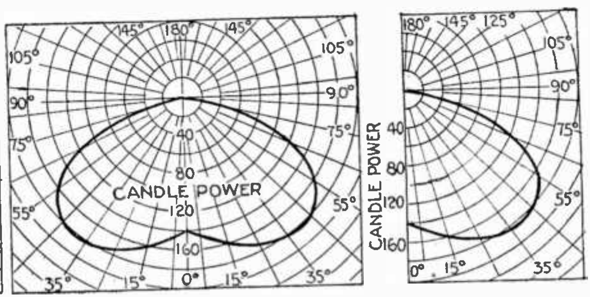


FIG. 8,365.—Bunsen's photometer. ***Principle:*** *A translucent spot in the center of a white screen will have the same appearance as the rest of the screen when the illumination on the two sides is equal.* A spot in a sheet of white paper may be made translucent by means of a little grease or oil. If this sheet be then held between the eye and a window or other source of light, the grease spot will appear brighter than the surrounding paper. On the other side of the paper the spot appears much darker than the paper. That is, *when the paper is viewed from the side of greater illumination, the oiled spot appears dark*, and *when it is viewed from the side of lesser illumination the spot appears light.* Accordingly when the two sides of the paper are equally illumined, the spot ought to be of the same brightness when viewed from either side, which, in fact it is. Hence to find the candle power of any unknown source it is only necessary to set up a candle on one side, and the unknown source on the other, as in the figure, and to move the spot to the position of equal illumination. The candle power of the unknown source will then be $\overline{CA}^2 \div \overline{BA}^2$.

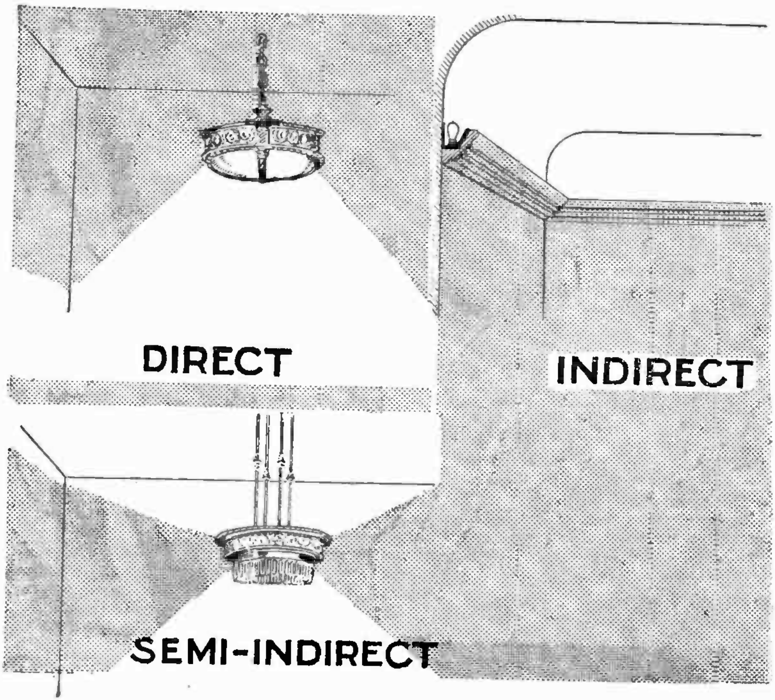
ANGLE	CANDLE POWER	ZONE	LUMENS
0	142.0		
5	148.0	0-10	14
15	161.0	0-20	60
25	178.0	0-30	142
35	183.0	0-40	257
45	181.0	0-50	397
55	165.0	0-60	545
65	108.0	0-70	652
75	44.1	0-80	699
85	5.1	0-90	704
90			



FIGS. 8,366 to 8,368.—Three methods of recording candle power distribution data. The value at any angle represents the average candle power of the source at that angle as the source rotates about its vertical axis. In fig. 8,366 the data are given in tabular form; in figs. 8,367 and 8,368 they are plotted to polar co-ordinates. Distribution curves are used simply as a graphical method for presenting the data given in the table. All have exactly the same meaning. A distribution curve is a graphical, not a pictorial, representation of the light distribution from a source, although its general shape might convey the wrong impression. It is simply a convenient engineering method of presenting tabulated data graphically.

Figs. 8,359 to 8,361 are three methods of showing the manner in which the candle power of a unit measured at different angles can be recorded. The area of a distribution curve is not a criterion of the total amount of light emitted by a source.

Systems of Lighting.—The light from a bare incandescent lamp is distributed in such a manner that under most conditions it cannot be employed effectively without the use of reflectors or enclosing glassware.



FIGS. 8,369 to 8,371.—The three systems of illumination. Fig. 8,369, direct; fig. 8370, indirect fig. 8,381, semi-indirect. Direct illumination is objectionable on account of the glare; indirect illumination eliminates glare; in semi-indirect illumination, most of the light is thrown to the ceiling.

Such accessories should not only redirect light into useful angles which would otherwise be ineffective, but should serve the additional purposes of modifying the brilliancy of the light source and diffusing the light to produce a soft and pleasing illumination.

For general illumination, three systems of lighting are commonly employed. These systems are known as:

1. Direct lighting;
2. Indirect lighting;
3. Semi-indirect lighting.

Direct Lighting System.—With this method *the light is distributed directly downward upon the surfaces to be illuminated.* The distribution of the light emanating from the lamp may, however, first be altered by means of reflectors or enclosing glassware.

The direct and reflected glare which would result from the use of a bare lamp may also be modified by the use of an opal glass diffusing globe. The use of such a globe will also soften the resultant shadows.

Indirect Lighting System.—In this method *all of the light emitted from the unit is thrown first to the ceiling and from there diffused throughout the room.*

In such a system the ceiling acts as the light source, and the glare is reduced to a minimum. The resulting illumination is softer and more diffused, the shadows are less prominent and the appearance of the room is much improved over that which results from direct lighting.

Semi-indirect Lighting System.—Here *the features of both the direct and indirect systems are combined.*

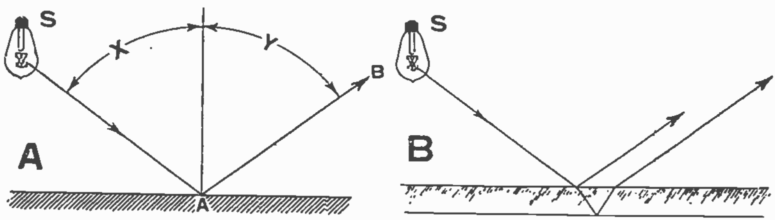
A small portion of the light passes directly downward through the unit, lighting the room in a similar manner to the direct lighting system.

The major portion of the light, however, is thrown to the ceiling and from there diffused throughout the room.

Of course, with the last two named systems it is important that the ceilings be light in color in order that there may be a maximum efficiency of reflection.

Methods of Distributing Light.—In designing accessories which are to be used with the bare lamp, use is made of the four methods of altering the straight line course of a ray of light, known as

1. Absorption;
2. Refraction;
3. Reflection;
4. Diffusion.



FIGS. 8,372 and 8,373.—Effect of various media on light rays **A**, reflection from polished surface; **B**, reflection from mirrored surface.

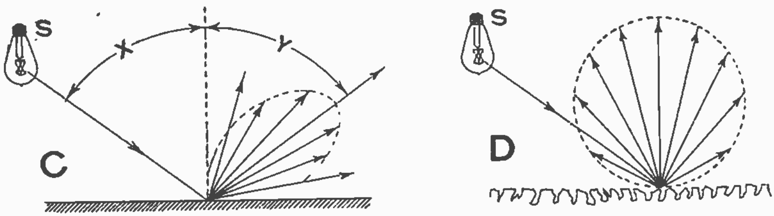
By the proper control and manipulation of these four factors the light from the bare lamp may be distributed as desired, as shown in figs. 8,372 to 8,379, designated for convenience as **A**, **B**, **C**, etc.

The simplest form of reflection is that which occurs when a ray of light strikes a polished metal surface.

As indicated in fig. **A**, the ray of light upon striking the surface at A, is reflected off in the direction AB, so that the angle of incidence X, equals the angle of reflection Y. However, all of the light is not redirected along AB, since some of it is absorbed by the surface of the metal. All of the light falling upon an opaque surface is either reflected or absorbed by that surface.

Similar to the reflection characteristics of the polished metal are those of mirrored glass.

Fig. **B**, shows the path of a ray of light striking the surface of a mirror having silvering on the back of the glass. A small portion of the light is reflected immediately upon striking the surface of the glass. The remainder is refracted or bent and passes through the glass to the silvered surface and is from there reflected back out through the glass. Of course, some of the light is absorbed by the glass and by the silver.



FIGS. 8,374 and 8,375.—Effect of various media on light rays. **C**, reflection from semi-mat surface; **D**, reflection from rough mat surface.

A dull finished or semi-mat surface can be considered as one which has many small polished surfaces, making innumerable slight angles with the apparent contour. A surface coated with aluminum paint affords a good example. When a shaft of light strikes such a surface, a spread reflection such as is shown in fig. **C**, results.

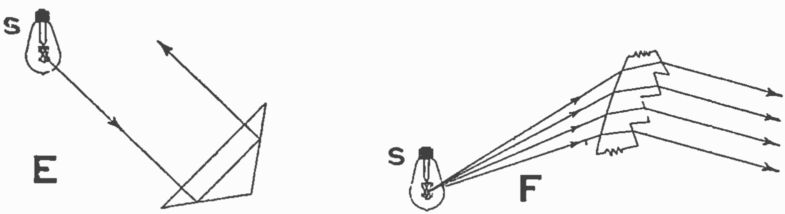
Such reflections are more difficult to control than reflections from polished surfaces and require more careful designing as to shape of reflectors for efficient results. The aluminized steel reflector is the only commercial semi-mat reflector in general use.

Diffuse reflection occurs when a ray of light strikes an unpolished or rough diffusing surface and is broken up into many separate rays, reflected in all directions, as shown in fig. **D**.

The relative brightness of such a surface would be the same viewed from any angle. Most of the light received from the walls and ceiling of a room is by diffuse reflection.

Another type of reflector is the prismatic glass reflector, which is made up of a carefully designed combination of small prisms which compose the entire body of the reflector.

By means of triangular pieces of glass, known as prisms, the path of a ray of light may be altered, either by reflection or refraction, as indicated in figs. **E**, and **F**.



FIGS. 8,376 and 8,377.—Effect of various media on light rays. **E**, reflection by prism; **F**, refractions by prisms.

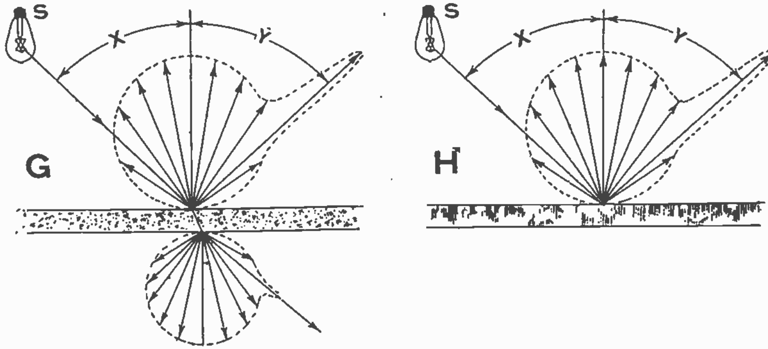
Opal glass finds considerable application in illumination practice, both as a reflecting and a transmitting medium.

Opal glass may be regarded as a common glass in which fine white particles are held in suspension. When a ray of light strikes the surface, a portion, depending upon the density of the glass, is reflected as with polished metal. The remainder passes through the glass in straight lines until it strikes these white particles, which disperse it in all directions. Some is thrown back and reflected as shown in fig. **G**, while the remainder is transmitted through and out in all directions.

Opal glass is a very desirable reflector material, since the smooth surface minimizes the collection of dirt and makes cleaning easy. The glass transmits a portion of the light, rendering the reflector luminous and enhancing its appearance. This glass is used in the manufacture of many of the commercial units in use today both in direct and semi-direct units.

The enameled metal or porcelain enameled steel reflector in common use today presents a surface which may be likened to a plate of dense opal glass in optical contact with a steel backing.

Fig. H, shows the characteristic distribution of a porcelain enameled steel reflector. Porcelain enameled reflectors find their principal use in industrial plants, where the advantages of efficiency, ruggedness, and permanency of reflecting surface are important.



FIGS. 8,378 and 8,379.—Effect of various media on light rays. G, reflection and transmission of opal glass; H, reflection from porcelain enameled steel.

Use is made of the frosted glass transmission characteristics as shown in fig. I, in frosted or bowl enameled lamps.

This frosted or etched glass is used to give a spread or diffused transmission rather than as a good reflector. Unless a frosted glass is of very fine texture, it accumulates dirt very rapidly and is difficult to clean.

Diffusion of Light.—In addition to a knowledge of reflecting surfaces and reflectors, a knowledge of such other factors as glare, shadow, and illumination of vertical surfaces, in a word, the diffusion of light; is necessary before an intelligent selection of a lighting system can be made. These factors all require most careful consideration if the best results are to be obtained.

Glare.—By definition, glare *is any brightness* within the *field of vision of such a character as to cause annoyance, discomfort, interference with vision, or eye fatigue.*

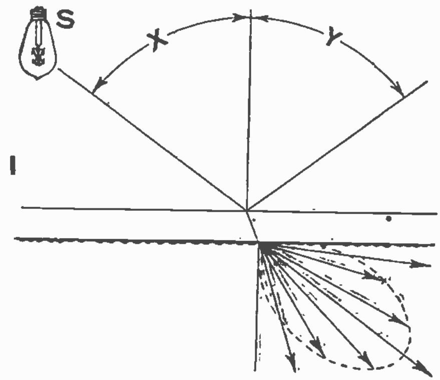


FIG. 8,380.—Effect of various media on light rays. F, reflection and transmission by etched glass.

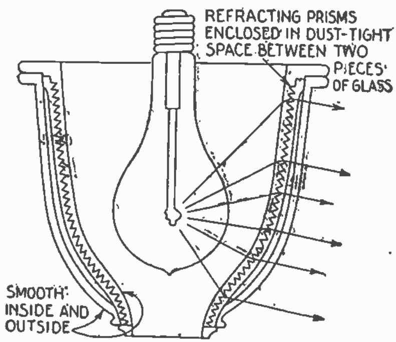


FIG. 8,381.—Holophane diffusing globe. Sectional view showing features.

Glare may be *direct* or *reflected*, that is, it may come directly from the light source to the eye, or it may be reflected brightness such as from a desk top, nickeled machine parts, or calendered paper.

Direct glare from a light source is the more common, and is more often a hindrance to vision. A glance at the sun proves that an extremely bright light source is capable of producing acute eye discomfort. Light sources of far less brilliancy than the sun, such as the filament of an incandescent lamp, or the incandescent mantle of a gas lamp, are also quite capable of producing discomfort by a direct glare. Reflected glare is glare which comes to the eyes as glint or reflection of the light source in some polished surface.

Toleration of bright light sources in the immediate vicinity is made possible by locating them at such a height as to place them above the ordinary range of vision.

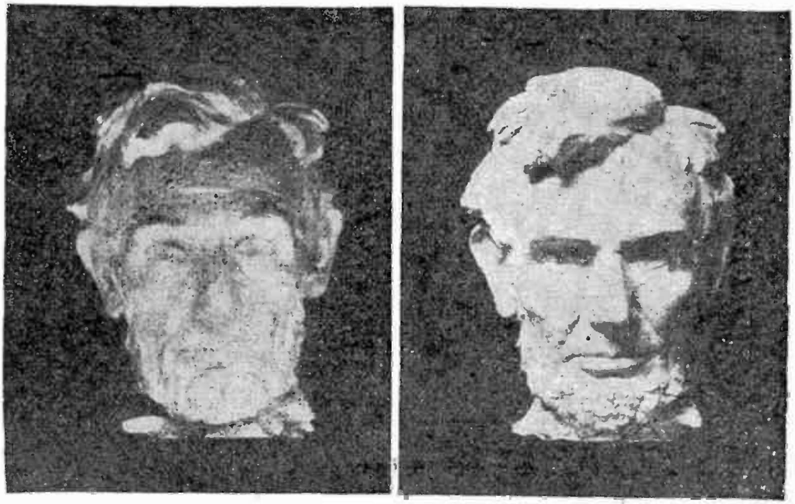
Metal reflectors for industrial lighting are ordinarily provided with a skirt around the rim of the reflector.

Shadow.—Contrary, perhaps, to popular opinion, *a certain amount of shadow is desirable in artificial lighting.*

FIG. 8,382.—Glare. Direct glare from a bare lamp is one of the greatest hazards to vision. All lamps should be shaded. The extent to which glare is objectionable is partially dependent upon the contrast in brightness between the light source and the background. Automobile headlights on an unlighted highway, for instance, may be so glaring as to be blinding to the eye; the same lights in the daytime or on a well lighted street would scarcely be noticed.

Objects illuminated by perfectly diffused light appear flat and uninteresting, contours are lost, and it is difficult for the eye to form a correct judgment of the shape of an object. On the other hand, deep, black shadows are troublesome and are a source of constant danger because of what they may conceal.

Illumination of Horizontal and Vertical Surfaces.—For many locations, such as offices and drafting rooms, light is required



FIGS. 8,383 and 8,384.—Effect of shadows. Fig. 8,383 is an example of reversed shadows giving the appearance of fear or startled surprise; natural shadows bring out forcefulness, kindliness, and lifelike appearance as in fig. 8,384.

principally on horizontal planes, such as desk tops or table tops, and it has been the custom to calculate illumination on the basis of that delivered to horizontal surfaces with the assumption that the oblique surfaces of objects would be sufficiently lighted. This practice may result in inadequate illumination.

In the machine shop, for example, the lighting of the vertical surfaces of the work or of machine parts is fully as important as the lighting of horizontal surfaces.

Lighting Calculations.—A number of methods have been employed to determine the lamp wattage required in a given lighting installation, among which may be mentioned:

1. Point by point;
2. Watts per sq. ft.;
3. Lumen.

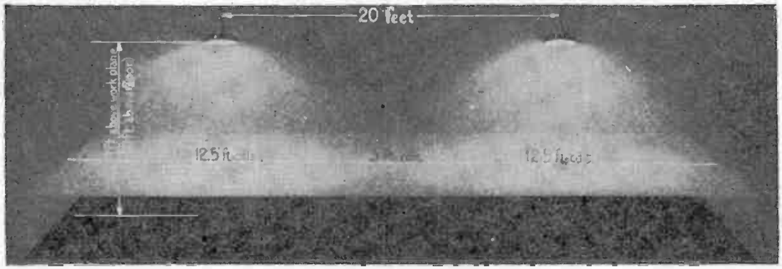


FIG. 8,385.—Spacing between luminaires should not exceed 1½ times the mounting height above the work plane, non-uniform lighting (foot candle values based on 200 watt luminaires).

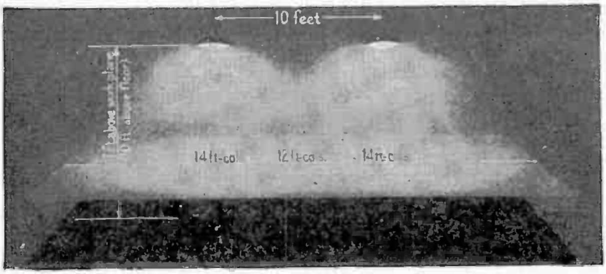


FIG. 8,386.—Illumination of vertical surfaces. Spacing between luminaires should not exceed 1½ times the mounting height above the work plane—uniform illumination (foot candle values based on 200 watt units).

Point by Point Method.—This method is not much used because of its complicated and cumbersome applications.

However, it is still employed in some special problems, such as flood lighting, yard lighting, etc. An example of the point by point method is given in fig. 8,387.

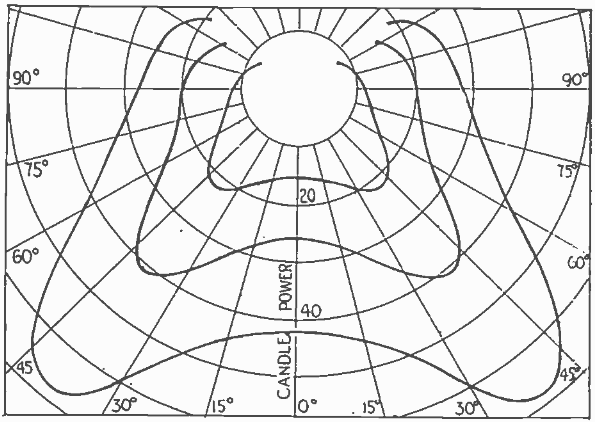


FIG. 8,387.—Illumination curves for "Mazda" 25, 40, and 60 watt 100-125 volt bowl frosted lamps with extensive reflectors, illustrating "point by point" method of calculating illumination. *Example:* Let it be required to determine the illumination given by a "Mazda" 40 watt bowl frosted lamp with extensive holophane reflector, at a point 12′ below and 8′ to one side of the lamp. From an illumination table, the illumination obtained from a light of 1 candle power at the point considered would be .004 foot candle. The corresponding angle is 33° 42′; at this angle, according to the distribution curve here shown, the intensity is 38.6 candle power. Now 38.6 × .004 = .15, which is the illumination in foot candles at the point investigated (neglecting reflection from ceiling and walls).

Watts per Sq. Ft. Method.—This is principally a "rule of thumb" method, very handy for rough calculation or checking.

It consists in making an allowance of watts per sq. ft. of area to be lighted according to the illumination desired on the assumption of an average figure of overall efficiency of the system.

Lumen Method.—This method has the advantage that the technical considerations which are important as influencing the result and which require the experienced judgment of the engineer have been taken into account in the preparation of the charts and tables and therefore automatically receive due allowance in the lighting design.

The data apply in interiors where standard types of reflecting equipment are used to obtain general lighting of substantially uniform intensity.

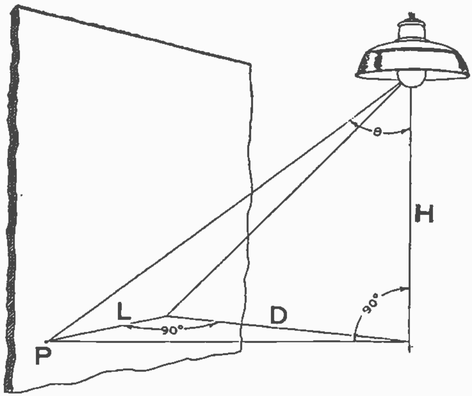


FIG. 8,388.—Illumination of vertical surfaces. *In calculating* the illumination at the point P on a vertical surface the distance H (vertical), D (horizontal), and L (horizontal to the surface) must be known. From $\tan\theta = \frac{\sqrt{D^2+L^2}}{H}$ the angle θ may be found. From the distribution curve of the luminaire, determine the candle power at the angle θ (CP_θ). Then the vertical illumination in foot candles at P is as follows:

$$\text{Vert. Ill.} = \frac{CP_\theta \times \text{Cos}^3\theta}{H^2} \times \frac{D}{H}$$

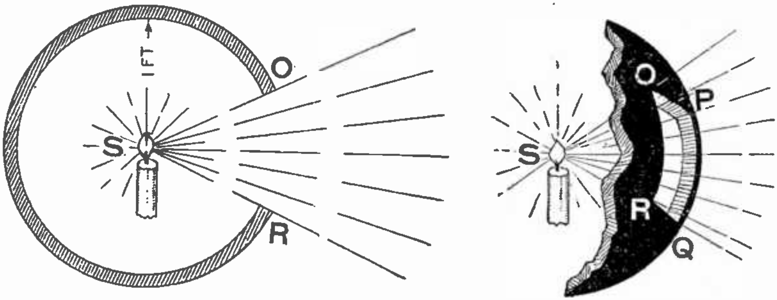
The well known formula for horizontal illumination (foot candles) at the same point is:

$$\text{Hor. Ill.} = \frac{CP_\theta \times \text{Cos}^3\theta}{H^2}$$

The three steps to be carried out in the design of a general lighting system for a room are:

1. Decide the foot candles of illumination required:

2. Determine the location of outlets, the mounting height and number of lighting units required;



FIGS. 8,389 and 8,390.—The lumen. Here S, represents a light source giving one candle power in all directions and surrounded by a non-reflecting sphere (shown in section) one foot in radius through which is cut an opening, OPQR (fig. 8,390), which has an area of one square foot and subtends a unit solid angle. Through this opening the light source, S, emits one lumen. As the entire surface of the sphere equals 12.57 sq. ft., the total flux emitted by S, equals 12.57 lumens. In other words, total lumens = 12.57 × mean spherical candle power.

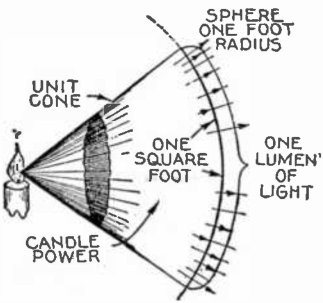
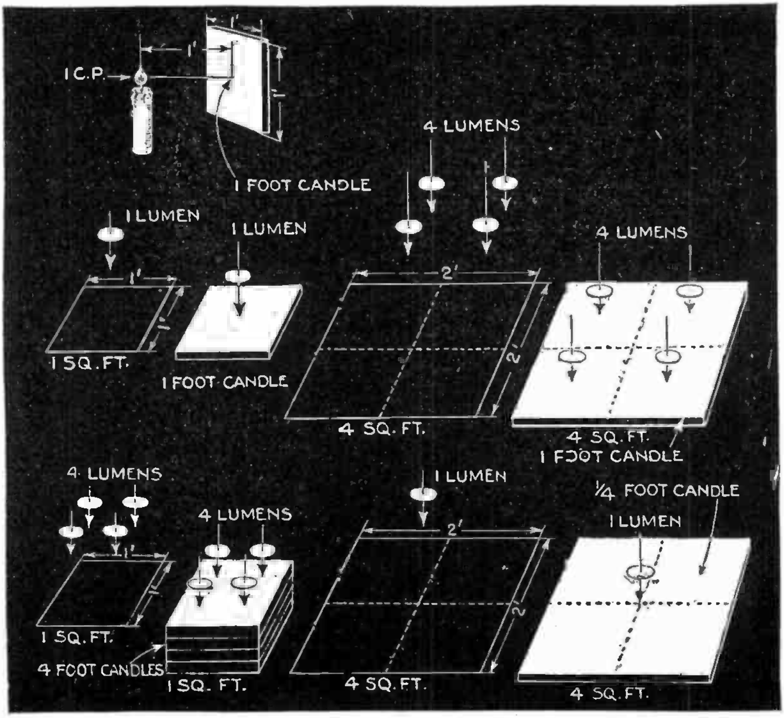


FIG. 8,391.—A unit cone. Imagine a standard candle as shown in the figure and a sphere of one foot radius with its center at the candle. One square foot of the surface of this sphere is contained inside of a unit cone, and such a unit cone contains one ***lumen*** of light flux. Therefore, one lumen of light flux passes through each square foot of the surface of the sphere; that is, the light which radiates from the given lamp has a sectional intensity of one lumen per square foot *at a distance of one foot from the lamp*. This sectional intensity is sometimes called the ***foot candle***. That is, the foot candle is the sectional intensity of a one candle power beam at a distance of one foot from the lamp.

3. Select the type of lighting unit best adapted to the location and ascertain the size of lamp which will provide the foot candles desired.

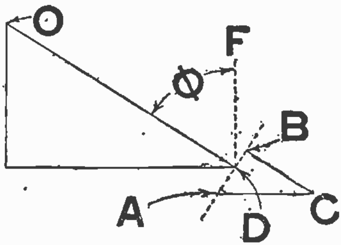
1. **Foot Candles.**—Table 1 lists the foot candle value, corresponding to present standards, for different classes of industrial operations, offices, etc.



FIGS. 8,392 to 8,400.—Diagram showing the difference between lumens and foot candles. A light source of one candle power in a particular direction will produce one foot candle of illumination on a point one foot distant from it. One lumen of light flux will illuminate one square foot of area to one foot candle of illumination. The product of foot candles and the area in square feet lighted will give the lumens of light flux on that area.

The desirable illumination varies rather widely, depending on the conditions in any particular installation, such as the accuracy of the operation and fineness of detail to be observed and the color of objects worked on or handled.

The foot candle values recommended in the tables are the minimum to be adhered to if fully satisfactorily lighting is to be assured. Under particular conditions considerably higher levels of illumination are often desirable.



FIGS. 8,401 and 8,402.—The foot candle. If A, be a lamp giving 16 candle power in a horizontal direction, the illumination at the point B, four feet distant, would be $16 \div 4^2 = 1$ foot candle, since the *intensity of light varies inversely as the square of the distance.* To get the normal illumination at any given point, the candle power in the proper direction must be divided by the square of the distance to the point illuminated. If the surface illuminated be not at right angles to the direction of the light, the value of the illumination obtained as above must be multiplied by a reduction factor, taking into account the angle at which the rays strike. A beam of light coming in the direction OD, fig. 8,402, falls upon a plane AB, illuminating it with an intensity of 1 foot candle. Then the illumination on the plane AC, which intercepts the same amount of light as AB, would be less than 1 foot candle (as the light is spread over a larger surface) in the ratio of AB, to AC, which is the cosine of the angle ODF. Thus the illumination effective on any plane at a given point will be (candle power ÷ distance²) × cos ø, where ø is the angle between the direction of the ray and a perpendicular to the plane considered.

Table 1. Foot Candles for Interior Lighting

	Good Practice	Minimum
Cars		
baggage	8	5
day coach, dining and Pullman	8	5
street railway and subway	10	6
Piers		
freight (loading docks)	3	2
passenger	4.	2

Table I—*Continued*

	Good Practice	Minimum
Office building (private and general office)		
close work	15	10
no close work	10	8
drafting rooms	25	15
halls, passageways in interior	3	2
Shops—carpenter		
rough sawing and bench work	8	5
fine bench and machine working fine sanding and finish	15	10
Electric repair		
storage battery charging room	10	6
coil and armature winding, mica working, insulating processes	20	12
Erecting		
forge shops and welding	10	6
Foundries		
rough moulding and core making	10	6
fine moulding and core making	15	10
Freight stations		
sorting areas	6	4
loading platforms	3	2
storage areas	3	2
offices	15	10
Machine shops		
rough bench and machine work	10	6
medium bench and machine work	15	10
fine bench and machine work	20	12
extra fine bench and machine work	50–100	25
Power House		
boilers, coal and ash handling, storage battery rooms	5	3
auxiliary equipment, oil switches and transformers	8	5
switchboard, engines, generators, blowers, compressors	10	6
Stations—passenger		
ticket offices	12	8
baggage rooms	12	8

Table I—*Continued*

	Good Practice	Minimum
platforms (terminals)	4	2
platforms (way stations)	.25	.15
subways (concourse)	6	4
waiting room	8	5
toilets and wash room	6	4
Warehouses	3	2
Exterior Lighting		
Automobile parking spaces	1	0.5
Building		
construction work	6	4
excavation	2	1
Dredging	2	1
Docks	3	0.5
Railway yards		
general	.25	.15
approach to hump	1	0.5
turntables	2	1
Yard thoroughfares	1	0.5

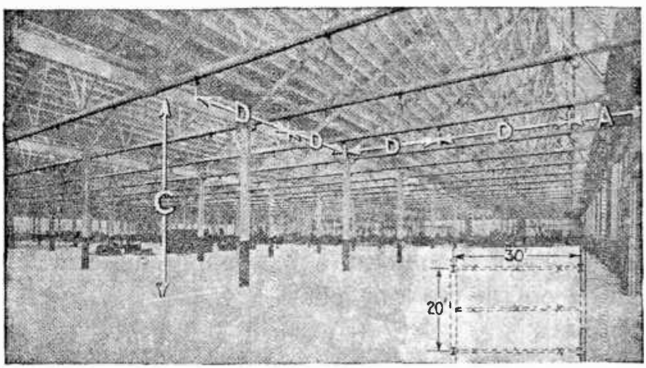


Fig. 8,403.—The layout of lighting outlets for a large industrial building. Indicating the application of data in table No. 2. The 13 foot clearance allows a spacing of 13 feet. For a symmetrical layout in the bays a 10 foot spacing is adopted.

Location of Outlets.—The number of outlets to provide for any given area is determined by the maximum allowable spacing between lighting units and is in turn regulated by their height above the floor.

Table 2.—Spacing of Outlets

Ceiling Height (Or Height in the Clear) (C)	Spacing Between Outlets		Spacing Between Outside Outlets and Wall		Approximate Area per Outlet (At Usual Spacings)
	Usual (D)	Maximum (For Units at Ceiling) (D)	Aisles or Storage Next to Wall (A)	Desks, Work-benches, etc., Against Wall (B)	
(Feet)	(Feet)	Not more than*		Not more than*	(Square Feet)
8	7	7½	Usually one-half actual spacing between units	3	50-60
9	8	8		3	60-70
10	9	9		3½	70-85
11	10	10½		3½	85-100
12	10-12	12		3½-4	100-150
13	10-12	13		3½-4½	100-150
14	10-13	15		4-5	100-170
15	10-13	17		4-5	100-170
16	10-13	19		4-6	100-170
18	10-20	21		4-6	100-400
20	18-24	24		5-7	300-500
22	20-25	27		5-7	400-600
24	20-30	30		6-8	400-900
26	25-30	33		8-9	600-900
30 and up	25-30	40		8-10	600-900

*Where it is definitely known that some form of indirect lighting will be used, the maximum spacing between outlets may be increased about two feet, and the distance from the outside outlets to the wall may be increased by one foot.

The relation between height and spacing is based on the distribution of light to procure a reasonably uniform level of illumination on the working plane.

Tables 2 and 3 will be helpful in determining the location of the outlets.

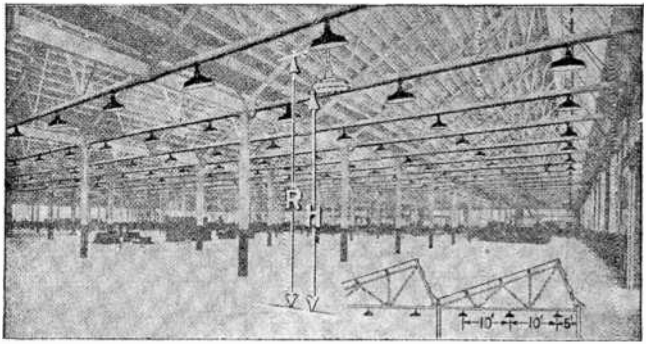


FIG. 8,404.—Mounting height of lighting units. When units are spaced less than the maximum permissible distance, they may be dropped from the ceiling for reasons of appearance, ease of cleaning, etc., but in no case should they be dropped below the minimum value shown in column of Table 3 for a given spacing. For a 10 foot spacing the units might be dropped to 10 feet above the floor as shown by the dotted outline of a reflector at height H. They are, however, mounted on the trusses 12 feet to minimize glare.

Table 3—Mounting Height of Lighting Units

DIRECT LIGHTING UNITS				SEMI-INDIRECT AND INDIRECT LIGHTING	
Actual Spacing Between Units (D)	Distance of Units from Floor Not Less Than (H)	Desirable Mounting Height in Industrial Interiors (R)	Desirable Mounting Height in Commercial Interiors (R)	Actual Spacing Between Units (D)	Recommended Suspension Length (Top of Bowl to Ceiling) (S)
(Feet)	(Feet)			(Feet)	(Feet)
7	8	12 feet above floor if possible — to avoid glare, and still be within reach from step-ladder for cleaning.	The actual hanging height should be governed largely by general appearance, but particularly in offices and drafting rooms, the minimum values shown in Column H should not be violated.	7	1-3
8	8½			8	1-3
9	9			9	1-3
10	10			10	1½-3
11	10½			11	2-3
12	11			12	2-3
14	12½	Where units are to be mounted much more than 12 feet it is usually desirable to mount the units at ceiling or on roof trusses.		14	2½-4
16	14			16	3-4
18	15			18	3-4
20	16			20	4-5
22	18			22	4-5
24	20			24	4-6
26	21			26	4-6
28	22			28	5-7
30	24			30	5-7

Size of Lamp Required.—After the outlets have been located on the plan, the size of lamp to be used may be determined by the following calculation:

Table 4—Initial Lumen Output of Multiple Mazda Lamps

Size of Lamps in Watts	Bulb	Finish	Approximate Initial Lumen Output: 110, 115 & 120 volt Standard Lighting Srv.	Approximate Initial Lumen Output: 220, 230, 240, 250 Volt Service
25	A-19	Inside Frost	240	202
40	A-21	Inside Frost	408	...
50	A-21	Inside Frost	535	450
60	A-21	Inside Frost	678	...
100	A-23	Inside Frost	1340	1030
150	PS-25	Clear	2310	...
200	PS-30	Clear	3280	2620
300	PS-35	Clear	5340	4290
500	PS-40	Clear	9500	7650
750	PS-52	Clear	14550	12600
1000	PS-52	Clear	20400	18000
60	A-21	Inside Frost Daylight	441	...
100	A-23	Inside Frost Daylight	870	...
150	PS-25	Clear Daylight	1500	...
200	PS-30	Clear Daylight	2130	...
300	PS-35	Clear Daylight	3471	...
500	PS-40	Clear Daylight	6180	...

$$\textbf{A. } \left\{\begin{array}{l}\text{Area in sq. ft.}\\ \text{per outlet}\end{array}\right\} = \left\{\frac{\text{Total floor area in sq. ft.}}{\text{Number of outlets}}\right.$$

$$\textbf{B. } \left\{\begin{array}{l}\text{Lamp lumens re-}\\ \text{quired per sq. ft.}\end{array}\right\} = \left\{\frac{\text{Foot candles}}{\left\{\begin{array}{l}\text{Coeffi. of}\\ \text{Utilization}\end{array}\right\} \times \left\{\begin{array}{l}\text{Probable average illumination}\\ \text{in \% of initial illumination}\end{array}\right.}\right.$$

$$\textbf{C. } \left\{\begin{array}{l}\text{Lamp lumens re-}\\ \text{quired per}\\ \text{outlet}\end{array}\right\} = \left\{\begin{array}{c}\text{Area in sq. ft.}\\ \text{per outlet}\\ \text{(From A)}\end{array}\right\} \times \left\{\begin{array}{l}\text{Lamp lumens required}\\ \text{per sq. ft.}\\ \text{(From B)}\end{array}\right.$$

Having determined the lamp lumens required per outlet by the above calculation, the wattage of Mazda lamps to be used may be found by reference to Table 4, which lists the lumen output rating for each size of lamp.

Locate in this table the size of lamp of the desired type which most nearly meets the requirements of lumen output. When the lamp lumens required fall nearly midway between two sizes, it will usually be found best to choose the larger size.

Flood Lighting Calculations.—The illumination of surfaces such as building facades, sign boards, etc., to a desired level of illumination intensity is a problem frequently arising and requiring an immediate solution.

Such a problem may be roughly separated into three steps and a satisfactory solution found as illustrated in the example which follows:—

Example.—A light gray limestone office building along a white way, having a front facade 150 ft. high by 50 ft. wide. Determine: type, number and wattage of flood light projectors required to illuminate building from roof of building opposite. Shown in fig. 8,405.

First Step: *Foot candles required.* This depends upon the type of building, the purpose of the flood lighting, the amount of conflicting light in the vicinity, etc. While the brightness to which one illuminates buildings is largely based on experience, the general practice is indicated in the values given in Table 5, which, for the requirements in the example, gives 20 foot candles.

Second Step: *Type of projector.* Two considerations enter into the choice of a projector, viz., beam size and light output. The former determines the area covered by the beam and the latter the illumination provided.

In Table 7 a factor F, is given for each projector and the various types of reflectors and lens equipments. This factor multiplied by the distance of the projector from the surface gives the diameter of the beam pattern on the surface, assuming that the beam is perpendicular to the surface.

It is desirable to cover as large a part of the surface with one projector as possible and obtain the desired illumination by the superimposing of beams. The maximum diameter of the beam that can be utilized without waste for the building in question is 50 feet and as the projectors are to be placed 100 feet away, look for a projector with the factor .5.

From Table 7, it is seen that the following projectors have the required factor:

L30-B, medium angle. 500 watt, G-40 lightly stippled lens, 3,663 beam lumens,

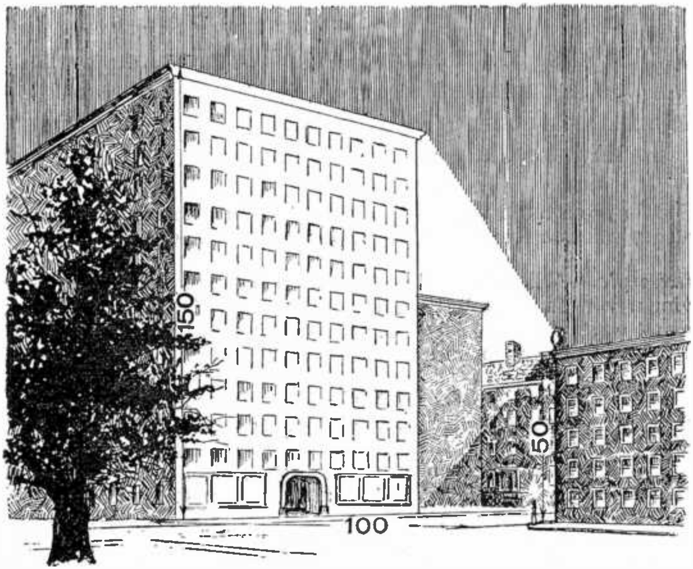


FIG. 8,405.—Flood lighting of building by flood light projectors located on building on opposite side of street. See example on page 5,253.

L-31-A, wide angle, 1000 watt, PS-52 lightly stippled lens, 7,900 beam lumens.

Third Step: Number of projectors. For any desired intensity over a definite surface the number of projectors is obtained from the following formula:

$$N = \frac{A \times E}{L}$$

in which

N = Number of projectors.

A = Area of building facade in square feet.

E = Foot candle intensity required.

L = Beam lumens delivered by one projector.

From the conditions of the example:

Table 5. Building Characteristics

Building Surfaces	Reflection factors per cent	Recommended foot candle intensities		
		A	B	C
White terra cotta.................. Cream terra cotta.................. Light marble......................	60-80	15	10	5
Light gray limestone.............. Bedford limestone................. Buff limestone.................... Smooth buff face brick............	40-60	20	12	7
Briar hill sandstone.............. Smooth gray brick................. Medium gray limestone............. Common tan brick..................	20-40	25	15	10
Dark field gray brick............. Common red brick.................. Brownstone........................	10-20	30	18	12

A—Buildings on white ways: intensive street lighting; streets with many conflicting signs and light sources; lower portions of buildings falling under Class B locations.

B—Medium-intensity white ways: secondary business streets with few conflicting signs, etc.

C—Very little conflicting light, such as on residential streets, parks, lighted highways, etc.

A = 150×50 = 7,500 sq. ft.

E = 20 foot candles as already found.

L = 3,663 lumens for type L-30-B, and 7,900 lumens for type L-31-A, according to Table 3.

The number of L-30-B projectors required is

$$\frac{7{,}500 \times 20}{3{,}663} = 41 \text{ (approx.)}$$

Table 6. Floodlighting Intensities

	Recommended foot candle intensities	
	Good Practice	Minimum
Decorative and spectacular effects (Christmas trees, flags, etc.)	20.0	10.0
Landscapes	15.0	5.0
Stained glass windows	30.0	15.0
Billboards	30.0	10.0
Signs	30.0	10.0
Smoke stacks and water tanks	12.0	8.0
Quarries and shipyards	6.0	2.0
Construction work	6.0	4.0
Dredging	2.0	1.0
Railroad yards		
(a) Classification	0.15	0.1
(b) Mechanical retarder areas	1.0	0.5
Docks, loading platforms, etc	3.0	2.0
Mines	1.0	0.5
Gasoline filling stations		
(a) Buildings and pumps	15.0	2.0
(b) Yard and driveways	4.0	2.0
Roadside stands and houses	4.0	0.5
Parking areas	1.0	0.5
Real estate developments	10.0	5.0
Air advertising	30.0	15.0

The number of L-31-A projectors required is

$$\frac{7{,}500 \times 20}{7{,}900} = 19 \text{ (approx.)}$$

By comparison, considering cost of installation and of operating, it is found that the required amount of light can be obtained more cheaply by using 20 type L-31-A projectors with 1000 watt general service Mazda lamps than by using 40 type L-30-B projectors equipped with 500 watt flood lighting Mazda Lamps. The recommendation is therefore, 20 type L-31-A projectors.

Power Required for Flood Lighting.—An approximate allowance for calculating the power required is .15 watt per sq. ft. of surface per foot candle.

Table 7. Illuminating Data

(For estimating purposes only. General Electric Co.)

TYPE	WORKING DISTANCE	LAMP 115-VOLT	REFLECTORS	LENSES CLEAR	BEAM Angle in Degrees	BEAM Candles	BEAM Lumens	TOTAL LUMENS	*F	DISTRIBUTION CURVE
L-29A	Up to 175 ft.	200-watt PS-30 C. General Service Lamp—6-in. L.C Medium Base	10 7/16-in Parabolic Glass Silver Plated	Plain	26V–28H	27700	1393	2225	0.48	H-133230
				Lightly Stippled	38	11850	1400	2215	0.69	H-133231
				Heavily Stippled	72	3870	1620	2205	1 45	H-133232
				Spread Light	29V–58H	8400	1467	2185	0.50V–1 10H	H-133233
L-29B	Up to 200 ft.	250-watt G-30 Flood-light Lamp. 3-in. L.C. Medium Base	10 1/16-in Parabolic Glass Silver Plated	Plain	18V–18.2H	51200	1500	2450	0 32	H-.33234
				Lightily Stippled	31V–32H	17000	1520	2420	0 56	H-133235
				Heavily Stippled	68	4600	1660	2380	1.36	H-133236
				Spread Light	21V–50H	13200	1494	2420	0.37V–0.93H	H-133237
L-30A	300 ft.	500-watt G.S. Lamp PS-40 C. General Service 7-in. L.C. Mogul Base	14¾-in. Parabolic Glass Silver Plated	Plain	20.6V–26.6H	107000	4164	6820	0.37V–0.48H	H-133238
				Lightly Stippled	30.2V–35H	42300	4157	6750	0.54V–0.63H	H-133239
				Heavily Stippled	48	21000	4030	6580	0.89	H-133240
				Spread Light	20V–53H	33100	4098	6550	0.36V–1.01H	H-133241
	Up to 100 ft.	500-watt General Service Lamp PS-40 C. General Service 7-in. L.C. Mogul Base	14¾-in. 1-piece Sectional Glass Silver Plated	Plain	60	18800	4900	6940	1.15	H-133242
				Lightly Stippled	72	14100	5375	6840	1.45	H-133243
				Heavily Stippled	100	9200	5850	6660	2.38	H-133244
L-30B	Up to 400 ft.	500-watt G-40 Flood-light Lamp 4½-in. L.C. Mogul Base	14¾-in. Parabolic Glass Silver Plated	Plain	11.2V–13.3H	278000	3796	5900	0.20V–0.23H	H-133149
				Lightly Stippled	24.0V–25.6H	66000	3863	5800	0.44	H-133150
				Heavily Stippled	43.5V–44.5H	26600	3467	5725	0.81	H-133151
				Spread Light	11.4V–43H	57700	3785	5650	0.20V–0.79H	H-133152
	Up to 150 ft.	500-watt G-40 Flood-light Lamp 4½-in. L.C. Mogul Base	14¾-in. 1-piece Sectional Glass Silver Plated	Plain	44	28000	4230	6080	0.81	H-133245
				Lightly Stippled	54	19000	4400	5970	1.04	H-133246
				Heavily Stippled	70	13000	4750	5830	1.40	H-133247
L-31A	Up to 175 ft.	1000-watt PS-52 General Service Lamp 9½-in. L.C.	14¾-in. Composite 1-piece Solid Glass Silver Plated	Plain	21V–27H	142000	7558	13400	0.37V–0.48H	H-133248
				Lightly Stippled	31V–37H	78600	7900	13100	0.55V–0.67H	H-133249
				Heavily Stippled	52	42000	8600	12940	0.98	H-133250
				Spread Light	21V–53H	70000	8458	13020	0.37V–1.01H	H-133251

	RED	AMBER	BLUE	GREEN
Approximate correction factors either lenses or color plates..............	10 to 20%	50 to 65%	3 to 5%	10 to 15%

*F. Beam diameter in feet = Distance from projector in feet × Factor F. H = Horizontal. V = Vertical.

Example.—Required the approximate power necessary for flood lighting 10,000 sq. ft. of building to an intensity of 10 foot candles.

$$\text{Power} = 0.15 \times 10 \times 10{,}000 = 15 \ kw.$$

Colored Lighting for Buildings.—Colored glass lenses obviously absorb light in excess of the plain glass, and the output of light is reduced. The beam and total lumens given in Table 7 should be multiplied by the following transmission factors in order to obtain the light flux delivered when using colored lenses.

Transmission Factors for Colored Lenses

Red	.15
Amber	.50
Blue	.04
Green	.12

Example.—Beam lumens for L-30 medium angle, plain clear lens is 3,796. Beam lumens for same projector with red lens is 3,796×.15=570.

Color lighting requires particularly careful study. It frequently is found advisable to use colored light on colored buildings, such as red light on red brick, for the best effect. For high commercial buildings, where the illumination is not influenced by street lights, it has been found that two watts per sq. ft. of clear light and four watts per sq. ft. of colored light will give excellent results, unless there be special conditions which would require different values from those just given.

Air Port Lighting Principles.—The simplest specification for lighting landing fields, reduced to the fundamentals applied to other general lighting problems, can be stated in terms of lumens of light or foot candles, delivered per square foot of area. The best illuminating system provides practically uniform distribution of light over the entire area.

The requirement for uniformly distributed illumination carries with it certain related qualities which must be considered.

1. Upward light should be reduced to a minimum;

2. Glare from light sources should be eliminated as far as possible;

3. Harsh shadows should be avoided;

4. The color quality of the light should not distort normal color appearance of objects.

If it were not for the necessity of keeping the landing area free of overhead obstructions a system of overhead lighting from ordinary industrial type reflectors would probably give the best lighting results. This being impractical, the only alternative is to locate the lighting equipment at the boundaries, and, by proper design of equipment, project light to cover the area most effectively.

Air Port Lighting System.—There are two systems of flood lighting of air ports known as:

1. Distributed system;

2. Concentrated system.

Distributed System.—This comprises a number of 1000 or 1500 watt flood lights spaced at intervals of 200 to 300 feet around the boundaries of the field, as shown on pages 5,260 and 4,417, Vol. VIII of this Series.

This allows, perhaps, a nearer uniform distribution of light over the entire area, particularly where the ground is uneven or slightly rolling, since each individual projector may be so adjusted and directed as to cover a particular section.

The disadvantage is that the multiplicity of light sources introduces a large number of glare points.

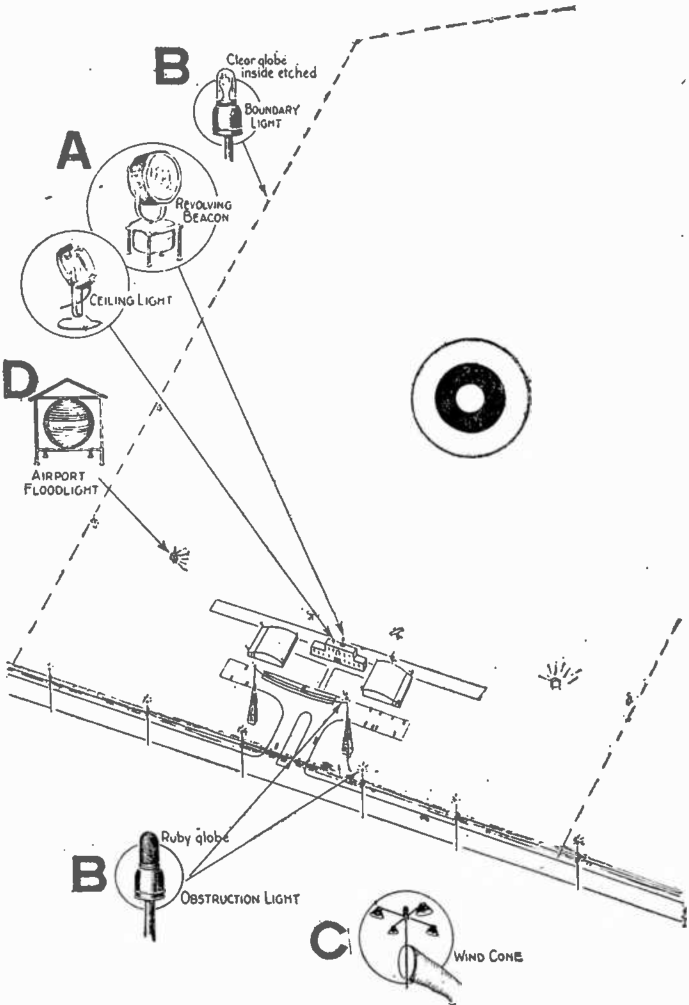


FIG. 8,406 to 8,412.—Minimum lighting facilities required for an air port to obtain an "A" rating **A**, ***air port beacon***. Minimum candle power not less than 100,000 for long range, and in no case less than 15,000 candle power. Rotating or flashing with flashes not less than one-tenth

Concentrated System.—In this system there are several batteries of relatively small individual projectors or, more commonly, one or more large units with one or more light sources built into a composite, high powered projector.

The uniformity of light distribution from the concentrated system is dependent upon mechanical and optical limitations of design. In general the ratio of minimum to maximum horizontal illumination over the field

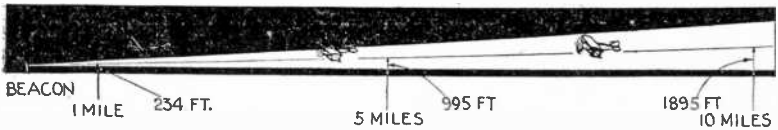
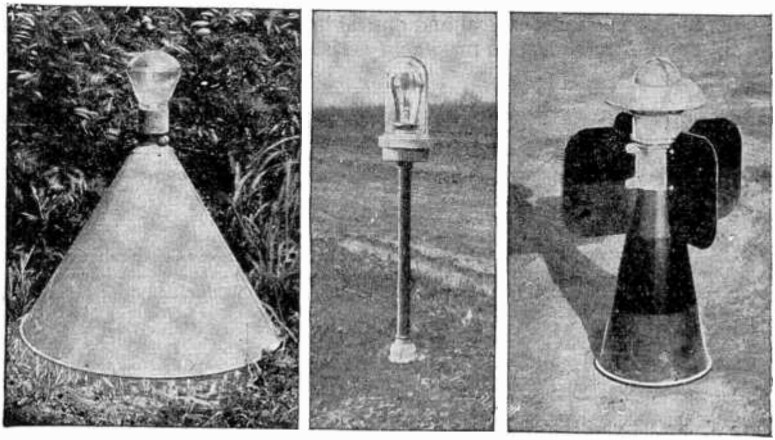


FIG. 8,413.—A beacon with only a slender pencil of light is ineffective at close range at normal flying height. ***Requirements for air port beacons:*** 1, high candle power for long range visibility; 2, visibility from all normal flying heights; 3, suitable duration of flash period; 4, positive identification.

FIGS. 8,406 to 8,412.—*Text continued.*

second duration or luminous period not less than 10%. Light distribution such as to be visible all around horizon and to the zenith, or nearly so, for altitudes of 500 to 2,000 ft. distinctiveness for identification, automatic lamp changers or auxiliary units for reliability; B, ***boundary and obstruction lights.*** Either 600 lumen series or 25 watt multiple lamps in clear weather proof globes on standards 30 ins. above ground and spaced not more than 300 ft. apart to outline boundaries or landing strips. Multiple circuits limited to 5% voltage drop. Green substituted for white to show points of best approach, and red globes to show hazardous approaches, using 1,000 lumen series or 50 watt multiple lamps. All obstructions in vicinity must have red lights at highest points of obstruction; C, ***wind cone and hangar lighting.*** Illuminated wind direction indicator to be visible from 1,000 ft. in all directions if externally flood lighted. Wind cones internally lighted require not less than 200 watt lamp in suitable reflector. Exterior surface of each hangar to be flood lighted to 2½ foot candles with surface reflection factor at least 50%. A 12 in. 250 watt incandescent lamp search light 7 degree maximum beam spread to be installed for ceiling height measurements; D, ***field flood lighting.*** One or more units to provide an even distribution of illumination without shadow areas and of sufficient illuminating power to make ground details visible from an altitude of 30 ft. The minimum vertical plane illumination over the usable portion of landing area shall not be less than .15 foot candles. System to be controlled from convenient point and sufficiently flexible to permit landing under all conditions of wind direction without the necessity of landing directly toward the light source. Units shall be mounted as low as possible consistent with contour of ground, and shall project a beam of narrow vertical divergence with sharp cut off at top so as not to produce glare. When more than one unit is used, each shall be independent of the other in operation. In case of a single light source flood lighting unit, an automatic lamp changer shall be provided. In lieu of a lamp changer an auxiliary unit may be used which will give not less than .035 foot candle over the usable portion of the field.

will be considerably greater than with the distributed system. However, the problem of glare is reduced, since precautions may be applied more readily to a single source than to a large number of sources; furthermore, no glare is experienced when the direction of flight is in the same general direction as the projected beam.



FIGS. 8,414 to 8,416.—General Electric typical boundary light installations. Fig. 8,414, prismatic globe and conical skirt; fig. 8,415, plain globe and stem; fig. 8,416, white glass globe with reflector type guard, and conical base.

Amount of Light Required for Air Ports.—The air port rating regulations of the Department of Commerce specify an even distribution of light over the entire usable portion of the landing area with a minimum illumination of .15 foot candle on the vertical plane.

To meet this requirement, projector units of the order of 20,000 watts capacity are employed. However, on a landing field of average dimensions, say 2000 feet square, 4,000,000 sq. ft., the lighting result from this 20,000 watt projector is roughly equivalent to the lighting of a room 20 feet square by means of a single candle set on the floor in the corner.

Illumination Results and Calculations.—A combination of circumstances has made it seem desirable to mount field flood lighting units only 10 feet or so above the ground, and to attempt to sweep the entire landing area with a flat fan of light.

With such an acute angle of projection, the zone of maximum candle power must be aimed only the slightest amount below the horizontal plane in order to project light to the far boundaries of the field. Under these conditions of projection the lower half of the beam falls on the field, while the upper half is lost as far as lighting the ground is concerned.

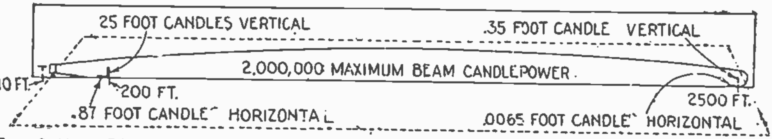


FIG. 8,417.—Illumination readings on horizontal and vertical planes taken 3 ft. above the ground for two locations on field, at zone of maximum projected candle power. It will be noted that at 2,500 ft. the vertical illumination is well over .15 foot candle minimum required by the Department of Commerce, but the horizontal illumination is of the order of .0065 foot candle or only about one-fiftieth of the vertical. At 200 ft. the vertical illumination was of the order of 25 foot candles while the horizontal foot candles fell to .87 foot candle. The ground in the immediate vicinity of the projectors appears fairly well lighted and favorable for landing with the beam, since the pilot has the advantage of absence of glare, relatively high ground illumination at the point where he grounds the wheels and has the further advantage of high vertical lighting on grass tufts, or weeds, that indicate the field conditions ahead. On the other hand, if he be forced to approach from the far side of the field toward the unit, the horizontal illumination is almost negligible (the reading of .0065 foot candle is only about half what one could expect from full moonlight), so that the ground conditions are quite obscure; furthermore, he cannot benefit by the vertical illumination since he is on the dark side of all such obstacles.

With a narrow vertical spread and a sharp cut off this upper part of the beam produces in effect a layer of light above the field projected nearly parallel with the ground. Except when the atmosphere is extremely clear of dust or moisture particles, this upward light may produce a blanket of light sufficient to obscure the ground. In fact, some pilots have learned to gauge their height above the ground by the depth of the beam. On the other hand, if more light can be directed toward the ground and if the landing surface be light in color, the surface brightness will be high enough to overcome the apparent ground haze and allow the ground to be seen through the haze.

With the present scheme of low mounting of field flood lighting equipment, the ratio between vertical and horizontal illumination is very marked.

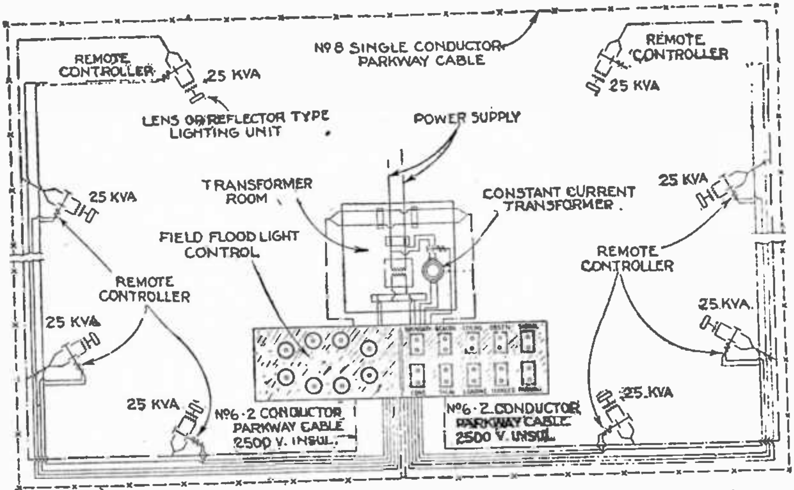


FIG. 8,418.—Wiring and electrical provisions for convenient control of all lighting equipment from a central point. Field flood lights each with individual remote control.

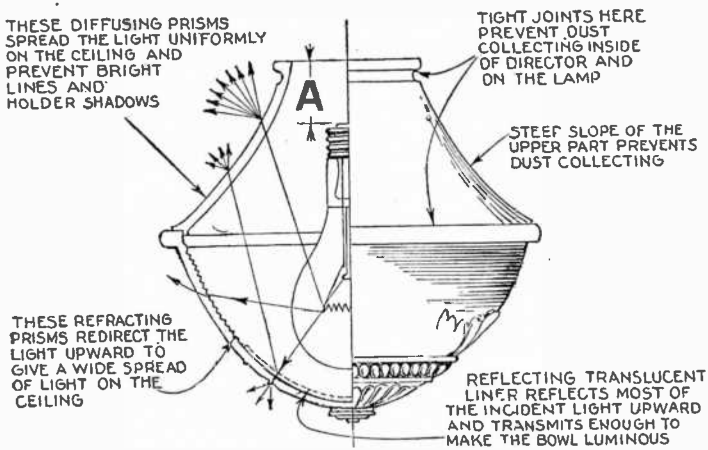


FIG. 8,419.—The refraction of light due to prisms in a globe. The prisms redirect the rays and pass them out in the planes desired; this is important in street illumination as it is desired to reflect all or nearly all to the street surface.

This is shown in fig. 8,417, which illustrates some illumination measure ments taken at 200 feet and at 2,500 feet from a 24 *kw*. 180 degree aviation flood light developing slightly over 2,000,000 maximum beam candlepower.

Street Illumination.—In the lighting of streets *there should not be glare in one spot and darkness in another; there should not*

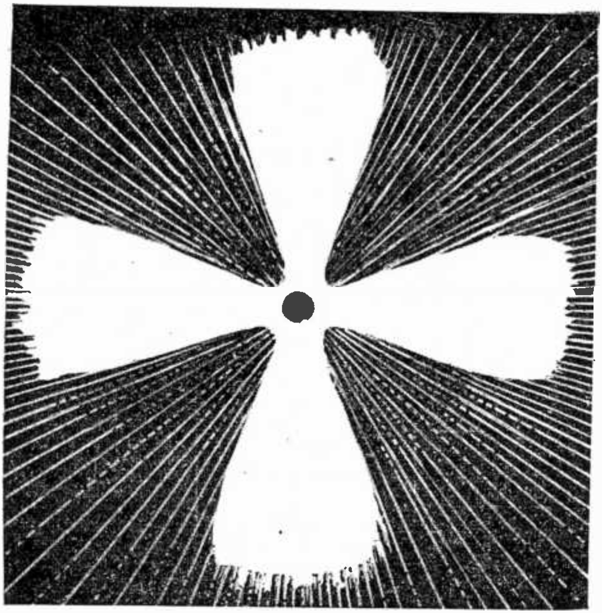


FIG. 8,420.—Plan view of direction in which illumination is desired at street intersections and along streets and how prismatic globes direct the rays.

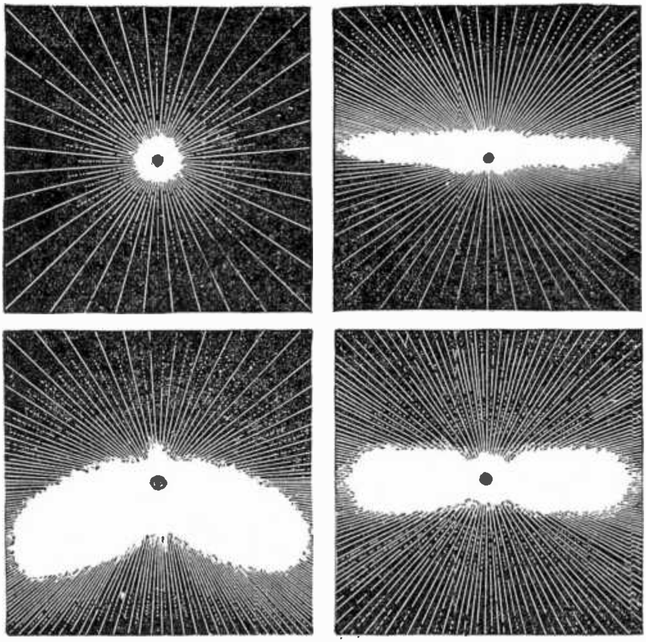
be waste of illumination through throwing it upward to the sky instead of downward where pedestrians and traffic need it and it should be figured in accordance with the size of town, type of street and need.

Street illumination generally runs .05 foot candle to .50 foot candle on the plane of the street surface—a general average being .10 foot candle. The type of units which are best suited for highways, street intersections, streets with existing illumination from store windows, etc., should be considered. The height at which they should be placed, the distance apart—are all factors. Excellent illumination is considered when the distance apart is no more than eight times the height of the luminant; that is, with the lamps 25 feet above street level, they should be spaced no more than 200 feet.

FIG. 8,421.—The outside view of a prismatic globe. ***In principle:*** when a light ray strikes a piece of glass it is reflected or refracted in accordance with the shape of the piece of glass. By changing the shapes of the pieces of glass or prisms, the direction of the rays may be changed. This principle is used in the manufacture of globes for street lamps. The inside is cut up into prisms so shaped that they take the rays from the lamp in its various directions and redirect them in the directions desired; some of the prisms are horizontal, some vertical—definitely arranged to carry out the requirement. An outer globe then diffuses or smooths out the light.

Globes surrounding the lamps should have the quality of directing the rays sideways and downward so as not to waste the illuminant in directions where it is not needed. A bare lamp will send about 50% of its light upward.

Prismatic globes are made which by refraction due to the prisms, direct the light given by the lamp into the desired planes. Spacing and height cannot be set down with any definite rules nor can the size of bulbs or type of fixtures, these are all based on local conditions and the amount of money to be expended for the installation.



FIGS. 8,422 to 8,425.—Light distribution of bare lamp and various Holophane symmetrical units. Fig. 8,422, bare lamp; fig. 8,423, Holophane asymmetric refractor highway type; fig. 8,424, Holophane asymmetric refractor bi-lux type; fig. 8,425, Holophane asymmetric refractor 2-way type.

TEST QUESTIONS

1. *Define the term illumination.*
2. *Give definitions of the terms used in illumination.*
3. *What is a foot candle?*
4. *What is the principle of Rumford's photometer?*
5. *Name three systems of lighting for general illumination.*

6. *Describe a, the direct; b, the indirect, and c, the semi-indirect lighting systems.*
7. *Name four methods of distributing light.*
8. *Explain how light is a, absorbed; b, refracted; c, reflected; d, diffused.*
9. *Explain the diffusion of light.*
10. *What is glare?*
11. *Describe two kinds of glare.*
12. *Are shadows desirable in artificial lighting?*
13. *What may be said with respect to the illumination of horizontal and vertical surfaces?*
14. *Name three methods of lighting calculations.*
15. *What is the objection to the point by point method?*
16. *Is the watts per sq. ft. method accurate?*
17. *What is the advantage of the lumen method?*
18. *Describe in detail the lumen method.*
19. *What is a unit cone?*
20. *Mention some points relating to the location of outlets.*
21. *Explain the calculation of the size of lamp required.*
22. *Describe in detail the method of making flood lighting calculations.*
23. *How is the power required for flood lighting determined?*
24. *What are the points relating to colored lighting for buildings?*
25. *Give the air port lighting principles.*
26. *Name two systems of air port lighting.*
27. *Describe in detail both systems of air port lighting.*
28. *How is the amount of light required for air ports determined?*
29. *Give points relating to street lighting.*

CHAPTER 215

Resonant Control for Street Lights

The rapid development of radio has greatly stimulated interest in the properties of electric circuits. This knowledge and experience has lately been turned to great practical advantage in providing a solution for the problem of street light control.

The difficulty of turning multiple street lights on and off has been a serious obstacle to the general adoption of the multiple system. This problem has been solved *by the use of medium frequency currents.*

These currents are superimposed on the regular power currents and in no way affect or interfere with the normal operation of the power system.

Resonant control is also well adapted to the remote control of series lighting systems fed by pole type regulators.

General Principle.—The basic idea of the control system is *to use the existing power conductors as the control circuit.*

The control currents are transmitted over the lines just like power currents. The frequency of the control currents used is sufficiently higher than the power frequency to make it easy to separate the control currents from the power currents.

Special relays employing tuned circuits are provided at points where control is desired. These relays are connected across the 110 volt mains which feed the individual street light or group of lights. The relays respond only to currents having the particular frequency for which they are tuned.

Sufficient energy is fed through the power system to the control relays to operate them by the direct electro-magnetic pull of the control currents themselves without the use of vacuum tubes, amplifiers or rectifiers of any kind. This avoids complication and delicacy in the control units and also avoids using parts requiring periodic replacement.

Two control frequencies are used, one to turn the lights on and one to turn them off.

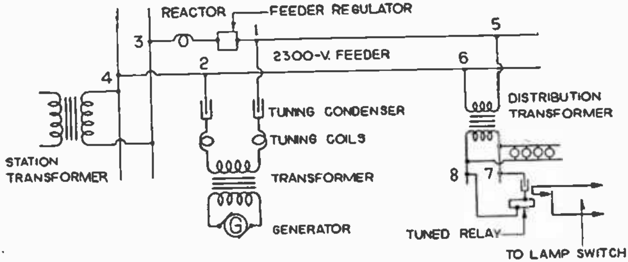


FIG. 8,426.—Diagram of substation bus with single feeder. The control currents are produced by the alternator G. This is a rotating machine of a standard type driven by a two speed induction motor or by a single speed induction motor with a two speed gear shift. The two speed motor runs at 1,200 and 1,800 *r.p.m.*, while the single speed motor runs at 3,600 *r.p.m.* The latter is a smaller unit, and, since it is for short period use, the oil immersed gears are not objectionable. The alternator produces control frequencies of 480 and 720 cycles at 1,200 and 1,800 *r.p.m.* respectively. The alternator is coupled to the feeder by means of a tuned circuit. This tuned circuit consists of suitable condensers, and inductance coils. A transformer of suitable ratio is interposed between the alternator and the tuned circuit so as to adapt the alternator to the low impedance circuit which it feeds. The condensers are connected directly to the feeder and serve the double purpose of tuning the alternator circuit and of introducing a high impedance to the flow of power frequency current back through the alternator.

Method of Feeding Control Currents into the Power System.—The control currents are fed into the power system at the substation. A single feeder may be energized alone or all the feeders on a bus may be energized at the same time. Single phases may be energized by switching from feeder to feeder, or the entire bus may be energized by making connection to the bus instead of to individual feeders. The control currents flow along the conductors just as though the power currents were not present.

The frequency of the control currents is selected so as to avoid serious loss in transmission and to permit being efficiently stepped up or down through the existing power transformers. Frequencies of about 500 cycles are used.

The method of introducing the control currents into the power system is shown in fig. 8,426.

In the diagram the current delivered by the alternator and tuned circuit to the feeder has two paths in which to flow. It may flow from junction 1 back through the feeder regulator, reactor, station transformer bank to junction 2. It may also flow from 1 out along the feeder through the numerous distributing transformers and their connected load and back to 2. The current divides between these paths inversely as their respective impedances. The two paths in parallel present a combined or resultant impedance to the flow of input current from the generator.

The input current multiplied by this resultant impedance gives the value of the control frequency voltage superimposed on the power system as measured across the feeder terminals at points 1 and 2. This voltage is superimposed on top of the power frequency voltage and it acts independently, *i.e.* as though the power frequency were not present. The value of this voltage for a 2,300 volt feeder is approximately 100 volts. So far as the control currents are concerned the system can be viewed as though the feeder were energized by a 100 volt alternator connected across points 1 and 2 as shown in fig. 8,426. This 100 volt control voltage acts throughout the whole length of the feeder and excites the primary side of all distributing transformers on the feeder. The transformers step this control voltage down, in the same ratio as the power voltages, giving 5 volts on the 110 volt side of each transformer.

It is this voltage which is available for the operation of the tuned control relays.

The superimposed voltage does not add directly to the power voltage but adds vectorially at right angles.

Thus 5 volts of control voltage adds only .11 volt to the effective system voltage. A superimposed voltage of 20 volts will only increase the 110 volt secondary voltage by 2 volts. The energy required to produce the superimposed control voltage is a very small part of the energy rating of the power system. It may be of interest to note that the control frequency alternator runs at 100% power factor and supplies only the power component of the superimposed *kva.*

The existing wires and cables of a power system therefore provide an efficient channel for the transmission of independent control currents for all sorts of purposes. There is no difficulty in transmitting control currents, having sufficient energy to directly operate suitable relays, to all parts of the system.

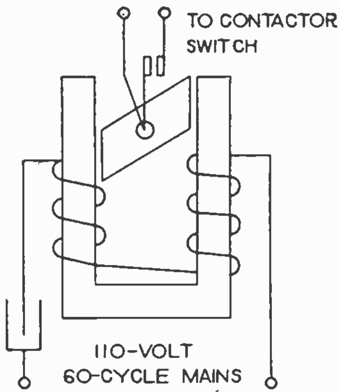
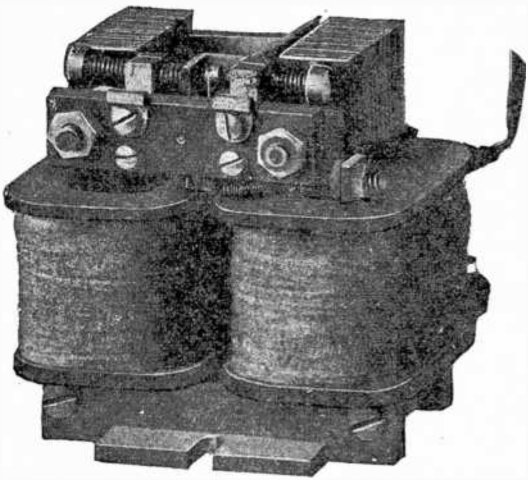


FIG. 8,427.—Diagram showing features of Westinghouse resonant relay. ***It consists of*** a simple *U* shaped electro-magnet acting on a balanced armature. The armature carries the control contact which completes a circuit through a contactor switch in the lamp circuit. The relay contact therefore does not carry the lamp current but only the control current for the contactor switch. The contacts of both the relay and the contactor switch are made of pure silver to assure perfect contact under all service conditions.

NOTE.—In fig. 8,427 the ***magnet winding of the relay*** plays a double part. In addition to its normal function in which it acts as a simple electro-magnet, it furnishes the inductance necessary to tune the relay to the desired control frequency. The relay is connected to the line through a condenser which furnishes the other element necessary to form a tuned circuit. The condenser also acts as a stopping condenser to prevent the flow of an appreciable amount of power frequency current through the relay. The inductance of the relay is so adjusted that the circuit consisting of the relay and condenser are in series resonance for the frequency on which the relay is required to operate. That is, the reactance of the relay circuit as a whole is zero for its operating frequency. This circuit is connected directly across the 110 volt line as shown at 7 and 8 in fig. 8,426.

Resonant Relays.—The relays used in this system of control *utilize the direct electro-magnetic pull of the control current;* that is, the control currents are themselves sufficiently strong to move the relay armature on which is mounted the control contact.



This is an advantage in that it avoids the complication of amplifying tubes, rectifying tubes or delicate relay mechanism.

Fig. 8,428 shows

FIG. 8,428.—Westinghouse resonant relay used for street light control.

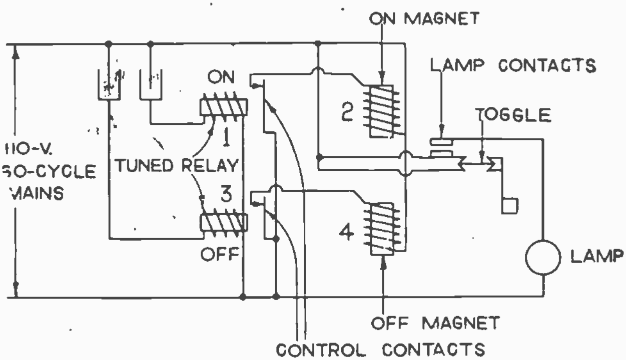
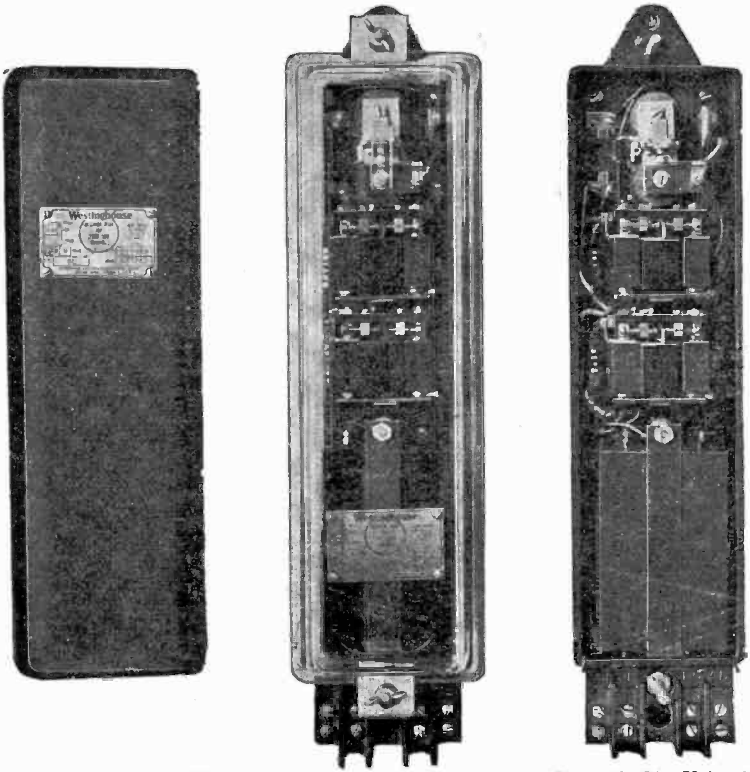


FIG. 8,429.—Diagram of Westinghouse resonant control unit. The tuned relays are shown at 1 and 3. The switch or contactor in the lamp circuit is of the toggle type; that is, it is pulled over a center and will remain permanently open or closed as the case may be. The operating coils of this toggle switch are indicated at 2 and 4.

the general appearance of the type relay used for resonant street light control, and fig. 8,427 the relay in diagrammatic form.

Since the relay is connected across the supply line at all times a small amount of power current will flow through the condenser and relay but this current is much below the operating value. This continuous flow of power frequency current is a leading current, being almost entirely wattless. This leading current is a benefit to the system in that it helps to correct the power factor.



FIGS. 8,430 to 8,432.—Westinghouse resonant control unit figs. 8,430 and 8,431. Unit with metal cover removed; fig. 8,432, unit with glass cover

Resonant Control Unit.—The appearance of the complete street light control unit is shown in figs. 8,430 to 8,432.

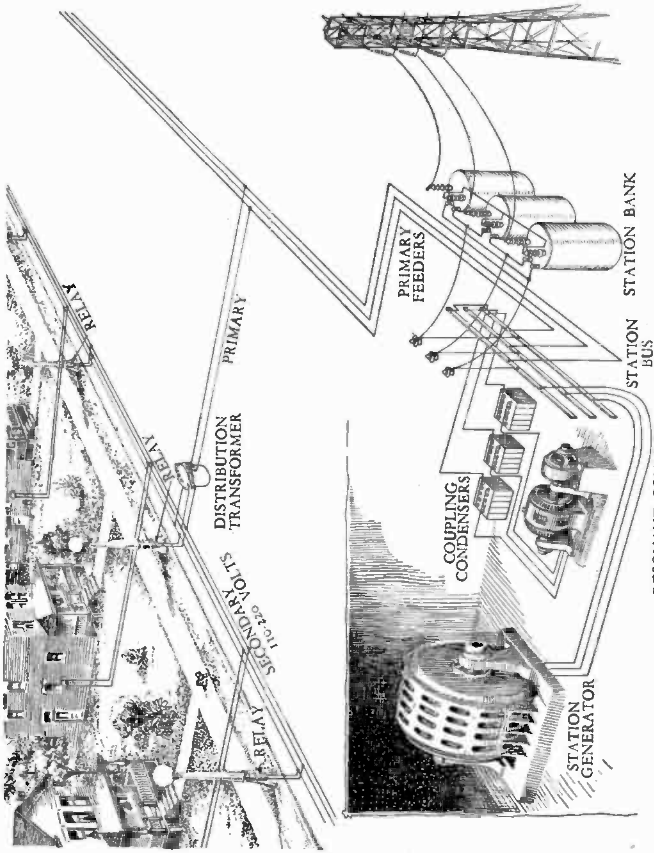


FIG. 8,433.—Westinghouse resonance control exterior circuits; three phases energized simultaneously.

The equipment is assembled in a water proof case and is of such dimensions as to permit its being mounted in the base of the majority of ornamental street light posts. The elements of the control unit are shown in fig. 8,429.

Operation of Resonant Control.—When it is desired to turn *on* the street lights *the control frequency alternator in the substation is brought up to speed and run at the* ***on*** *frequency.*

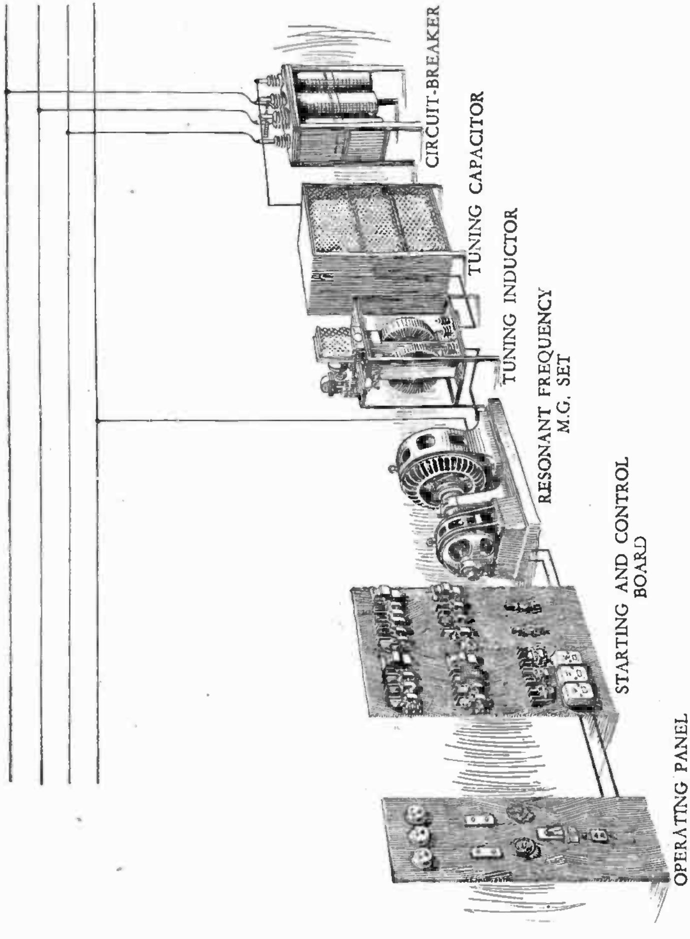


FIG. 8,434.—Westinghouse resonant control station equipment, three phases energized consecutively.

The alternator circuit is closed momentarily on the feeder carrying the street lights being controlled. This sends the *on* frequency to all parts of the feeder and all its connected apparatus. All relays tuned on the *on* frequency immediately respond and close their control contacts. Then relay 1, fig. 8,429, is pulled up, thus energizing the operating magnet 2 of the toggle switch, closing the switch and lighting the lamp or lamps. The alternator at the sub-station is then disconnected. The *on* relays drop back to the open circuit position but the contactor switch remains closed owing to the toggle. The lights remain *on*.

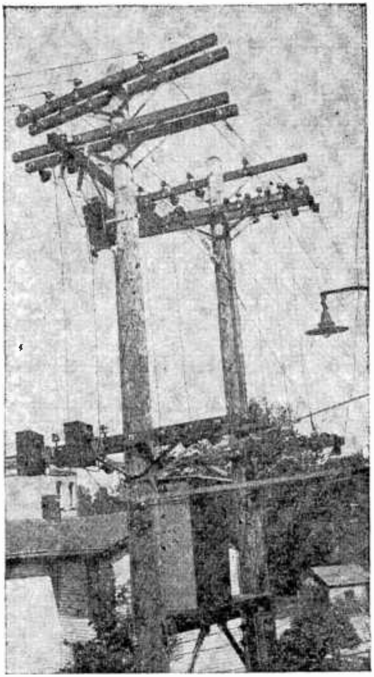


FIG. 8,435.—Westinghouse resonant control installation as applied to *series lighting circuits*.

When it is desired to turn the lights *off* the control alternator at the sub-station is brought up to speed at the *off* frequency and closed momentarily on the feeder.

This energizes the *off* relays all over the system. These relays in turn energize the operating magnets of the toggle switches and pull the switches to the open position. The control alternator is then disconnected, the *off* relays drop back to the open position but the toggle switches remain open and the lamps remain *off*.

Application to Series System Using Constant Current Regulators.—While the system as developed was worked out with special attention to the requirements for multiple street lights, it is also well adapted to the series systems fed from automatic station type, manhole type and pole type regulators.

In addition to advantages in the concentrated lighting areas, resonant control makes possible the central control of series street lighting circuits for rural districts, over a wide area without the necessity of long pilot circuits. The method of applying Westinghouse control to series systems fed from constant voltage feeders through a pole type regulator is indicated in fig. 8,436.

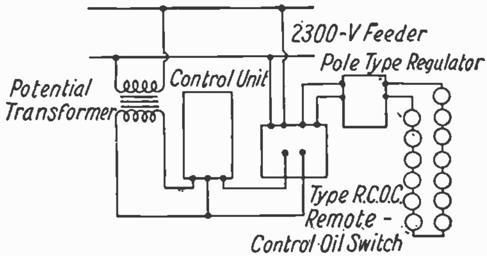


FIG. 8,436.—Diagram of Westinghouse resonant control for ***series system.*** The pole type regulator is connected to the 2,300 volt power feeder by a remote control oil switch. This switch is controlled by a standard resonant control unit energized from the 2,300 volt feeder, through the medium of a step down voltage transformer. This transformer is necessary to provide the 110 volt source for operating the street light control unit and also for supplying the control current for the oil switch. If a 110-220 volt distributing circuit be nearby, the voltage transformer may be omitted and the control frequency and operating current supplied from it.

TEST QUESTIONS

1. *What is the general principle of resonant control?*
2. *Describe the method of feeding control currents into the power system.*
3. *Draw a diagram of sub-station bus with single feeder*
4. *What are resonant relays?*
5. *Describe a resonant control unit.*
6. *Explain the operation of resonant control in detail.*
7. *Describe the application to series system using constant current regulators.*

CHAPTER 216

Electric Bells

An electric bell is *a device in which a hammer is vibrated so that it beats against a bell.*

It operates by an electro-magnet which attracts an armature or piece of soft iron forming part of the hammer lever, the attraction ceasing when the circuit is broken by the *contact breaker*, the hammer being drawn back to its original position by a spring whereby the circuit is closed and the operation repeated.

The great multiplicity of bells may be classified

1. With respect to the ringing feature, as

   a. Trembling or vibrating;
   b. Single stroke;
   c. Combination vibrating and single stroke;
   d. Continuous ringing;
   e. Buzzers.

2. With respect to the magnet winding, as

   a. Series winding;
   b. Shunt winding;
   c. Differential winding;
   d. Combined differential and alternate winding;
   e. High voltage winding;
   f. Alternating current winding (polarized).

3. With respect to the form of the interrupter, as

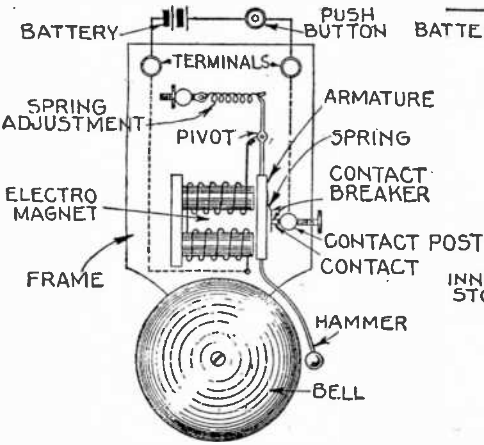
   a. Contact breaker;
   b. Contact maker.

4. With respect to the magnet, as

a. Single magnet;

b. Double magnet;

c. Four magnet (double acting).



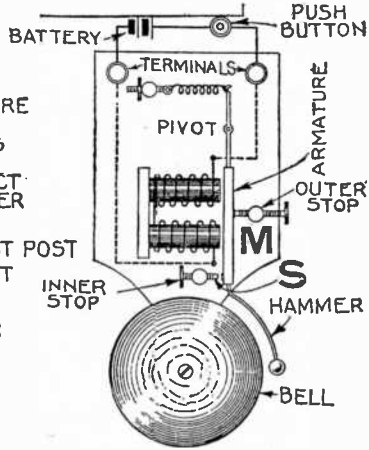


FIG. 8,437.—Elementary series vibrating bell. It consists of an electro-magnet, armature, contact breaker, pivoted hammer, bell, and frame. ***In operation,*** when the push button is pressed, the current energizes the magnet which attracts the armature causing the hammer to strike the bell but before it reaches the end of the stroke, the contact breaker breaks the circuit and the hammer, influenced by the tension of the armature spring rapidly moves back to its initial position thus completing the cycle.

FIG. 8,438.—Elementary single stroke bell. ***In operation,*** when the push button is pressed. the current energizes the magnet and attracts the armature causing the hammer to strike the bell. The armature remains in the attracted position so long as the current flows through the magnet. When connection with the battery is broken, the hammer spring pulls the armature back against **M**. A stop **S**, averts the motion of the armature, momentum springing the lever and causing the hammer to strike the bell.

5. With respect to the frame, as

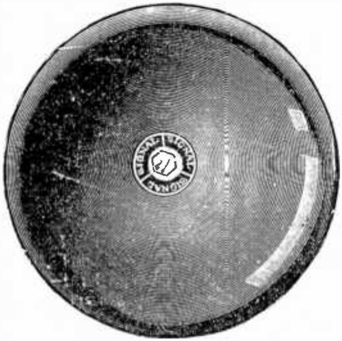
a. Skeleton;

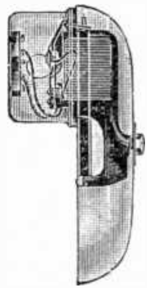
b. Iron box;

c. Wooden box.

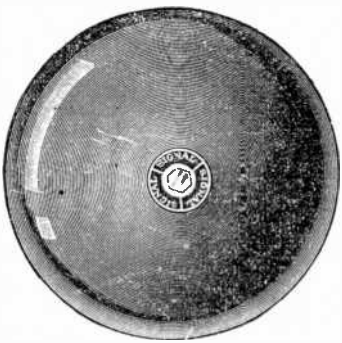
6. With respect to the mode of operation, as

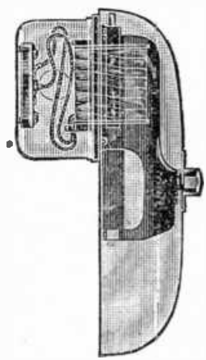
- *a*. Single acting;
- *b*. Double acting;
- *c*. Electro-mechanical;
- *d*. Relay.





FIGS. 8,439 and 8,440.—Bunnell *a.c.* and *d.c.* vibrating bell; 24 to 250 volts *a.c.*; 6 to 250 volts *d.c.* The striking element is a heavy plunger moving in a moulded condensite tube. A long time element is thus secured between strokes which permits the gong to vibrate freely and give a true ring of great penetrating or signaling power. The contact is not broken or the contact pressure reduced until the plunger has practically reached the end of the stroke when it engages the interrupter and opens the circuit with a quick break.





FIGS. 8,441 and 8,442.—Bunnell *a.c.* and *d.c.* single stroke bell for series or parallel circuits. In construction the only moving part is a heavy plunger, which travels within a moulded condensite tube when the current is turned on. The plunger strikes the gong a single, direct blow, setting it in complete vibration.

Trembling or Vibrating Bells.—This form of bell is perhaps more extensively used than any other. It consists essentially, of

1. Electro-magnet;	4. Contact breaker;
2. Pivoted armature;	5. Bell;
3. Hammer;	6. Frame.

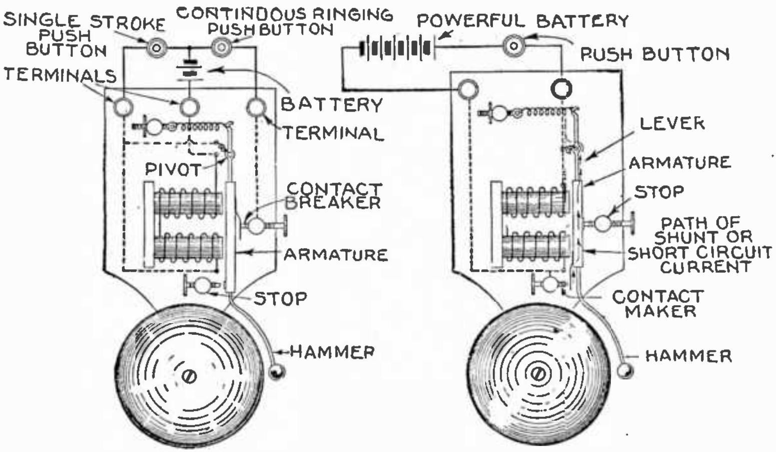


FIG. 8,443.—Elementary combination vibrating and single stroke bell. It is essentially a vibrating bell as shown in fig. 8,437, with a third terminal, and a stop to prevent continued contact of the hammer with the bell when working single stroke.

FIG. 8,444.—Elementary shunt or short circuit, combination vibrating and single stroke bell. This is simply an ordinary shunt bell with a switch arranged so that the short circuit through the contact maker, armature and lever may be cut out, thus restricting the current to the magnet winding.

The essential parts are shown in fig. 8,437.

Single Stroke Bells.—This type of bell is one which *gives only a single tap each time the battery is connected in circuit.* Such operation is often desirable, as in signaling with a code.

NOTE.—The series of cuts representing various elementary bells is intended to illustrate ***principles***, metallic circuits being shown for simplicity. ***It should be noted that in construction***, the metal frame of the bell is used as a "ground" or return instead of a separate wire.

Combination, Vibrating and Single Stroke Bells.—This type of bell is simply a *combination of the two bells just described*, as the classification indicates.

Any vibrating bell may be made single stroke by bringing out a third connection so that the current may pass through the magnet without traversing the interrupter.

A vibrating bell may be made single stroke by adjusting the contact breaker spring so that it does not open the circuit.

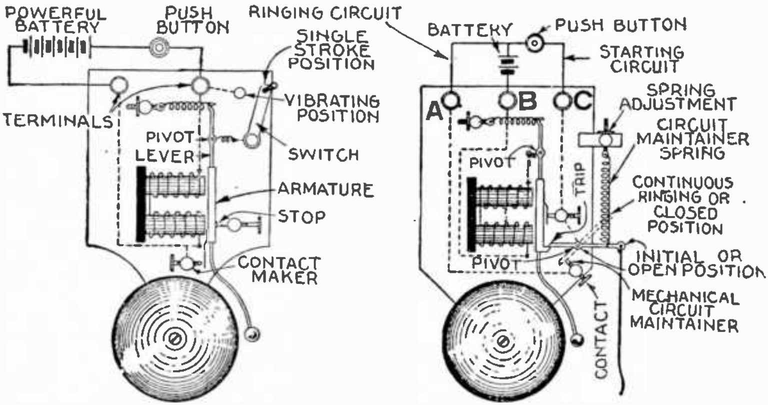
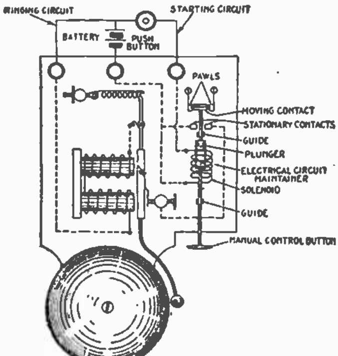


FIG. 8,445.—Elementary shunt bell with single stroke switch. ***Shunt*** cycle when the push button is pressed: 1, Current magnetizes the electro-magnet; 2, magnet attracts armature, 3, contact maker short circuits the current; 4, magnet loses practically all of its magnetism; 5, momentum acquired by moving element causes hammer to strike bell; 6, tension of the hammer spring overcomes weak magnetism of magnets and pulls armature away from magnet; 7, near end of outward swing, contact maker breaks circuit; 8, current again magnetizes the magnet; 9, momentum acquired by the moving element causes it to continue its outward swing (against the attraction of the magnet) to the stop.

FIG. 8,446.—Elementary continuous ringing bell with *mechanical circuit maintainer*. ***It is essentially*** an ordinary vibrating bell fitted with a mechanical circuit maintainer and connections as shown. ***In operation***, when the battery circuit is closed momentarily, the path of the current is via terminals B and C. On the swing of the armature toward the magnet the circuit maintainer trips and its spring causes it to move to the continuous ringing position, thus switching terminal A, wire to contact breaker via trip lever. With this circuit it is evident that the bell will continue ringing irrespective of whether the push button be held down or released, and also that the ringing will continue until the circuit maintainer is reset in its initial or open position by a pull on the manual control cord. ***This type*** bell is useful for burglar alarms.

Shunt, or "Short Circuit" Bells.—In this form of bell the current, during operation, is not broken, but *as the magnet attracts the armature, the current is shunted or short circuited*, and thus being offered a path of very little resistance as compared with that of the magnet winding, most of the current flows through the short circuit.

Since this reduces the magnetism to such a small amount that the attraction of the magnet becomes less than the pull of the hammer spring, the hammer swings back to its initial position.



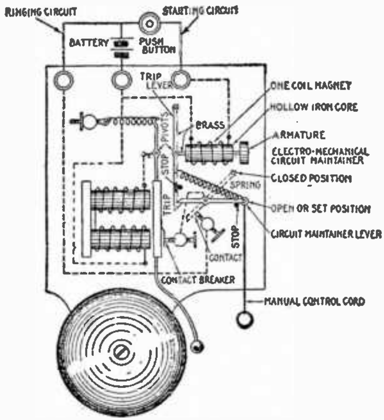


FIG. 8,447.—Elementary continuous ringing bell with electrical circuit maintainer. ***In operation,*** when the *starting circuit* is *closed* by depressing the push button, current flows through the solenoid and draws down the plunger, thus ***closing the ringing circuit.*** The bell will now ring until the ringing circuit is broken by pushing upon the manual control button. To reset the circuit maintainer the manual control button is pushed upward until the moving contact rises above the pawls and the latter spring back to their normal (vertical) position, then the weight of the moving element is held by the pawls.

FIG. 8,448.—Elementary continuous ringing bell with *electro-mechanical circuit maintainer*. ***In operation,*** when the starting circuit is closed by depressing the push button, current energizes this one coil electro magnet attracting the armature which disengages the trip. The spring snaps the circuit maintainer lever over to the closed position as shown by the dotted lines, the trip lever being drawn back by the spring against the stop when the push button is released. The bell beginning to ring as soon as the circuit maintainer lever closes the circuit through the contact breaker and bell magnet. ***To reset,*** the manual control is pulled down until the circuit maintainer lever strikes the stop, the trip end will then engage with the claw of the trip lever.

Continuous Ringing Bells.—This classification represents a form of vibrating bell, provided with *a suitable attachment for maintaining the circuit after it has been once established by pressing the push center*, regardless of the fact that the latter may be only momentarily held in the closed position.

There are three types of continuous ringing bell, classified with respect to the circuit maintaining device, as those with

1. Mechanical circuit maintainer;
2. Electrical circuit maintainer;
3. Combination mechanical and electrical circuit maintainer.

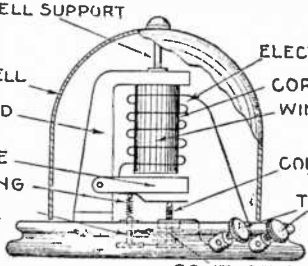


FIG. 8,449.—Sectional view of a buzzer. *In construction,* the armature is pivoted to the lower part of an upright soft iron shield or standard from the top of which the magnet is firmly suspended. The armature being pivoted to the shield, vibrates between the magnet and wooden base and is regulated by adjusting screws underneath. The mechanism is enclosed in a bell or brass shell.

Buzzers.—A buzzer is virtually *an electric bell without a hammer or gong.*

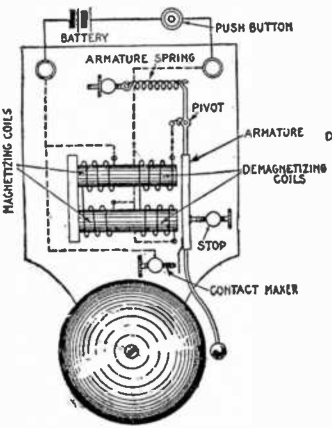
It operates on the same principle as the electric bell and can be adjusted to emit a pleasing musical hum.

Differential Bells.—This type of bell represents one of the numerous schemes to eliminate sparking at the contacts of the interrupter.

The electro-magnet is provided with two windings which, for convenience to distinguish their function, may be spoken of as: 1, the magnetizing winding; 2, the demagnetizing winding.

Combined Differential and Alternate Bells.—In this type of bell *there are two separate electro-magnets, and an armature pivoted centrally between them,* so that it is alternately attracted, first by one magnet, then by the other, as in fig. 8,451.

High Voltage Bells.—In designing a bell for operation on high voltage circuits, that is, on circuits of voltages higher than is usual in ordinary battery installations, provision must be made:



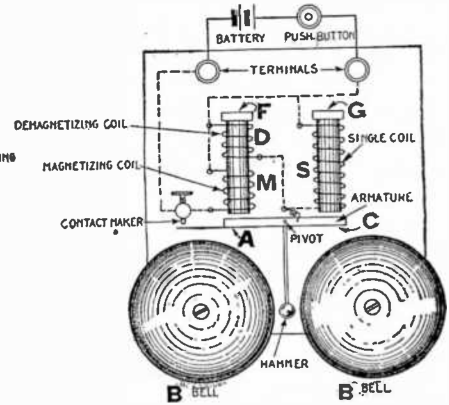
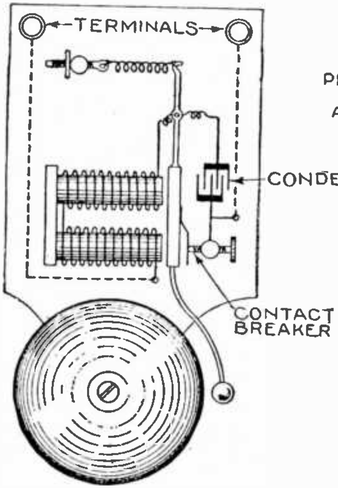


FIG. 8,450.—Elementary differentially wound vibrating bell. ***In operation,*** when the battery circuit is closed: 1, Current flows through the magnetizing winding and energizes magnet; 2, magnet attracts the armature; 3, contact maker closes circuit through demagnetizing coils; 4, demagnetizing coils demagnetize the magnet; 5, armature spring pulls armature back against the stop, while, 6, the contact maker breaks the circuit through demagnetizing coils.

FIG. 8,451.—Elementary differential and alternate bell. ***In operation,*** when the battery circuit is closed: 1, current flows through the magnetizing winding M, and energizes magnet F; 2, magnet F, attracts end A, of the armature; 3, contact maker closes circuit through demagnetizing coil D, and single coil S, (of magnet G); 4, demagnetizing coil demagnetizes F, and 5, magnet G, attracts end C, of the armature; 6, contact maker breaks the circuit through demagnetizing coil D, and single coil S, (of magnet G).

1. To limit the current to the proper value;
2. To secure the proper working conditions at the interrupter.

The first requirement is met by proportioning the magnet winding so as to avoid an undue amount of current. Sparking at the interrupter may be prevented by the use of a condenser.



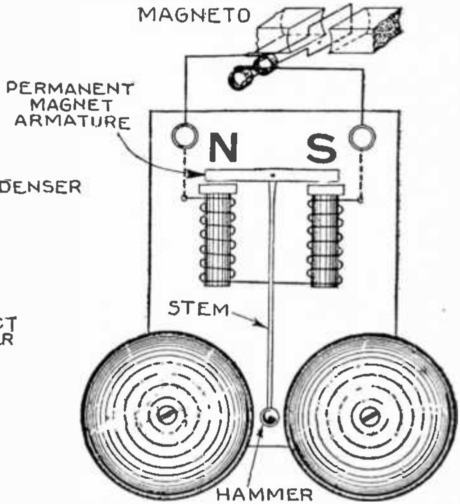


FIG. 8,452.—Elementary heavy duty high voltage bell. The winding is of fine wire to secure enough resistance to keep down the current to proper value. Sparking is avoided by connecting a condenser across the contact breaker as shown.

FIG. 8,453.—Elementary alternating current bell with permanent magnet armature. In construction the electro-magnets are wound similarly, that is, *in the same direction*, so as to produce like poles which simultaneously repel and attract the armature ends.

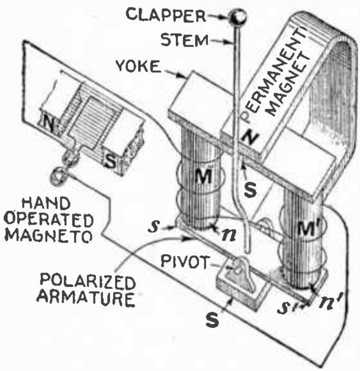
Alternating Current Bells.—A type of bell formerly *used extensively in telephone work*, to operate on the alternating current furnished by the magneto is shown in fig. 8,453.

Double Acting Bells.—This type of bell is desirable *for railroad signals or any place where an extra loud alarm is desirable.*

Motor Driven Bells.—This type of bell is desirable *for use where a loud ringing alarm or signal bell is required.*

It consists essentially of a motor having a double striker mounted at the armature shaft as shown in fig. 8,458, giving two strikes to each revolution.

Bells of this description are designed to operate on battery pressures of six volts and higher, also lighting circuits of 110 volts alternating and direct. A powerful blow is obtained by the revolving stroke of these bells, because of the amplitude of the stroke, which permits the hammers to acquire considerable *momentum* between blows.



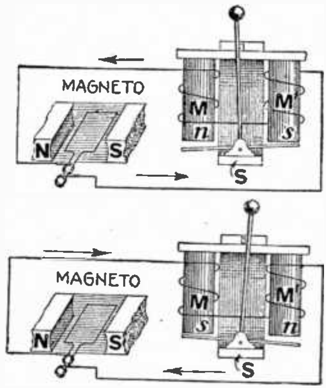


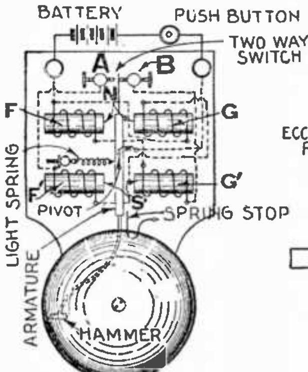
FIG. 8,454.—Elementary *a. c.* bell polarized by magnetic induction. N and S, are permanent magnet poles, and *n* and *s*, poles *induced* by the permanent magnet.

FIGS. 8,455 and 8,456.—Operation of the elementary *a.c.* bell of fig. 8,454. The figures show the induced poles and movement of the armature during one cycle of the low frequency *a.c.* supplied by the hand operated magneto.

Electro-mechanical Bells.—Where a very powerful bell is required to operate at a distance with little battery capacity, the electro-mechanical bell is well suited.

In this type of bell, *the electric current is used simply to control a spring operated mechanism which supplies the energy to ring the bell.*

A form of electro-mechanical bell is shown in fig. 8,459. It consists essentially of a large and small gear as shown, the large gear having rigidly fastened to it, a ratchet and pawl wheel and main spring for operating the gong, a control lever operated by the electro-magnet governs the movement of the two gears by pawl and detent device, and the small gear has attached to its shaft an air vane to prevent too rapid rotation of the gears. There is also a control handle by which the bell is rendered either single stroke or continuous ringing.



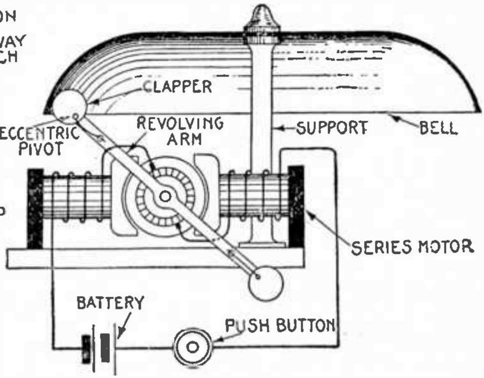


FIG. 8,457.—Elementary double acting bell. ***In operation***, magnets F,G', and F',G, are alternately energized. Assuming the current to flow first through F,G' and then through G F', F and G'. will have N and S poles, and G and F',S and N poles; these will induce unlike poles in the ends of the armature attracting it at both ends.

FIG. 8,458.—Elementary motor driven, or revolving strike bell. ***In construction***, the motor has a revolving member attached to the shaft and an eccentrically pivoted clapper at either end, which in operation delivers two blows to the bell at each revolution of the motor. A desirable type of bell for use where a very loud ringing alarm is required.

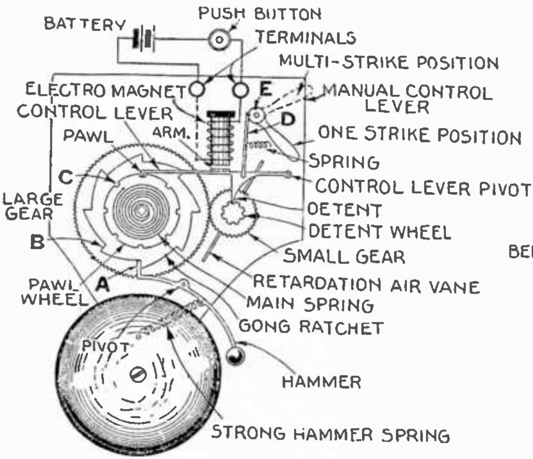
Relay Bells.—Where bells are to be operated *at a considerable distance a relay is usually employed*, especially in the case of large heavy duty bells requiring considerable energy to operate them.

A relay is a device *which* **opens** *or* **closes** *an* **auxiliary circuit** *under pre-determined electrical conditions in the main circuit.*

Its function is to act as a sort of electrical multiplier, that is to say, *it enables a comparatively weak current to bring into operation a much stronger current.*

This is very clearly seen in the operation of a telegraph relay, where a very weak long distance transmission current is used to operate a relay, which synchronously controls a strong local current to operate a "sounder."

The term relay has been used erroneously to a considerable extent, perhaps both through ignorance and abuse; thus, bells fitted with electrical, or electro-mechanical controlling devices, the equivalent of those shown in the accompanying cuts are often spoken of as "relay" bells. This



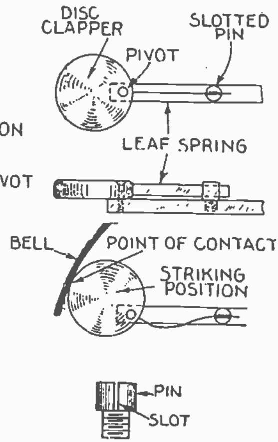
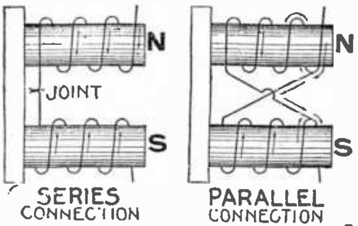
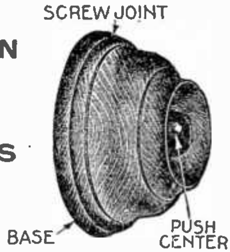


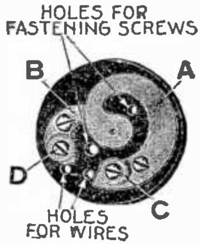
FIG. 8,459.—Elementary electro-mechanical bell. ***In operation***, the main spring having been wound up, a momentary push on the push button will energize the electro-magnet, attracting the control lever and raising the pawl out of engagement with the pawl wheel and also the detent clear of the detent wheel, allowing the gears to revolve. If the push button be now released, the pawl will ride on the pawl wheel, keeping the detent out of engagement with the detent wheel. As the large gear turns counter-clockwise, the finger A, rides on the ratchet, gradually drawing the hammer away from the bell against the tension of the hammer spring. As the finger rides off the point B, the hammer is suddenly released and strikes the bell a powerful blow. At the same instant the pawl falls into the depression C, on the pawl wheel and the detent engages with one of the numerous depressions in the detent wheel, thus stopping the mechanism. A moderate velocity of rotation of the gears is obtained by means of the retardation air vane.

FIGS. 8,460 to 8,463.—Construction details of clapper for motor driven bell, and view showing action of clapper on striking the bell.

error will be avoided, by remembering that *the object of a relay is to enable a weak current to bring into action a strong local current,* and thus reduce the size of battery required; *this involves two distinct circuits each having a separate source of current.*



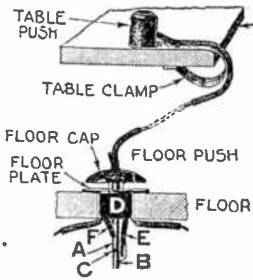




FIGS. 8,464 and 8,465.—Reducing resistance of bell coils. When connected in parallel (fig. 8,465) the resistance is reduced one half, allowing more current to flow through the coils for a given voltage.

FIGS. 8,466 and 8,467.—General construction of an ordinary push button. Fig. 8,466, exterior view; fig. 8,467, interior view.

FIG. 8,468.—Special push button with indicating buzzer inside, useful for any system where the caller desires to know positively that the bell has given the signal.



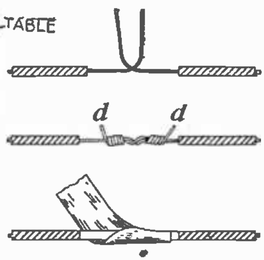
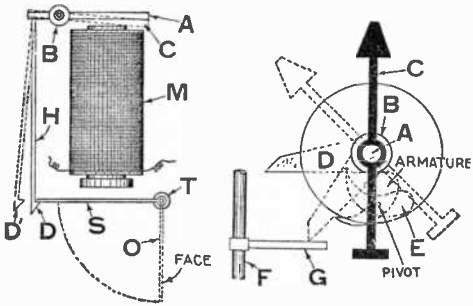


FIG. 8,469.—Paper weight type of multi-push button, suitable for desk use.

FIG. 8,470 and 8,471.—Combination floor and table push button suitable for dining room. The table clamp renders the push portable, permitting it to be moved at any time.

FIGS. 8,472 to 8,474.—Proper method of making a joint in covered wires. First scrape off about 3 ins. of the insulating covering on the end of each wire; scrape the bared copper wire until it is bright and clean; bend these wires into the position shown in fig. 8,472; and then firmly twist them around each other as shown in fig. 8,473. Second, cut off the projecting pieces *d*, *d*, close to the joint, and then solder the latter to prevent corrosion. This corresponds to a Western Union splice. Third, wrap a piece of adhesion or friction tape around the joint over about half an inch of the insulating covering of each wire, as in fig. 8,474.



FIGS. 8,475.—Shutter or gravity annunciator drop. *In operation*, when the circuit is completed by the depression of a push center, the current flows through the coils of the electro-magnet M, and energizes its core, and the latter attracts the armature A, pivoted at B. When the armature is drawn to the position C, the claw D, is thrown to the position D', thereby releasing the shutter S, pivoted at T, allowing it to drop by gravity to the position O, thus displaying the number marked upon its face.

FIG. 8,476.—Arrow or needle annunicator drop. *In operation,* when the current flows through the coils of the electro-magnet, the armature E, turns on its pivot towards the magnet core A, thereby releasing the arm D, which in falling rotates the arrow to the position shown in dotted lines. The arrow is reset by pressing a button, which raises the rod F, carrying the arm G,

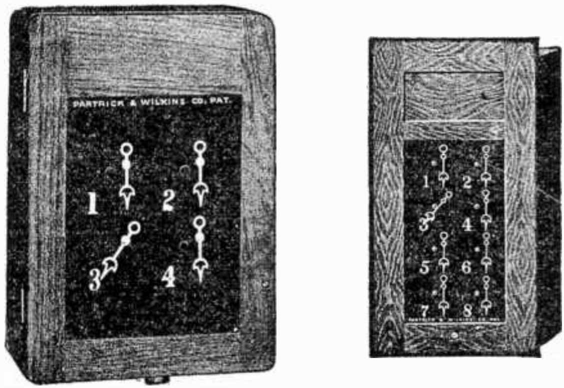


FIG. 8,477.—Partrick & Wilkins 4 *point hand reset* annunciator for *d.c.*, 4 to 6 volts or *a.c.* (transformer) not less than 12 volts, 25 watts. The hand reset is operated by a button at the bottom of the case.

FIG. 8,478.—Partrick & Wilkins 8 point *electric reset* flush case annunciator for *d.c.* 6 to 8 volts or *a.c.* (transformer) not less than 14 volts, 50 watts. Reset button is on front of case with extra connections so that a reset button, if desired, can be located remote from annunciator.

Annunciators.—An annunciator is a device *attached to an electric bell or other signal system in which a shutter, falling in one of a series of windows in a frame, discloses the number of the station calling.*

Annunciators are most extensively used in connection with elevator, office, hotel, and residence call bell service. The mechanism of an annunciator consists of an arrangement of electro-magnets the energizing of which, when the circuit is closed by the depression of the various pushes, allows shutters to drop, thereby exhibiting the circuit numbers painted

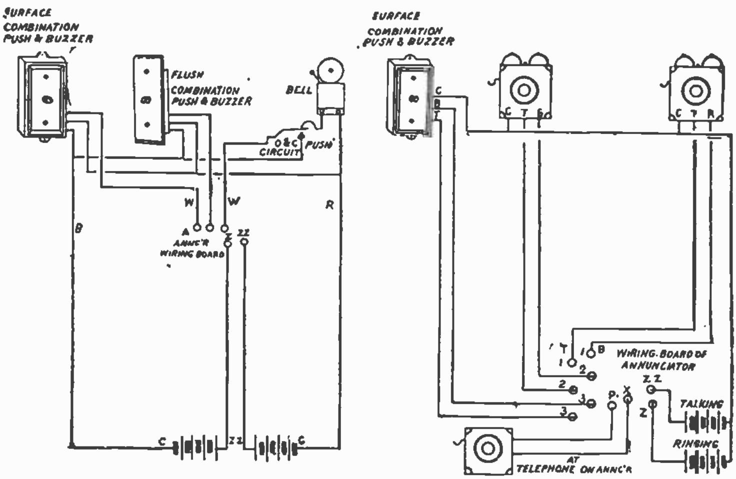


FIG. 8,479.—Partrick & Wilkins return call system using combination buzzers or buzzer pushes and buzzer or bulb separate.

FIG. 8,480.—Partrick & Wilkins telephone system using room sets or combination buzzers transformer or battery for calling and battery for talking circuit.

thereon, or causes arrows to move and point to the numbers of the circuits marked close to them on the indicator panel.

Bell Wiring.—Always start to wire at the push, and run the wires from the push to the bell, and to the battery.

Fasten each wire lightly to the woodwork with staples or double pointed tacks.

The wire from the push to the battery may be run through holes bored in the floor directly under the push, but inside the front door, then along the cellar beams to the battery. In many houses the wire from the push to the bell may also be run along the cellar beams. In such cases, a second hole should be bored in the floor by the side of the one accommodating the wire from the push to the battery, for the wire from the push to the bell.

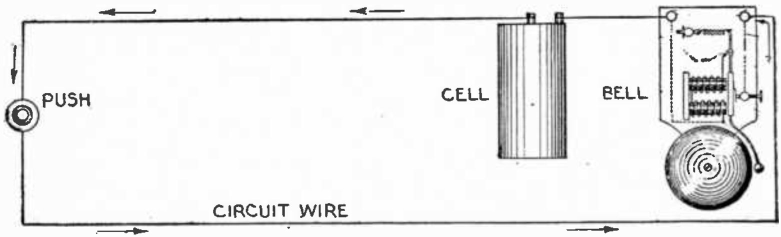


FIG. 8,481.—Simple bell metallic circuit.

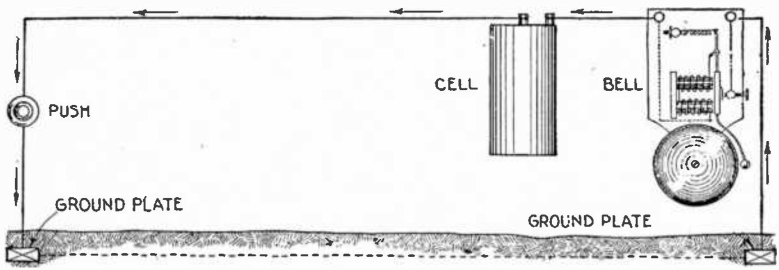


FIG. 8,482.—Simple bell circuit with *ground* return. Instead of using ground plates, a more convenient method consists in connecting the ground wires to a gas or water pipe.

Bell Circuits.—There is a great multiplicity of bell circuits, but they may all be divided into two general classes:

1. Metallic; 2. Ground.

NOTE.—***Low voltage bells*** ordinarily operate on 6 to 8 volts ***at the bell;*** this means 4 to 6 dry cells plus enough additional cells to allow for line drop depending on the length of line. ***It should be noted***, that in the wiring diagram the dry cell or cells shown do not represent the number of cells required but simply indicate an electrical source of current.

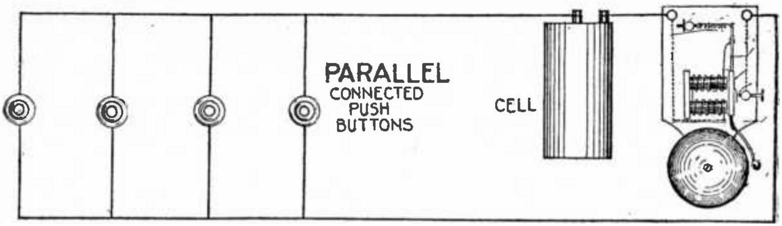


FIG. 8,483.—Parallel connected push buttons for ringing one bell from several points. It is obvious that if the push buttons were connected in series, all would have to be closed to complete the circuit.

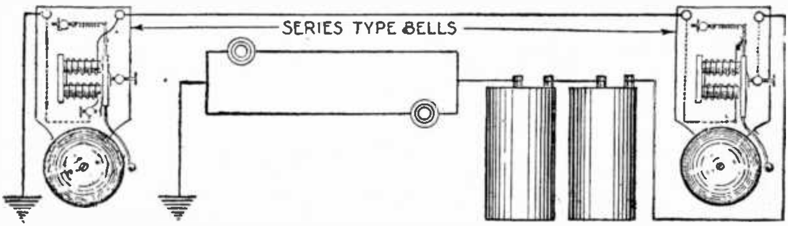


FIG. 8,484.—Two bells *connected in series* to ring from either one of two push buttons. ***It should be noted*** that ordinary bells cannot be connected in series, as they would not make and break the circuit in unison. Thus when two or more bells are to work on a series circuit, one of them should be an ordinary make and break bell, and the remainder single stroke bells, or two or more *shunt* or *short circuiting bells*, as here shown. It will be seen from the figure that the circuit through such a bell is never broken, the attraction of the armature short circuiting, and therefore demagnetizing the electro-magnet, which thereupon releases the armature. This operation is repeated as long as the outer circuit is closed; and the bell rings like any ordinary bell, but without interfering with the others in the circuit. Such a bell could obviously be used alone, but there would be a disadvantage in this, as the bell would short circuit the battery every time the armature was attracted. Even with two or more bells in series, the battery would be more or less short circuited when they were ringing. As these bells short circuit themselves when in action, there is appreciable sparking at their contacts.

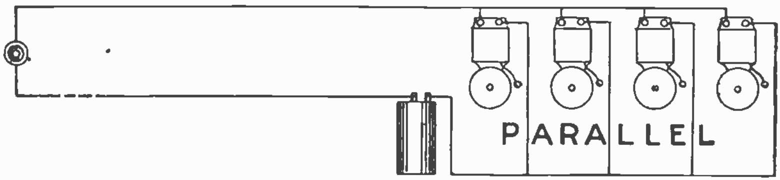


FIG. 8,485.—Several bells *connected in parallel* to ring from one push button.

according to whether a wire or the ground be used for the "return conductor," that is, to complete the circuit.

The simplest circuits representing these two classes are shown in figs. 8,481 and 8,482. Various other methods of connecting bells are shown in the accompanying illustrations.

In general, it makes no difference whether the positive or the negative pole of the battery connects with the bell or the push button, except where a ground return is used. In the latter case the negative pole should connect with the earth.

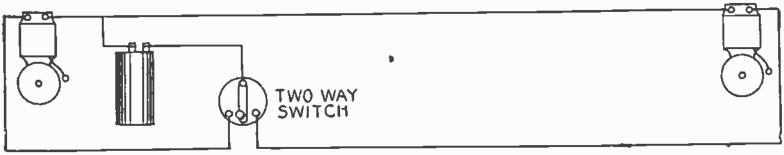


FIG. 8,486.—Diagram showing how either of two bells may be rung from one battery by means of a two way switch.

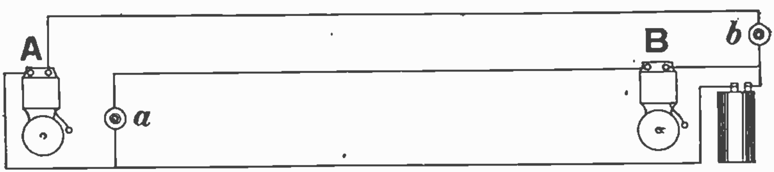


FIG. 8,487.—Two bell diagram so connected that push *a* rings bell B, and push *b* rings bell A.

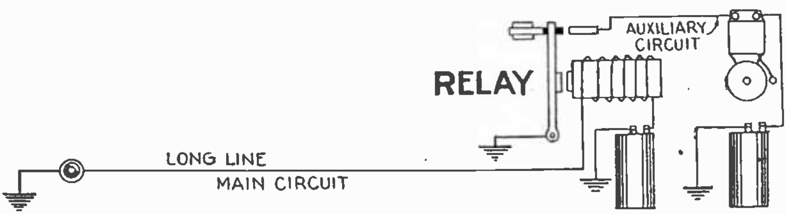


FIG. 8,488.—Method of reducing size of battery on long line by use of a relay. As explained elsewhere a relay is a device *which opens or closes an auxiliary circuit, under predetermined electrical conditions in the main circuit.* Its function is to act as a sort of *electrical multiplier*, that is to say, *it enables a comparatively weak current to bring into operation a much stronger current.*

It should always be remembered that the positive pole of the battery is at the top of the negative plate, and the negative pole is at the top of the positive plate.

For instance, in the case of a Leclanche cell, or dry cell, the positive pole is at the top of the carbon (negative) element, and the negative pole at the top of the zinc (positive) element. In the case of a gravity Daniell cell, the positive pole is at the top of the copper (negative) plate; and the negative pole is at the top of the zinc (positive) plate.

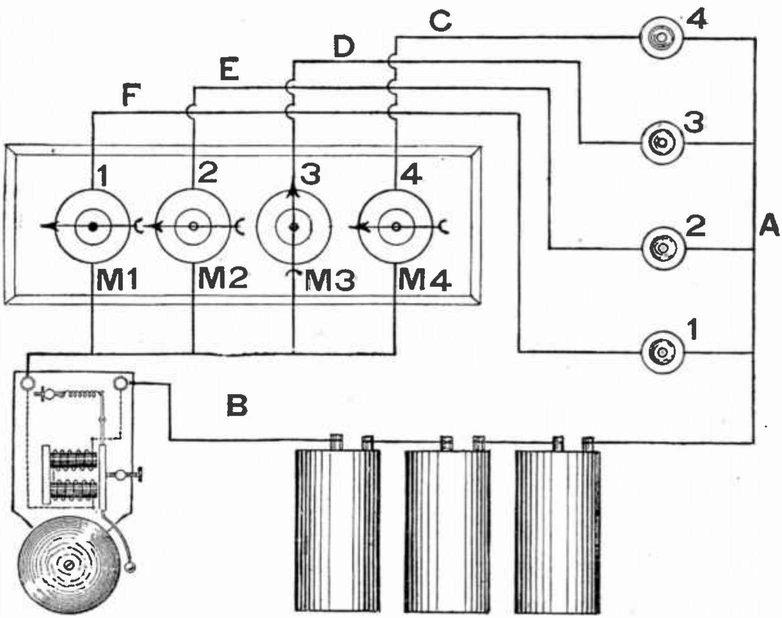
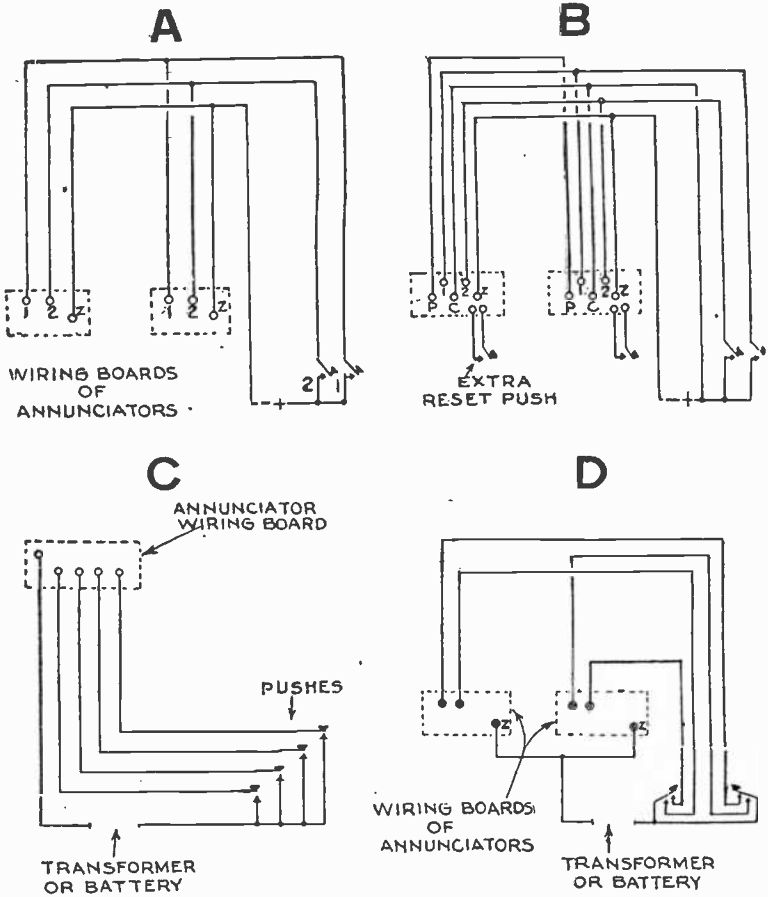


FIG. 8,489.—Method of wiring an annunciator; diagram shows the various circuits, bell, battery, push button, drops, etc.

Annunciator Circuits.—A general method of wiring an annunciator is shown in fig. 8,489. The wire A, runs from one terminal of the battery to one terminal of each push; the wire B, runs from the other terminal of the battery, through



FIGS. 8,490 to 8,493.—Wiring diagrams for Partrick & Wilkins annunciators. **A**, automatic annunciators in multiple; special winding of magnets required for this system; contact pushes used in rooms; **B**, electric reset annunciators in multiple with extra connections for extension push; **C**, plain single annunciator with single contact push; **D**, annunciators in multiple with double contact pushes, no special winding of magnets.

the bell, and thence to one terminal of each of the drop magnets M1, M2, etc. The other terminals of each of the magnets M1, M2, etc., and pushes 1, 2, etc., are connected as shown.

With this arrangement, the pressing of any push button does not affect any of the other drops except the drop controlled by that particular push. For instance: when push button 3 is pressed, the circuit is completed only through the drop magnet M3, as shown.

The use of the common battery wire B, and the common return wire A, obviates the necessity of running two wires from each push. These common wires should be larger than the other wires, however, and No. 16, B & S. gauge copper wire will be found suitable for the general run of annunciator work.

Bell Ringing Transformers.—There is a great difference in transformers and by actual test the voltage and wattage will often be found lower than rated.

Sometimes transformers when tested without a load are found to be properly rated, but when tested while signals are being operated show a deficiency of several volts.

Ques. Will a bell ringing transformer operate on direct current?

Ans. No.

Ques. Will bell ringing transformers burn out if the bell wires become short circuited?

Ans. No. They are so constructed that they will only heat up to about 50 degrees centigrade above the room temperature, and remain at that temperature until the short circuit is removed.

Ques. Do all bells operate on alternating current?

Ans. Battery types of bells up to six inches will operate on alternating current, above that size standard alternating current or transformer bells are required.

Ques. Upon what voltage do transformer bells operate?

Ans. The large size bells require from 12 to 18 volts.

Ques. Can a person get a shock from a bell ringing transformer?

Ans. No.

Ques. Does the wattage consumed by the bells determine entirely the wattage required from the transformer?

Ans. No. The power consumed by line losses may be equal or greater than that necessary to operate the bell.

Ques. What should be done if the highest voltage tap on the transformer will not operate the bell satisfactorily?

Ans. If using a 12 volt bell, substitute an 18 volt tap thus reducing the line loss. Increasing the size of bell wires will also accomplish the desired result.

Ques. Can a higher voltage transformer be used?

Ans. No. Voltage higher than 25 volts is not permitted by Underwriters.

Points to be Remembered.—Bell amperage should be equal to, or ten per cent less than lamp amperage, when lamps are used in series with bells or buzzers.

Wattage consumption of lamp has no relation to watt consumption of bell.

In the event of there being any doubt as to the proper bell to be used in a series installation, it is best to advise the factory of the installation and ask for a recommendation and authentic information.

If bells are to be used in series, first determine voltage to be used, the number of bells to be used and divide voltage by number of bells, which will give the correct voltage that the bells will require.

Practical Hints on Wiring.—Always use line wire of large enough size to prevent an extensive drop in voltage over the circuit depending on the entire length of the circuit.

If transformers be used, be sure to order same with a sufficient wattage capacity taking into consideration the number of signals on the circuit and the combined wattage and voltage drop.

If circuit breakers or relays be used on any of the bell circuits, find out the watt consumption of same and figure the same as a bell consuming that amount of wattage. Therefore, in obtaining the total wattage on bell circuits the amount of wattage the relay or circuit breaker consumes must be known.

Never use No. 18 wire for bell circuits excepting for ordinary residential door bells.

For longer distances use No. 12 or No. 10 wire to reduce the voltage drop. No. 14 wire is of ample size for most bell jobs.

TEST QUESTIONS

1. *Give a classification of bells.*
2. *Of what does a trembling or vibrating bell consist?*
3. *Describe the operation of a single stroke bell.*
4. *How does a combination vibrating and single stroke bell work?*
5. *What is the construction of a shunt or short circuit bell?*

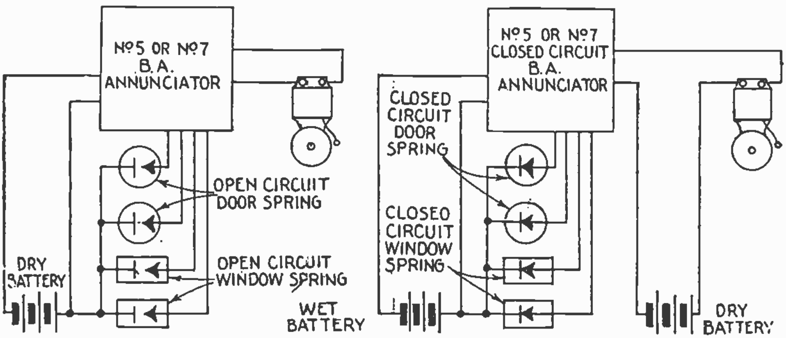
6. *Describe the construction of a continuous ringing bell.*
7. *What is a buzzer?*
8. *What kind of electro-magnet is used on differential bells?*
9. *How does a combined differential and alternate bell work?*
10. *What provision must be made in designing bells for high voltage?*
11. *Describe the operation of an alternating current bell.*
12. *For what service is a double acting bell suitable?*
13. *What is the construction of a motor driven bell?*
14. *For what service is an electro-mechanical bell suitable?*
15. *What is a relay?*
16. *On what bell service are relays used?*
17. *What is the construction of a push button?*
18. *What is an annunciator?*
19. *How does an annunciator work?*
20. *Name the two general classes of bell circuits.*
21. *Draw numerous diagrams showing various bell hook ups.*
22. *How is an annunciator wired?*
23. *Give a few points relating to bell ringing transformers.*

CHAPTER 217

Burglar and Fire Alarms

Electric signaling apparatus and systems of control have been developed to meet the requirements of various kinds of service. The special applications considered in this chapter are

1. Burglar alarms;
2. Fire alarms;
3. Hospital signals.



FIGS. 8,494 and 8,495.—Open and closed circuit diagrams of Edwards' burglar alarm systems with annunciators to indicate the point of contact. The window and door springs all go to an annunciator drop before connecting with the rest of the circuit and immediately tell what door or window has been tampered with.

Burglar Alarms.—Protective systems ordinarily known as burglar alarms are of two general kinds:

1. Those having connection to police stations, protective offices or other remote points where a signal receives immediate attention.

2. Those in which the alarm is in the building which it protects.

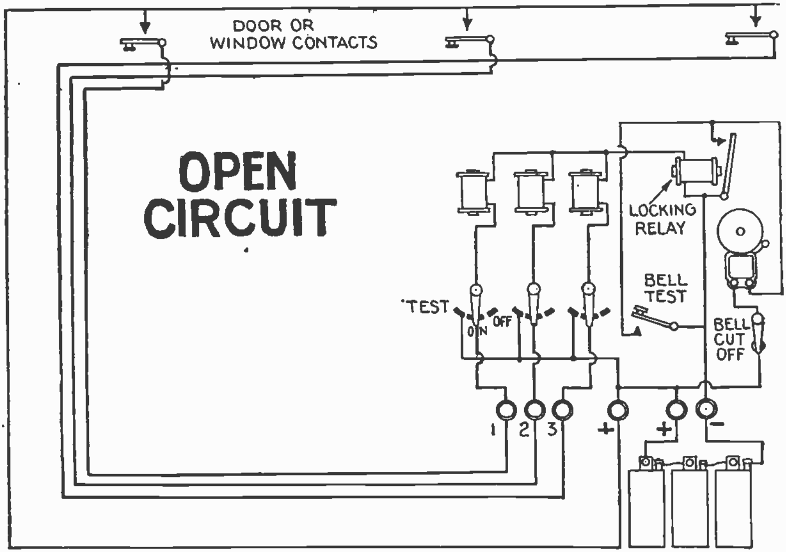


FIG. 8,496.—Open circuit burglar alarm annunciator system. 8 volts *d.c.* or 18 volts *a.c.* are required at terminals of annunciators for operation of system. ***In hook up*** there must be: 1, one common wire from all window and door springs to annunciator; *2, one direct wire from each window and door spring to annunciator; 3, two wires from battery or transformer to annunciator.

In general a burglar alarm system includes essentially a source of electricity, a bell, an annunciator, and various devices placed about the building in such a manner that an intruder will make the system operative. The bell sounds the alarm

*NOTE.—Where one drop is to indicate a group of springs, such as a room or section, only one direct wire from each group to the annunciator is required.

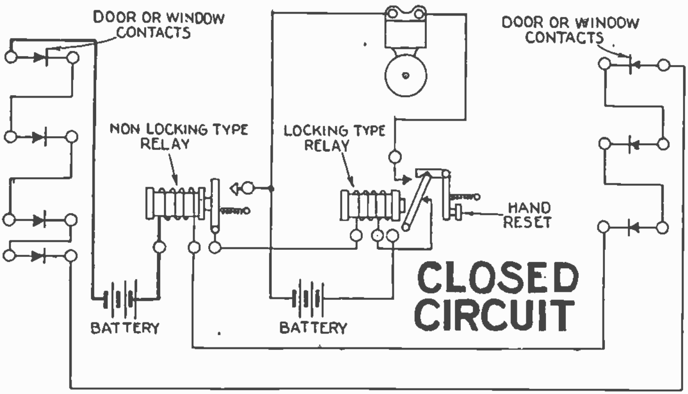


FIG. 8,497.—Closed circuit burglar alarm system. *It consists of:* 1, one direct wire from the closed circuit battery or transformer to the first window or door spring; 2, one wire from the other side of this window or door spring to the next window or door spring and continues on in series wiring to the last window or door spring; 3, one wire from the last window or door spring to the non-locking type relay; 4, one wire from the non-locking type relay to the closed circuit battery or transformer; 5, one wire from the non-locking type relay to the locking type relay; 6, one wire from the non-locking type relay to the bell and to open circuit battery or transformer; 7, one wire from the bell to the locking type relay; 8, one wire from the locking type relay to open circuit battery or transformer.

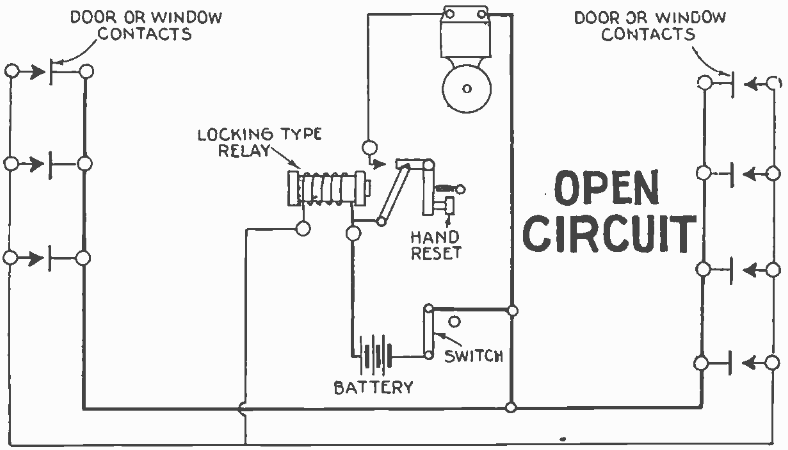


FIG. 8,498.—Open circuit burglar alarm system to be operated in parallel. *In hook up* there must be: 1, one common wire to one side of all window or door springs, switch and bell and the annunciator indicates the location at which the intruder is trying to enter. Devices for detecting the entrance of a burglar are made in many forms adapted for various purposes. Some are designed to be operated by the raising of a window or by the opening of a door, where entrance is likely to be attempted. Bells for burglar alarms should be either of the continuous ringing type, or controlled by a continuously ringing

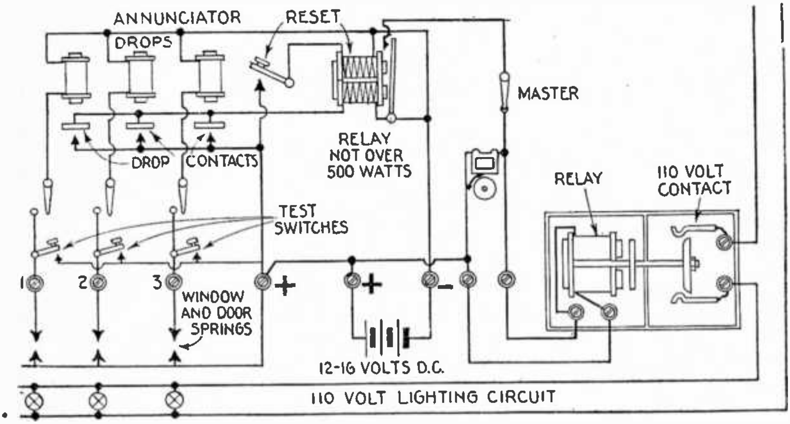


FIG. 8,499.—Burglar alarm circuit having annunciator with 110 volt relay to close lighting circuit; testing switches, master switch and bell.

relay. Otherwise, an entrance might be made so quickly that the bell would not ring long enough to arouse the occupants of the building.

With respect to the methods of working, burglar alarms are of two kinds:

1. Open circuit; 2. Closed circuit.

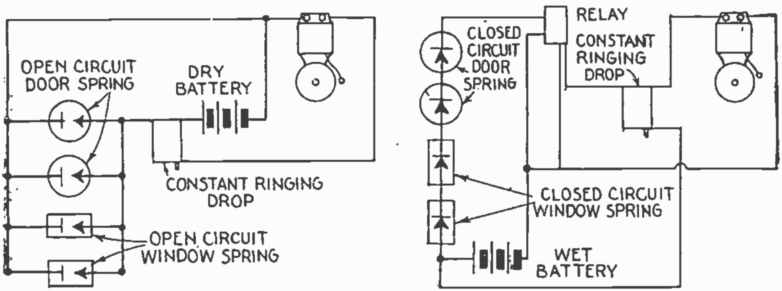
FIG. 8,498.—*Text continued.*

2, one common wire to other side of all window or door springs and to relay; 3, one wire from battery or transformer to relay; 4, one wire from relay to bell; 5, one wire from switch to battery or transformer.

In the *open circuit*, fig. 8,500, no connection is made on current flowing until the circuit is closed by some contact making device.

In the *closed circuit*, fig. 8,501, a small current is always flowing through the apparatus and an alarm sounded if any connection be broken or a wire opened. This is done by the small current holding a relay away from contacts which send current through the bells or howlers. A break in that small current then, would release the relay and send off the alarm. Both have their advantages and disadvantages and each is suited for its respective purposes.

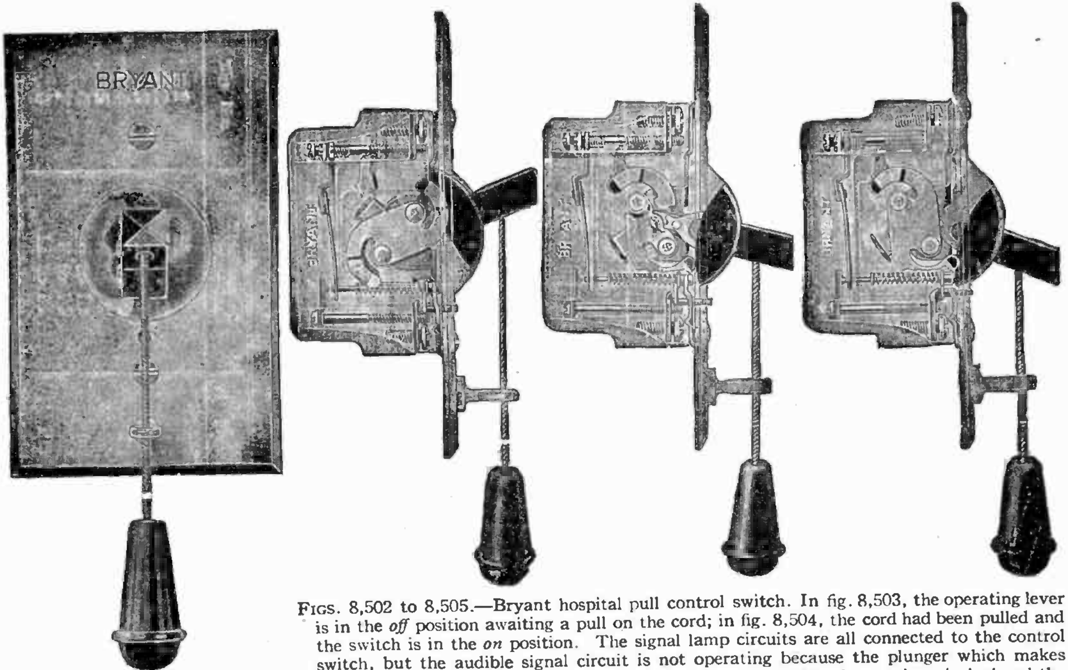
Contact making or breaking devices consist of foot switches, railings, knobs, handles, screens or anything where a touch or handling sets off the device.



FIGS. 8,500 and 8,501.—Open and closed circuit diagrams of Edwards' burglar alarm systems. These show the window and door contact springs of the open and closed types, the constant ringing drop to make the bell ring continuously when once started, and the actuating relay to close the bell circuit on the closed circuit system.

Notification to distant points is in the form of an annunciator drop, a light, a buzzer or other signal notifying that the alarm has gone off.

Hospital Signal Systems.—In every hospital it should be imperative that a means exist for patients to call nurses when needed; and it must not be bells or alarms that disturb other patients nor must it require much exertion on the part of the ailing patient. Therefore, silent call systems such as light signals, push buttons, or pull switches are necessary at the bedside.



FIGS. 8,502 to 8,505.—Bryant hospital pull control switch. In fig. 8,503, the operating lever is in the *off* position awaiting a pull on the cord; in fig. 8,504, the cord had been pulled and the switch is in the *on* position. The signal lamp circuits are all connected to the control switch, but the audible signal circuit is not operating because the plunger which makes the contact has not been depressed by the extension of the handle; in fig. 8,505, when the lock attachment is unlocked and the cord pulled to the limit of its travel, the extension of the handle depresses the plunger and closes the audible signal contacts. A separate circuit wire is connected from the *bell contact* on the back of the switch to the audible signal. If a vibrating bell or buzzer be used for an audible signal it continues to sound as long as the patient holds the cord taut. If a single stroke bell be used it sounds one tap on the bell and the cord must be released and pulled again for each successive tap.

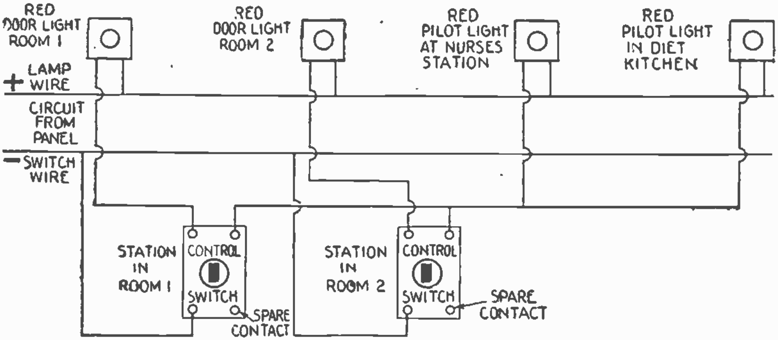


FIG. 8,506.—Diagram of Bryant silent call hospital signal system for two calling stations in two separate rooms. The lights are placed over the doorway of the patient's room and also at other places where nurses are apt to be, and pull switches are placed at the bedside. For two or more stations in same room connect in parallel. Note: if an annunciator for patients' signals be required an extra wire should be carried from the spare contact on the control switch to the proper numbered signal in the annunciator.

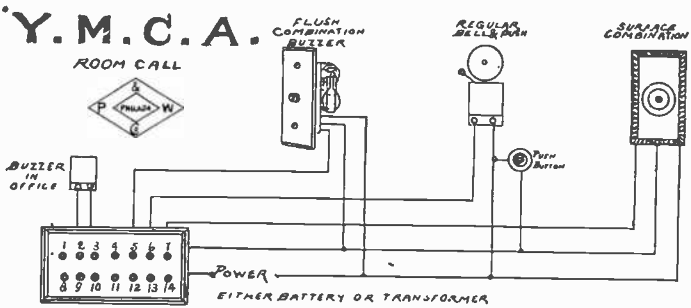


FIG. 8,507.—Partrick & Wilkins room call system without annunciators for Y. M. C. A. service. *In this system* a combination buzzer (or separate push and bell or buzzer) is used in the rooms. The No. 1 button board with one bell or buzzer in the office. The clerk in the office calls the room and the room occupant answers by pressing push. No annunciator required with this system. Adapted also for rooming houses where it is not necessary to have a complete return call annunciator system; pay station exchange telephones can be located on the different floors and when guests are wanted they can be called by clerk and by a given signal notified that they are wanted on the telephone. A caller can quickly ascertain if a guest be in his room. The guest can be called at a given hour, etc.

One system consists of colored lights and pull switches operated by a cord which can be sterilized or changed.

In the wall adjacent to the patient's bed is installed a pull switch. A linen cord connected to the lever of the control switch is placed where the patient can reach it. A gentle pull on the cord operates the switch and lights the signal lamps.

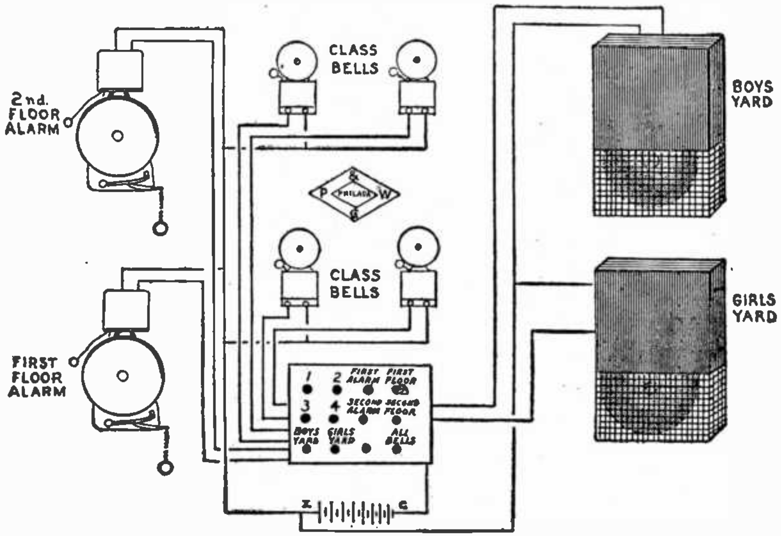


FIG. 8,508.—Partrick & Wilkins school house class call and alarm system. ***It consists of a*** P. & W. No. 1 compound push or school button board located in the principal's room. This push controls all of the class room bells, fire alarm bells and yard gongs. It can be arranged so that the bells can be rung singly, by floors or all together. The class room bells are 3 inch 40 ohm P. & W. wood box. The fire alarm bells, located in the halls, are 8 inch emergency gongs, of the non-weatherproof type. The yard bells are 10 inch, weatherproof type, enclosed in outside bell cover.

There is a door light in the corridor over the room door of the patient who has placed a call. This signals to the nurse. She attends the patient and cancels the call at the bedside by restoring the lever of the control switch to its original position. The calling station is the only place where the signal can be cancelled so the nurse must visit the patient to erase the signal. Only those signals operated by that station are extinguished by the cancellation of that call.

The pull control switch as shown in figs. 8,502 and 8,503 is a part of the calling station located in the wall adjacent to the patient's bed, and is operated by means of a cord which the patient pulls. When the cord is pulled, signal lamps are lighted at various points in the hospital to notify nurses and guide them to the patient who has called. These signal lamps remain lighted until the nurse visits the patient and cancels the call by raising the lever of the control switch.

Other lights called *pilot lights* are placed at intersections of hallways, in diet kitchens and other desired places. These pilot lights show when a call

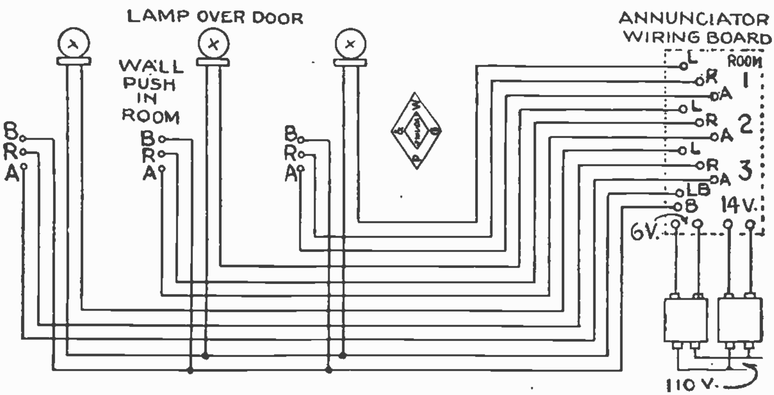


FIG. 8.509.—Partrick & Wilkins low voltage hospital call system with needle annunciator and relays. In this system there is located in the head nurse's room a master needle annunciator. A duplicate of this annunciator can be operated in parallel if so desired. In the patient's room a wall plate extension push, which is fitted with extension plug or pear push. In the corridor, over or alongside the room door is a wall plate lamp. *In operation*, when the pear push is pressed the relay operates and lights the red lamp over the door in the corridor and shows indication on annunciators. The lamp over door remains lighted and indications on annunciators remain until the nurse visits the room and presses the button on the wall plate push from which point the call has been made.

is registered from any room in a corridor; the light can be seen from an intersecting corridor. A nurse in the intersecting corridor goes to the intersection of the two corridors and the door lights over the room doors indicate which patients are calling.

A soft toned audible signal can also be connected in the circuit for night use and disconnected at will by the nurse.

Audible signals may be in the form of a bell or buzzer muffled or lightly toned and placed where nurses are apt to be. An annunciator may also be used and placed in the superintendent's office for registering the calls.

Fire Alarm Systems.—The fundamental fire alarm system consists of *a number of signal boxes from each of which the alarm bell can be sounded.*

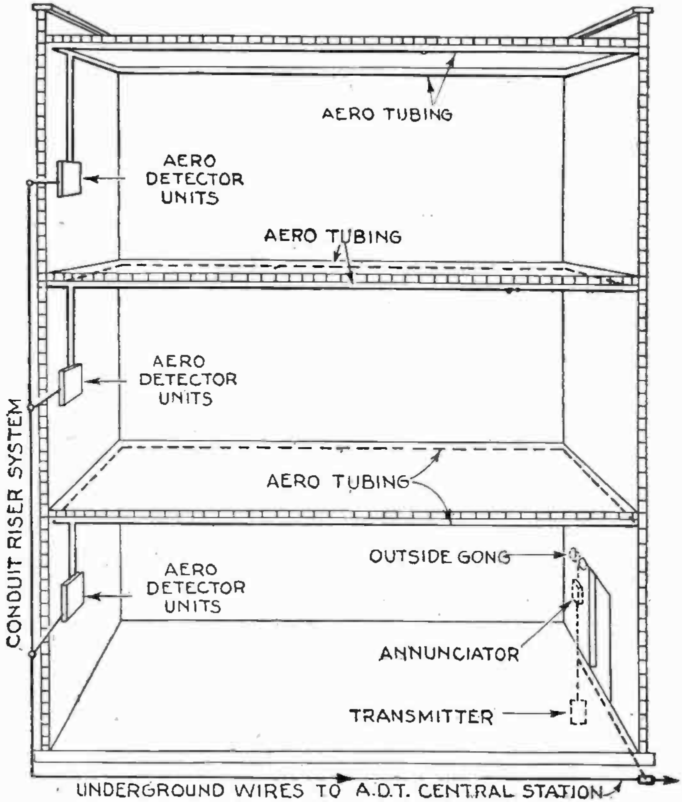


FIG. 8,510.—Sectional view of building showing layout of Aero fire alarm system, the operation being explained in fig. 8.511.

A simple system well adapted to a small loft building with three or four floors, or to a one story building with considerable floor area, is installed by placing on each floor or in each room or department a bell to give the alarm, and an annunciator to indicate the location of the station from which the alarm was sent.

On the larger systems fire alarm boxes are used.

In principle a fire alarm box is *a contrivance for turning in a signal in code, to indicate where the alarm came from.*

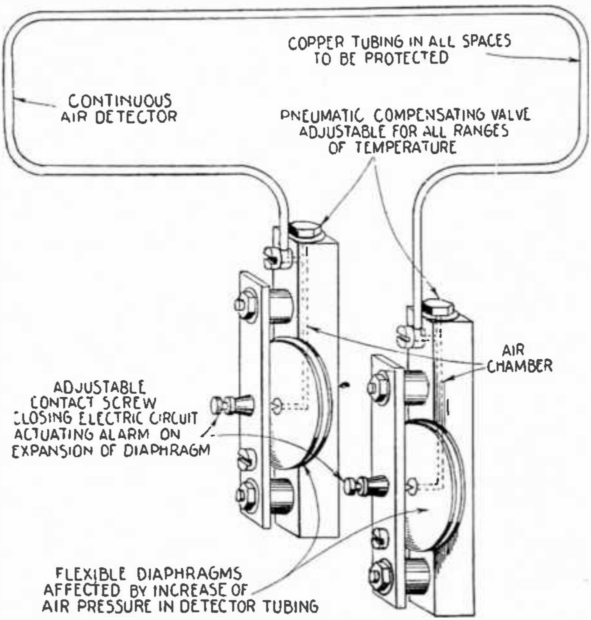
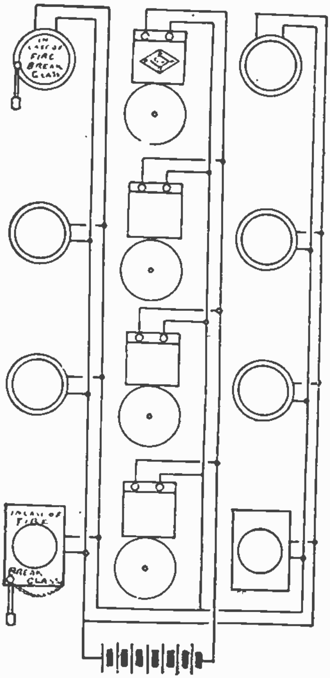


FIG. 8,511.—Aero air tube fire alarm system. ***In construction and principle***, the sensitive, fire detecting element is a very small copper tube less than 1/12 in. in diameter which is strung along or around the ceilings or roofs of the premises to be protected. The tubing contains nothing but air at ordinary atmospheric pressure. In case of fire, the contained air becomes heated and expands. At each end of the tube there is a diaphragm or small metal box with very thin sides capable of being bulged outward by air pressure. The bulging of the diaphragm closes electrical contacts which operate a transmitter, automatically sending the alarm to the fire department. An annunciator indicates the floor or section of the building where the fire originated and a local alarm is sounded on gongs.

It consists of a toothed wheel rotated by a spring which makes electrical contacts in accordance with the number of teeth cut and their spacings. These contacts ring a bell, or sound on a telegraph instrument, or record on a traveling tape. The number of rings or tape indicates the origin of the call. This constitutes the fire alarm telegraph as used in the large cities.

General Principles of Fire Alarm System.—There are two forms of circuits employed in the various systems.



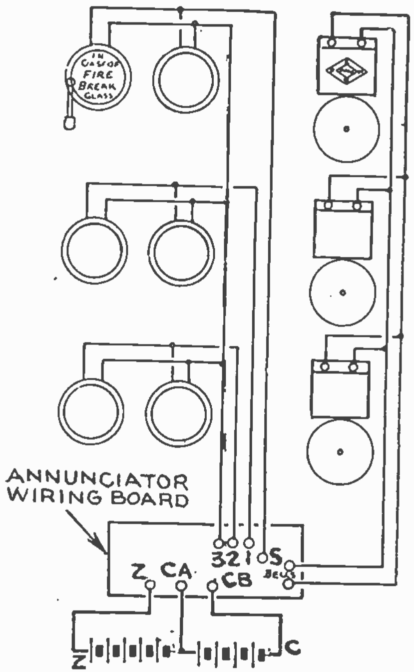


FIG. 8.512.—Partrick & Wilkins *open circuit* fire alarm system with break glass signals and vibrating bells. *In operation,* the breaking of the glass of any of the fire alarm signal boxes will cause all of the bells on the circuit to ring simultaneously until switched off.

FIG. 8.513.—Partrick & Wilkins *open circuit* fire alarm system. *In operation* breaking of the glass of any of the fire alarm signal boxes indicates on the annunciator the location of the corresponding fire alarm box, and at the same time rings all bells simultaneously until switched off at the annunciator.

1. Open;
2. Closed.

Open circuit systems are generally installed in small office buildings, small factories and lodging houses, where maximum protection must give way to limitation of expenditure. As current is employed at the time of alarm only, satisfactory service depends upon careful installation and periodic inspection and test of system. Fig. 8,514 illustrates the open circuit system.

Closed circuit systems afford maximum protection, as there is a supervising current passing through the apparatus and lines at all times. Part of the

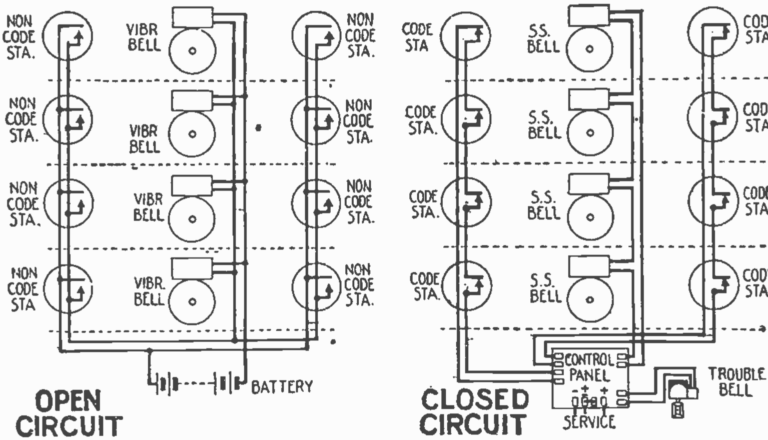


FIG. 8,514.—Edwards' open circuit fire alarm system. In the open circuit system any contact made in any box on a floor sets all the bells in operation.

FIG. 8,515.—Edwards' closed circuit fire alarm system. In the closed circuit system any contact broken in any box sets all the bells in motion, and where the boxes are code boxes, the bells sound the code. The closed circuit holds a relay armature in suspense and when released makes contact with the main circuit.

apparatus is a trouble bell which rings immediately and continuously should there be a break in the line, failure of current, etc. Fig. 8,515 illustrates the closed circuit system.

Pre-signal systems are closed circuit systems recommended for hospitals, hotels, and places where it is not desirable to sound a general alarm until the extent of the fire has been investigated. The operation of any station sounds an alarm in some pre-determined places only, such as the superintendent's office or service quarters. If necessary, after investigation, the general alarm may be sounded on all bells by anyone holding a key. The key is inserted in any station and the lever pulled as usual. Fig. 8,516 illustrates a pre-signal system.

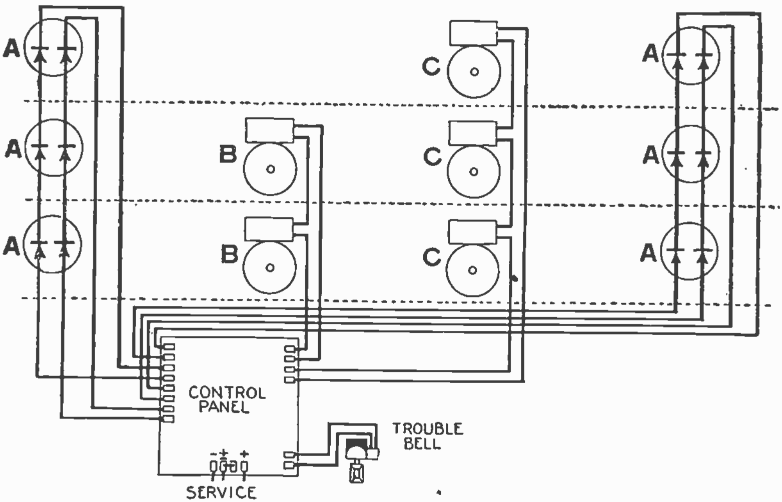
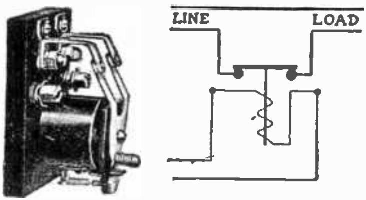


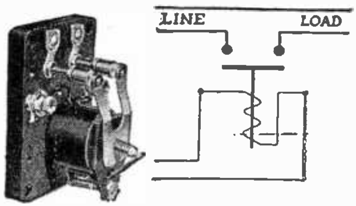
FIG. 8,516.—Edwards' pre-signal closed circuit fire alarm system. This type of system is arranged so that the operation of a station does not sound the general alarm, but gives the signal in pre-determined places such as the superintendent's office or service quarters, allowing the fire to be investigated beforehand. If necessary then the general alarm may be sounded by those in authority holding a key, which is inserted in any station and the lever pulled in the usual way.

Code Calling System.—The code calling system is designed to assist the telephone operator to locate individuals and call them to the telephone. The apparatus for the system consists of the sending station, the master relay and the signals.

The sending station is housed in a neat hardwood case which is located on or near the telephone switchboard. It has a name card and code number for each individual and may be obtained in 10, 20 or 30 call capacities. The master relay is operated by the sending station and the signals are operated from the contacts of the master relay.

Figs. 8,517 to 8,519.—Partrick & Wilkins break glass fire alarm signal boxesf or open circuit, with vibrating bells. Fig. 8,517, No. 1 signal, breaking of glass automatically closed circuit. For low voltage only; fig. 8,518, flush type for low voltage; fig. 8,519, type for 110 volts or less.





Figs. 8,520 and 8,521.—Partrick & Wilkins burglar and fire alarm relay and circuit diagram. It is known as a power off relay, closed circuit relay or back contact relay.

Figs. 8,522 and 8,523.—Partrick & Wilkins burglar and fire alarm relay and circuit diagram. This relay is used with temperature pressure and time control and is also adapted for the remote control of motors, heaters and lights where Underwriters' approval is required.

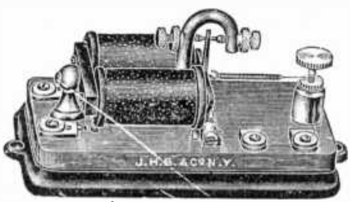


Fig. 8,524.—Bunnell fire alarm relay. Works on 25 milli-amperes; 25 ohm winding. This type usually called *trouble bell* relay.

Various types of tone signals are used. The selection of these is dependent upon the noise conditions which prevail at the locations where the signals are to be operated.

To call an individual to the telephone, the operator moves the code indicator to the proper code number and pulls the handle down once. The call is automatically sounded three times on all signals.

TEST QUESTIONS

1. *Name three classes of electric signals.*
2. *What are the two general kinds of burglar alarms?*
3. *What are the essential features of a burglar alarm?*
4. *Draw a diagram of closed circuit burglar alarm system.*
5. *Draw a diagram of open circuit burglar alarm syslem.*
6. *What are the features of hospital signal systems?*
7. *How is a hospital pull control switch constructed?*
8. *Draw a diagram of a hospital silent call signal system.*
9. *What are the essential features of a fire alarm system?*
10. *What principle is employed in the construction of a fire alarm box?*
11. *Describe the aero air tube fire alarm system.*
12. *What are the general principles on which fire alarm systems work?*
13. *Name two general classes of fire alarm systems.*
14. *Which class of fire alarm system is the better?*
15. *Draw a diagram of an open circuit fire alarm system.*
16. *Draw a diagram of a closed circuit fire alarm system*

CHAPTER 218

Traffic Signals

Owing to the ever increasing number of automobiles, proper control of modern city traffic has become necessary for the safety of pedestrians and motorists.

The movement of traffic is controlled by colored electric lights on signal units located at street intersections, the signals used are

Green..................go

Yellow................caution

Red....................stop

The yellow signal is really a "transition" signal which is displayed a few seconds between the green and red lights in order to allow the moving traffic time to cross the street intersection before the other line of traffic starts.

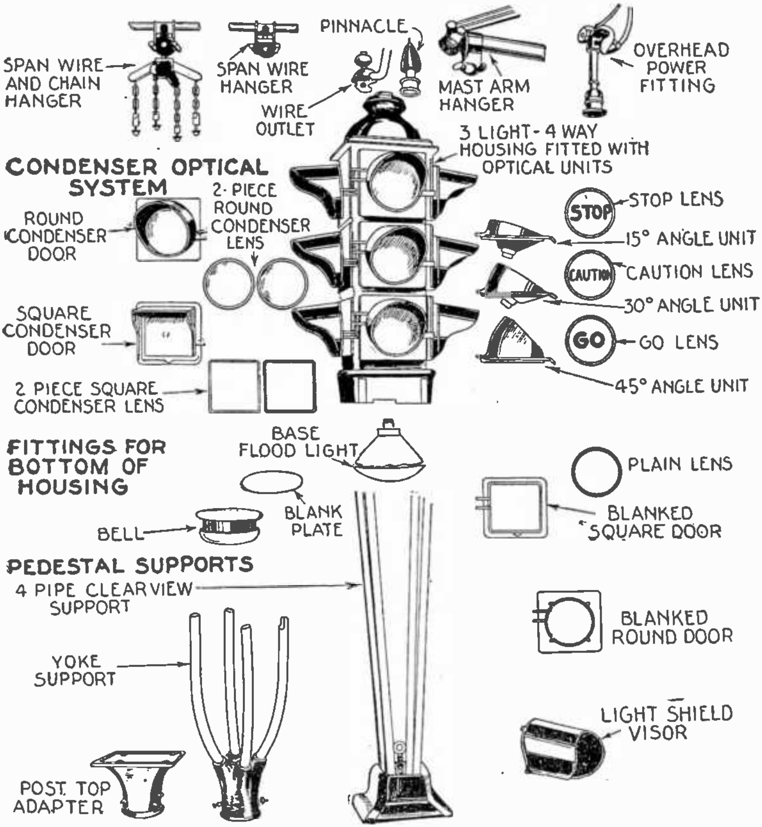
The duration of the transition period is of importance; that is, in the case of fast moving traffic, the transition period should be long enough to give a car (2 or 3 car lengths) from the street intersection, time enough to cross the intersection before the red light comes on.

Systems of Traffic Flow.—There are three main kinds of traffic flow:

NOTE.—*The long transition period* inflicted on drivers in some of the rural towns is ridiculous and is no doubt due to the dumbness of the officials in trying to make their towns appear important by apeing the traffic practice of the large cities.

1. Intermittent.
2. Semi-continuous or semi-progressive.
3. Continuous, or progressive.

These require control systems suitable to the individual requirements.



FIGS. 8,525 to 8,553.—Parts of General Electric pendant and pedestal signals.

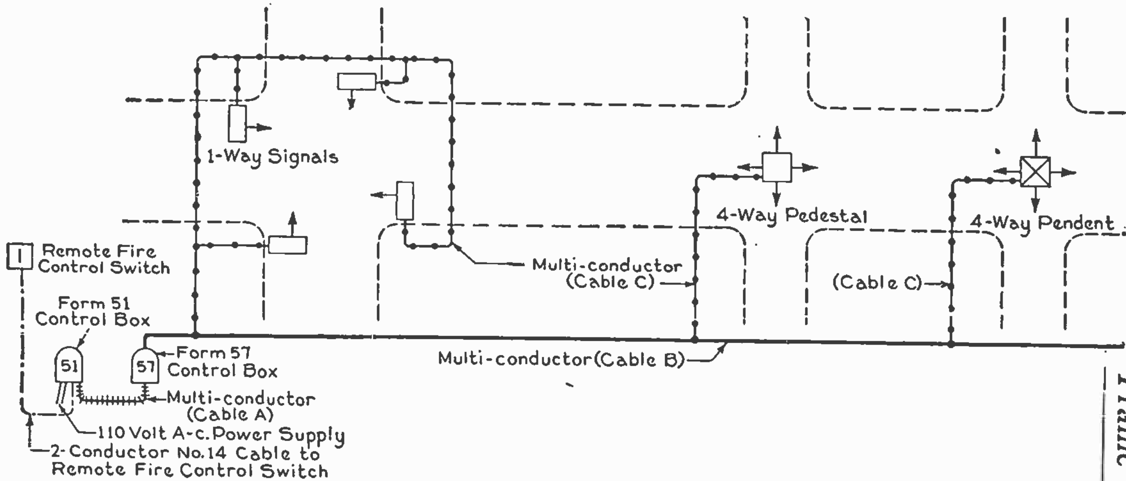


FIG. 8,554.—Central control system without local manual control. ***Advantages:*** complete universal control, that is, manual, automatic, steady amber, with optional special amber flash, fire, flood light, and bell control of system from a central point. ***Limitations:*** The system is inflexible. To control traffic properly it is usually necessary to operate signals at various intersections with different percentage allocations of time to main and side streets, which this system does not provide. The system requires power cable interconnection. Expansion of system requires additional interconnecting cable and relay boxes. Break down may affect a portion or all of the signals.

Intermittent Traffic Flow.—With this system *traffic along any one avenue alternately moves and stops at predetermined intervals.*

Intermittent traffic flow can be obtained by either of the following control systems:

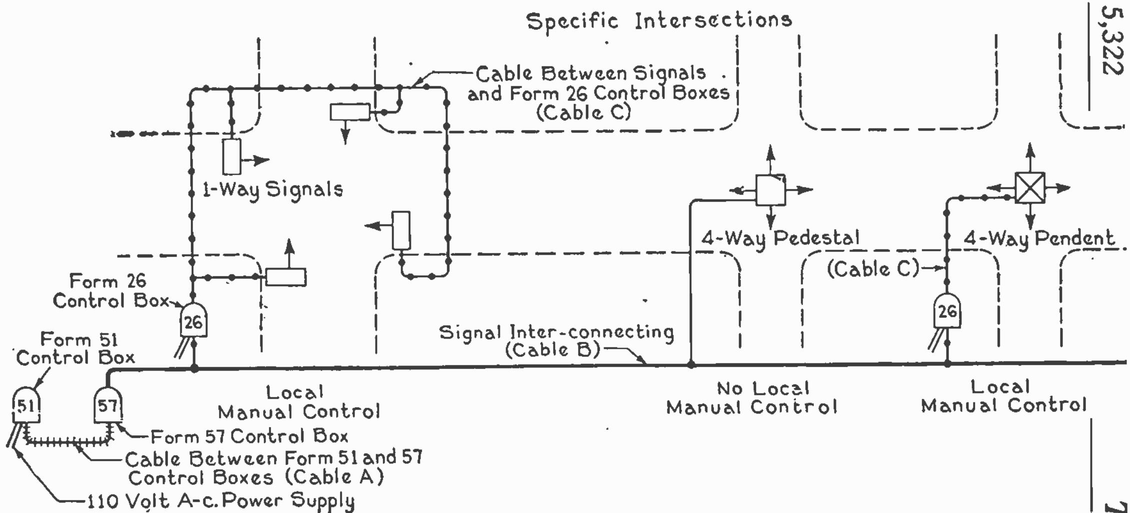


FIG. 8,555.—Central control system with local manual control at specific intersect ons. This system gives automatic control from central point; manual control from central point, local manual control of each intersection; steady amber from central point.

1. *The central control arrangement* employing a main controller at the central control point, and a 4 to 6 wire power cable interconnecting the signals and controller.

2. *The synchronous motor control system* employing a synchronous motor controller at each intersection.

The control system to give intermittent traffic flow can be identified by the fact that *all signals show the same color in the same direction at the same time*, and all signals *change colors simultaneously*

Semi-Intermittent or Semi-Progressive Traffic.—This type of traffic flow is the result of an attempt to obtain continuous or progressive flow with inflexible control equipment.

In districts where there is irregularity in spacing of intersections (which exists in most areas) and with marked variation in the density of traffic throughout a given area, it is practically impossible to obtain satisfactory results with this type of traffic flow. The control apparatus may be the same as that mentioned under "Intermittent Traffic Flow." The signals, however, operate in groups, some showing red while others show green, instead of all showing green at the same time, as they do in the intermittent flow system. The control system to give this type of traffic flow may be recognized by the fact that *although some signals may show green at the same time that others show red in the same direction, yet all the signals will change color simultaneously*.

Continuous or Progressive Traffic Flow.—Traffic at a given speed, either fixed or variable, or traffic flow through an area with a minimum of stops, is the ideal system of traffic movement.

In order to obtain continuous or progressive traffic flow with irregular spacing of intersections and with unequal traffic density through the area, and in order to be able at will to change the speed of traffic flow to suit weather or traffic volume changes, the control apparatus *must possess* extreme flexibility.

To obtain continuous or progressive traffic movement at a given fixed speed through an area, the synchronous motor control system employing a synchronous motor controller at each intersection may be used.

If, however, a continuous or progressive traffic flow with a speed variation possibility be desired, the control system would consist of a main controller or transmitter (speed setter) inter-connected by means of a small sized 4 to 6 conductor cable to a local controller or receiver at each intersection.

Traffic Signal Control Apparatus.—Adequate traffic control depends upon two main factors: 1, efficient traffic signals; 2, flexible and durable control apparatus. In the accompanying diagrams are shown layouts for the following systems.

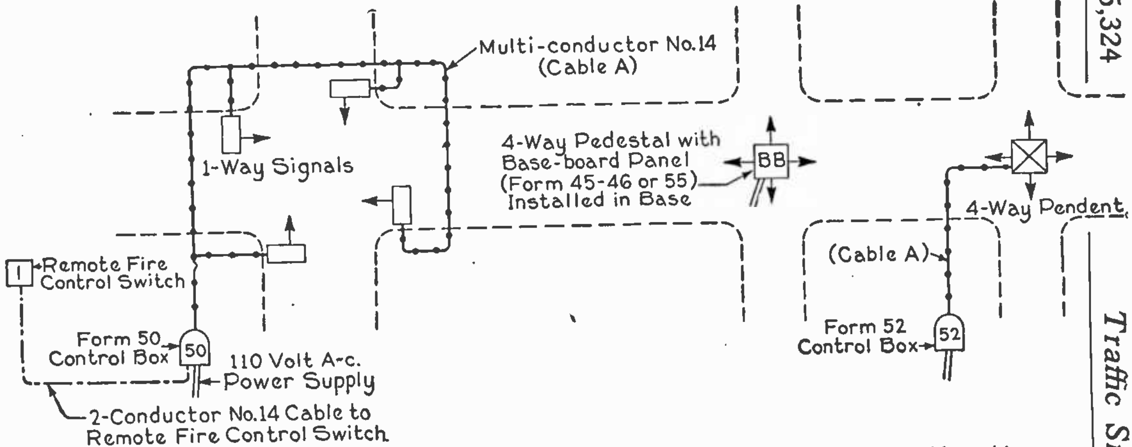


FIG. 8,556.—Synchronous control system (non-interconnected). This system requires the installation of a control box with synchronous timer at each intersection, either automatic or hand and automatic. The timers are set in the field with such relation to one another (depending on length of blocks, speed required, etc.) as to provide for progressive flow of traffic. The speed of traffic when once set cannot be changed without resetting each timer. *Advantages:* progessive control of traffic; no cable interconnection; break down in signal apparatus affects but a single intersection, and control system may be easily expanded at any time. The general scheme permits the setting of the control at each intersection to give the proper proportion of time to main and side street movements and also permits the smooth flow of traffic through a given area in both directions at predetermined speeds. The control apparatus applicable to this synchronous control system permits control combinations for the various types of control boxes.

1. Central control system;
2. Supervisory control system;
3. Synchronous control system;
4. Impulse control system.

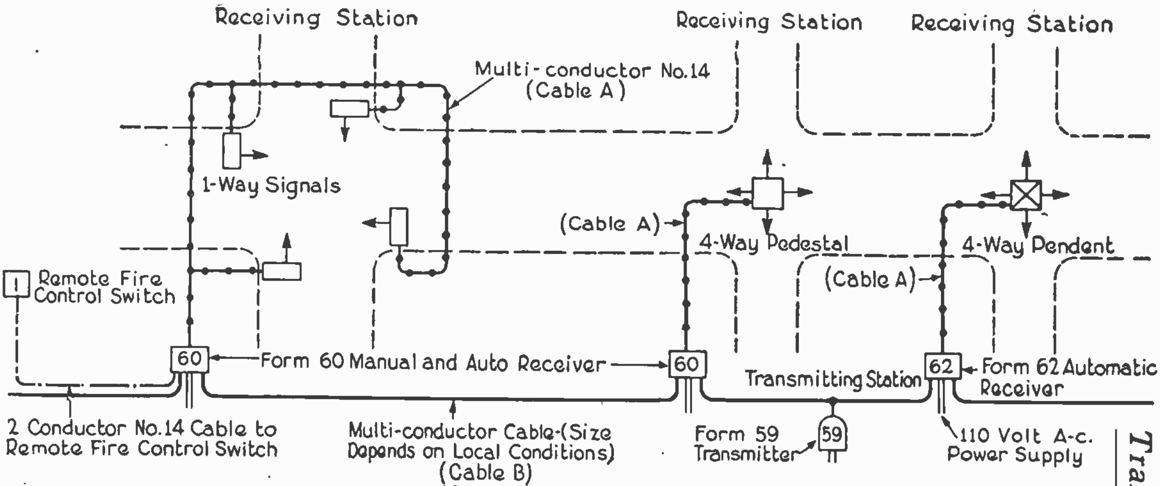


Fig. 8,557.—Impulse control system. ***Advantages:*** It permits the setting of the timers at each intersection to give the proper proportion of time to main and side street movements and also permits the progressive flow of traffic through a given area at any speed. A central control flexibility permits of varying the permissible speed of traffic flow through the area.

1. Central Control System.—This type of system as shown in fig. 8,554 provides for *the intermittent flow of traffic only.*

All vehicles move on the main street at one time, while all vehicles on the cross streets are halted. Signals require inter-connecting cables between intersections.

A special application of the central control system known as the "stagger" control system employs the same apparatus. By connecting the signals so that certain groups of signals show red while others show green in the same direction, progressive traffic flow may be approximated.

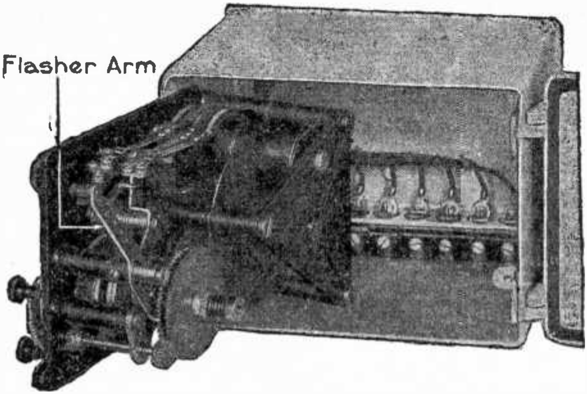


FIG. 8,558.—General Electric induction timer (interior view). This automatic timing device operates the lamps in a traffic signal system so as to give red, amber, and green indications. This controller consists essentially of a disc type induction motor geared to a cam mechanism which operates four pairs of silver tipped contacts each having a capacity of 5 amperes at 110 volts *a.c.* These contacts control the signal lamps either directly or through relays, the lamps being energized in sequence automatically, according to the division of the total cycle as determined by adjustments with which the timer is provided.

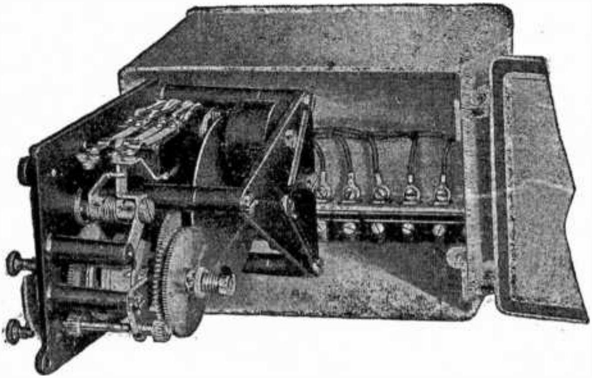


FIG. 8,559.—General Electric synchronous timer (interior view). This is similar to the standard induction timer except that a synchronous motor drive is used in place of the induction motor drive. The motor speed, is, of course, fixed for a given frequency and therefore the time of the complete cycle cannot be readjusted except by replacement of the driving gears.

2. **Supervisory Control System.**—This arrangement results in the same traffic movement as obtained with the central control system.

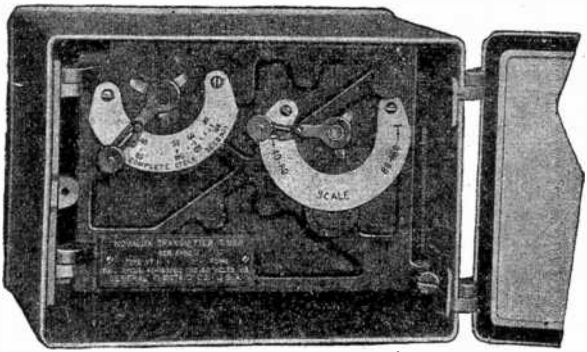


FIG. 8,560.—General Electric impluse transmitter timer. It is used as a main transmitter at the central control point of an impulse control system to perform the following functions: 1, to keep all receiver timers throughout the system operating at the same speed; 2, to vary the speed of operation of all the receivers; 3, to operate automatically to reset all receivers once each cycle. ***In consists of*** a standard induction timer motor mechanism having the standard shaded pole piece speed variation adjustment within a 2 to 1 range. In order to further increase the total time cycle range to give a 4 to 1 adjustment, the motor mechanism is connected to a front adjusting dial with a 2 to 1 gear shift mechanism. The motor mechanism operating through this gear shift drives a pair of cams which operate alternately to open and close a pair of contacts, the making and breaking of which at any established rate results in the alternate energizing of the two solenoids operating the receiver at each intersection. An increase in the rate of opening and closing of the transmitter contacts results in an increase in the speed of operation of each receiver timer. Similarly a decrease in the rate of make and break at the transmitter results in a decrease in the speed of operation of each receiver timer. Connected to the driving mechanism of the transmitter timer is a cam operated set of contacts which act automatically to insure that all receiver timers will operate in step.

Interconnecting cables are required between intersections, these are smaller than those required for the central control system. Such a system is advantageous only where fire alarm or police circuits are available.

3. **Synchronous Control System.**—This system as shown in fig. 8,556 provides for *the progressive flow of traffic at a* **fixed** *predetermined rate of speed.*

It allows the movement of vehicles on the main street to be continuous at a fixed speed while the movement on cross streets varies at each intersection according to the main street settings.

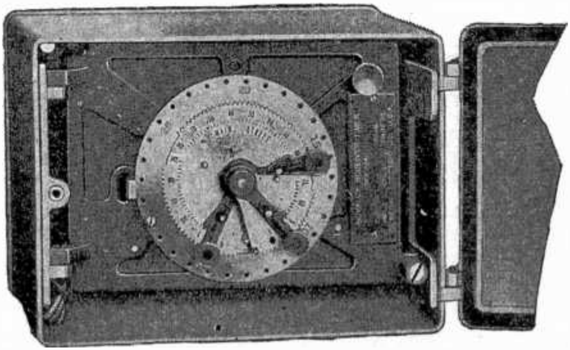


FIG. 8,561.—General Electric impulse receiver timer. This is essentially a synchronous motor timer with motor element replaced by a double solenoid "walking beam" driving element, the operation of which depends upon the energizing of each solenoid alternately from a central control source. The speed of operation of this controller depends upon the rate at which the alternate solenoids are energized from the main transmitter. Each coil for 110 volts, 60 cycles, *a.c.* operation takes 8 to 11 watts and .3 ampere operating, and 16 to 20 watts and .6 ampere inrush at 110 volts. These coils will operate on 10% plus or minus normal.

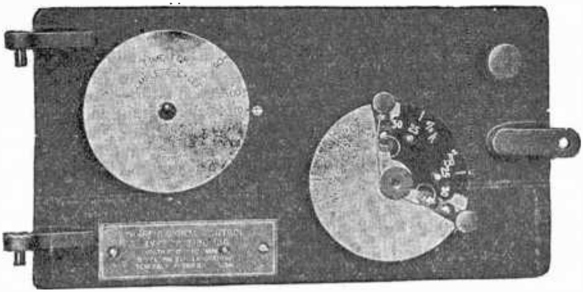


FIG. 8,562.—General Electric three street timer. ***In operation*** the total time cycle is varied by changing the motor speed. The right of way time for each street may be adjusted from approximately 20 to 50% of time for a complete cycle. A total cycle range of 60 to 120 seconds may be supplied. The amber period of 5 seconds may be overlap or non-overlap but is not adjustable. The current carrying capacity of this timer is 0.5 ampere per circuit at 110 volts. This necessitates the installation of a contactor for each circuit to carry any heavier amperage.

4. **Impulse Control System.**—This type provides *for the progressive flow of traffic, but the speed of such flow may be varied to meet different traffic densities and weather conditions.*

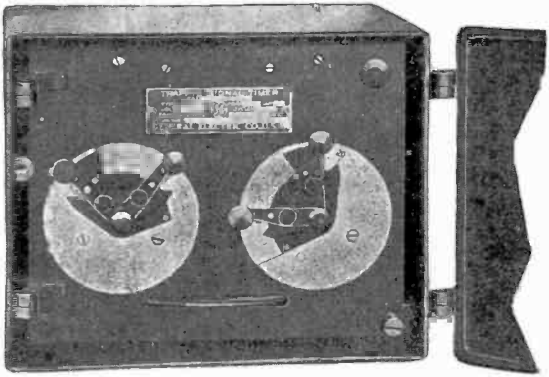
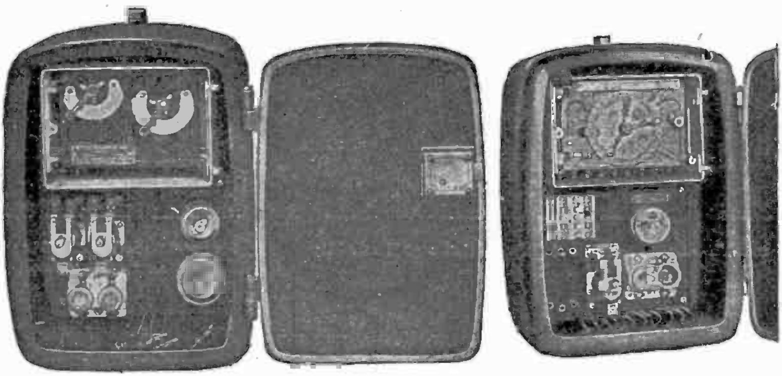


FIG. 8,563.—G. E. induction trial type timer. It is of the *a.c.* disc type motor driven element. The operating mechanism consists of two similar units, one controlling the green and green amber circuit, and the other controlling the red and red amber circuit. After either of the units has completed its operation, control is instantly transferred to the other unit and at the same time the first unit is returned to the zero position ready to begin operation again. On the face of the timer are four adjusting knobs which provide for the independent setting of the red, red amber, green, and green amber.



FIGS. 8,564 and 8,565.—General appearance of General Electric impulse boxes. Fig. 8,564, transmitter type, fig. 8,565, receiver type.

It allows the movement of vehicles on the main street to be continuous throughout, but with different speeds according to conditions.

Timers.—There are five types of timers available:

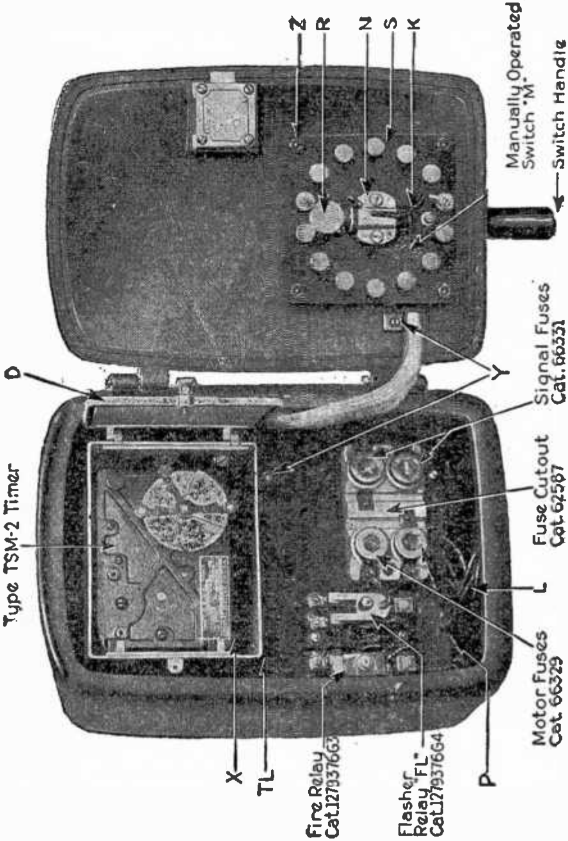


FIG. 8,566.—General Electric control box with fire and auxiliary relays.

1. Induction;
2. Synchronous;
3. Impulse;
   a. Transmitter;
   b. Receiver.
4. Three-street;
5. Trial type.

The features of these various timers are shown in the accompanying illustrations.

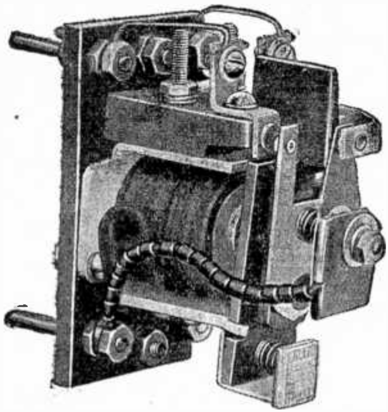


FIG. 8,567.—General Electric jack mounted fire relay. This fire type or remote off relay is exactly the same as the standard relay except for a third set of silver contacts which close when the relay is de-energized. The flasher relay is identical in all features with the standard relay except that different connections are made to the jacks.

TEST QUESTIONS

1. *Explain the meaning of green, yellow and red signals.*
2. *How many kinds of traffic flow are encountered in congested districts?*
3. *Describe intermittent traffic flow.*
4. *What are the conditions which cause semi-intermittent or semi-progressive traffic?*
5. *What are the features of continuous or progressive traffic flow?*
6. *Name the different kinds of signal control apparatus.*

7. *Describe the central control system.*
8. *What are the features of a supervisory control system?*
9. *For what does the synchronous control system provide?*
10. *Describe the impulse control system.*
11. *Name the five types of timers.*

CHAPTER 219

Sign Flashers

By definition a sign flasher is *a device used for giving flashing and changeable effects to electric lights in any form.*

The mechanism may be constructed to flash a sign by spelling the words out, one letter at a time, flashing border lights around a window, changing colors in glass signs, or in fact in any way to attract the eye.

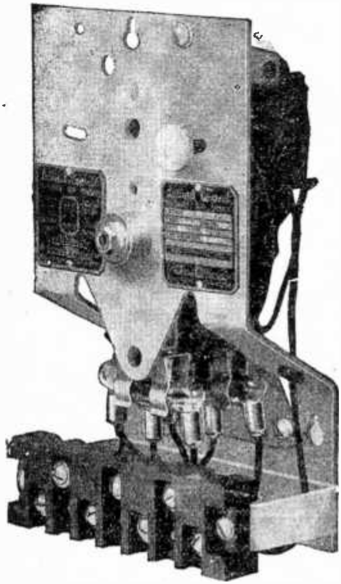
There are numerous kinds of flashers, and they may be classified, according to construction of the switch contacts, as:

1. Brush;
2. Mercury.

With respect to operation of the electrical effects, they may be classified as:

1. Simple on and off;
2. High speed;
3. Speller;
4. Script;
5. Chaser;
6. Combination;
7. Control or master;
8. Thermal.

Brush Flashers.—These machines are provided with a brush which bears on a steel cam or contact mounted on a slotted steel drum, and is usually made of several strips of copper and phosphor bronze.



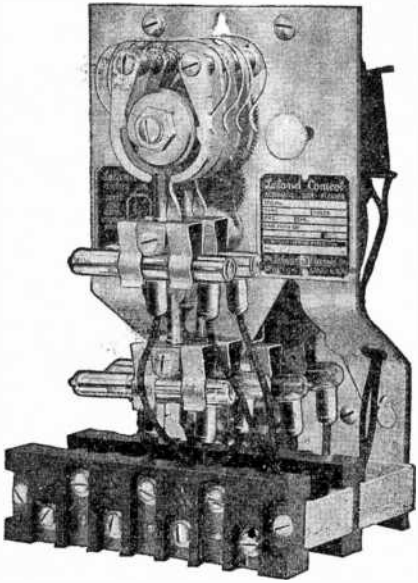


FIG. 8,568.—Leland speed border flasher; unit type for four circuits. The usual practice is to divide the display into four circuits or groups of circuits, and order the flasher for 1-2-3-4 wiring; or 1 to 4 wiring. The flasher then turns on the four circuits in succession and repeats interminably, each circuit going dark before the one preceding it is lighted up, so that there is always one or two circuits dark out of each set of four.

FIG. 8,569.—Leland combination flasher for four speed circuits and four speller circuits. This type is used on almost all displays, of any size, that compete for attention with other nearby displays. There is practically no limit to the intricacy of motion effects possible with a combination flasher.

Simple On and Off Flashers.—These are used for flashing whole signs or heavy loads on and off. A flasher of this type consists of a brush and contact with reducing gear and connection to a small motor for operating same.

The machine may have only one switch or any number of switches. The connection to motor may be by belt or chain, or the motor may be directly connected to the worm gear.

High Speed Flashers.—Machines of this type are used for giving what is generally known as *high speed effects*, such as fountains, steam, smoke and fire effects, traveling borders, revolving wheels and work of a similar nature.

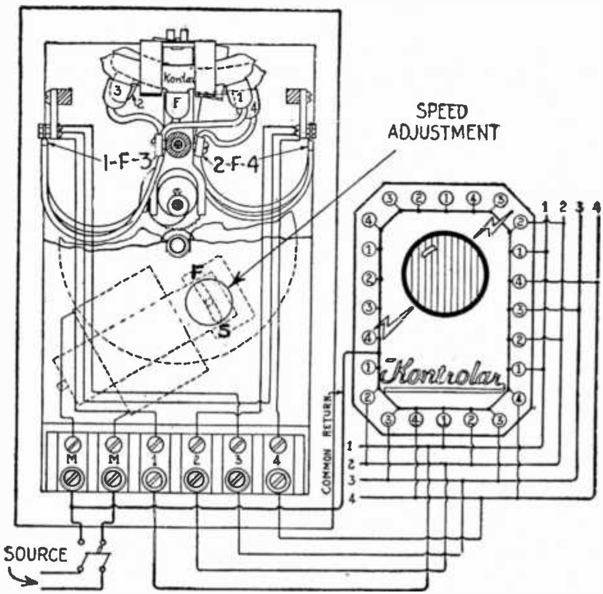


FIG. 8,570.—Leland unit speed flasher wired to sign. It is wired with four circuits with a common return. It has an extensive range, operating such arrangements as running or traveling borders, revolving wheels, lightning, radiating rays, flames, smoke, clouds, rain, sparks, dust, steam, fireworks, waving flags, fountains, etc.

There is very little expense attached to their operation because not more than two-thirds of the lamps are turned on at one time, and this number for only about one-sixth of the time, as compared with the sign burning steadily.

Speller or Script Flashers.—This type of flasher is used for large script signs, one socket at a time; that is, each lamp is lighted one after another until all are on.

After a few seconds they all go out simultaneously and repeat. This gives the appearance of an invisible hand, writing the name in the darkness, and is very effective. The result can be accomplished only with script, and to get the proper effect the smallest letter in a sign should be not less than two feet high; the larger the letter, the better the effect.

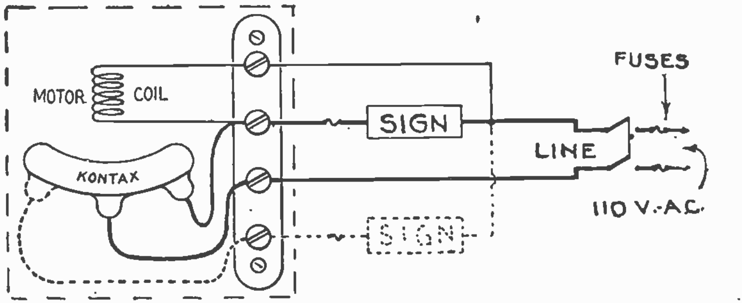


FIG. 8,571.—Wiring Diagram for Leland junior flasher. One on and off circuit or two alternating circuits. Dotted connections not used with single circuit flasher.

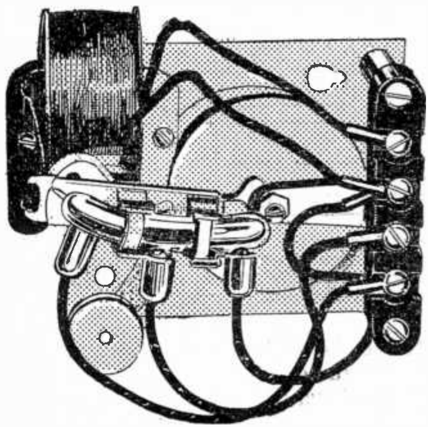


FIG. 8,572.—Leland junior flasher. 12 ampere capacity. It is operated by an *intermittent* induction disc motor. The motor circuit is led through the mercury switch so that when the flasher breaks the sign circuit, it also breaks the flasher motor circuit. The mechanism then returns by gravity action to its starting position from where the cycle is repeated.

Script Flashers.—This title is given to spelling flashers, and is sometimes used because the spelling is done with script writing.

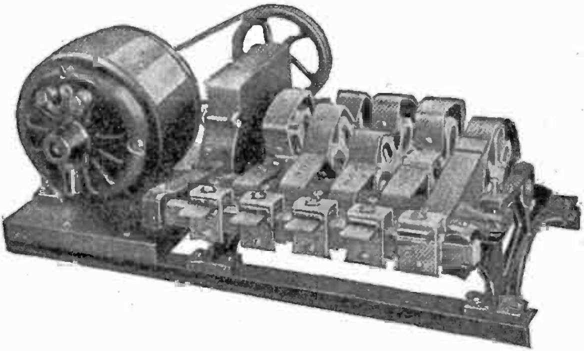


FIG. 8,573.—Betts & Betts high speed flasher. This is a standard mechanism which is usually assembled in multiples of four brushes, depending upon the load to be flashed. It is used to produce flowing or moving effects such as revolving borders, running water, foam, flames smoke, revolving wheels and globes, waving flags, fountains, lightning, fireworks, etc. The chaser type to reproduce crawling snakes, chasing rats, etc., runs at the same shaft speed but is assembled in varying multiples of brushes depending upon the effect to be obtained and the number of circuits to be flashed, etc.

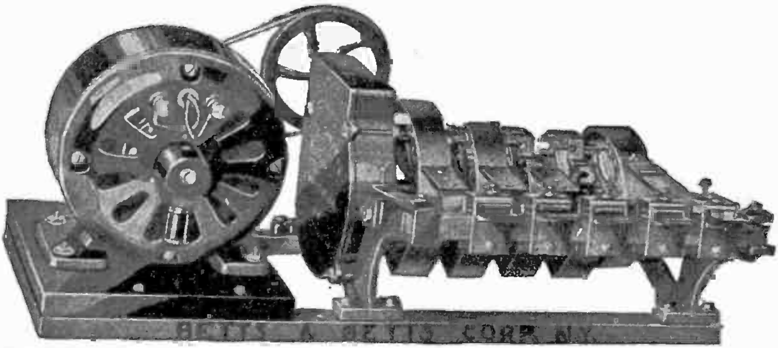


FIG. 8,574.—Betts & Betts spelling and on and off flasher. Used in flashing a whole word or display on and off, in spelling one letter at a time, in traffic controls, call systems, etc. Spelling flashers are built for two actions: 1, spelling out the letters one at a time until all are on, then all off with a brief *out* period, with operation then repeating; 2, spelling the letters until all are on, then all off, then all on together, last all off together with the operation then repeating.

Chaser Flashers.—This class of flasher is designed *to operate signs whose lamps are arranged to give the effect of snakes chasing each other around the border.*

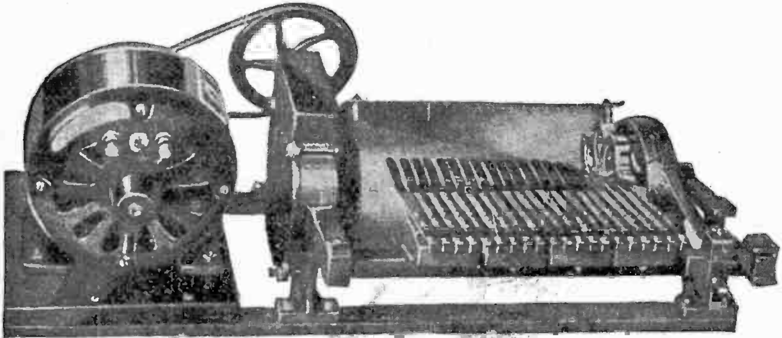


FIG. 8,575.—Betts & Betts script flasher. This machine is used to produce a smooth, advancing flow of light such as is required in writing letters or words one lamp at a time, for rockets, shooting stars, etc.

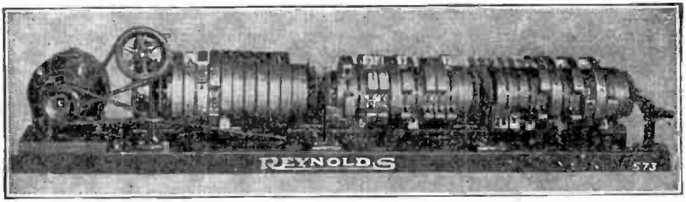


FIG. 8,576.—Reynolds figuregram control for electric scoreboards. Used for football stadia, race tracks, polo grounds, baseball parks, automobile racing, hockey, basket ball and other sports and games where it is necessary to record scores promptly, legibly and automatically.

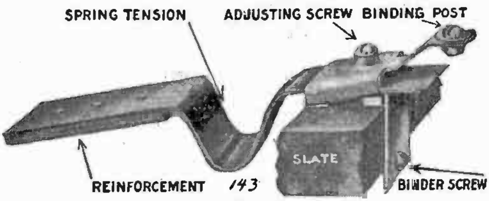


FIG. 8,577.—Detail of Reynolds brush and holder. The brush is built up with copper leaves and has phosphor bronze spring back, reinforced at contact point.

This peculiar effect is produced by having a separate wire and a separate switch on the flasher for each two lamps in the border, and the mechanism so arranged that when the tenth lamp is lighted (assuming the snake to be ten feet long) the first lamp goes out; when the eleventh is lighted, the second goes out, etc., progressing in this way around the entire border.

In operation, the lamps are turned on and off so rapidly that it produces the effect of snakes.

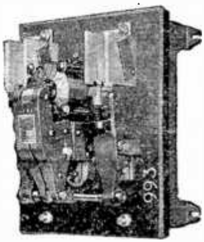


FIG. 8,578.—Reynolds magnetic switch for heavy loads. A magnet switch built specially for sign work. Sometimes it is more practical as well as more economical to break a number of circuits as one and in cases of this kind a magnet switch is used, controlled by a flasher.

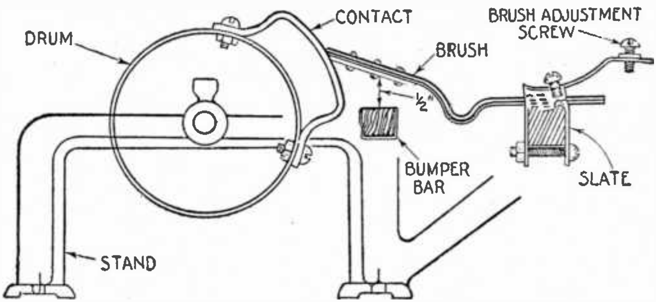
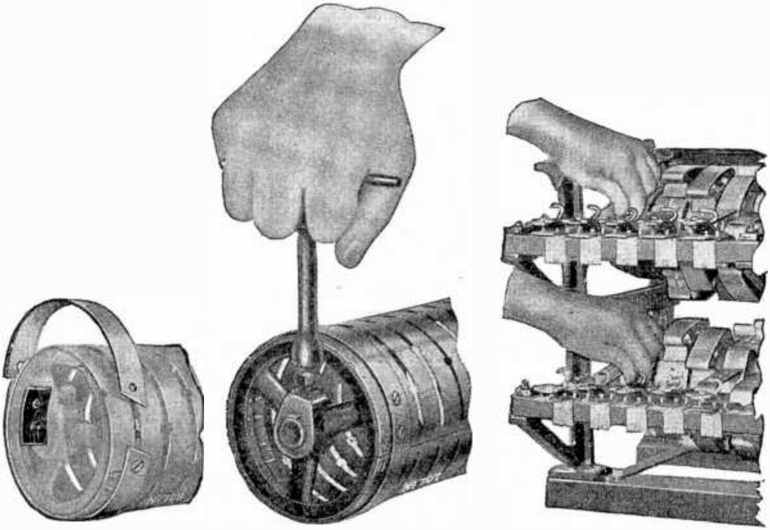


FIG. 8,579.—Reynolds brush mechanism showing provision for adjustment. Grounds in signs are common especially after a rain and cause an excess of current to flow through the flasher brushes. The condition corrects itself with weather conditions, but in the meantime the flasher brushes require more frequent attention. A temporary ground can be located with a test lamp or magneto, but as a rule the safest way to test for grounds is to apply an ammeter. Contacts on speed type flashers should be *wiped with an oily cloth* while the contacts on slower running flashers should be *run dry*. Keeping the contacts smooth and clean is sufficient. Many make the mistake of keeping the contacts covered with grease or oil which causes burning.

It is not advisable to build these signs small nor cheaply, as in order to produce the desired effect, the curved path taken by the snake should cover at least 10 inches width, which would mean a total of 20 inches lateral space for the snake in addition to the electric letters in the center. In order to get the proper effect, the sign should be at least ten feet long.

Chaser signs are expensive because of the care required in their construction, large amount of wiring necessary and large flasher required.



FIGS. 8,580 to 8,582.—Reynolds flasher details. ***Fastening collector rings*** (fig. 8,580). Splicer plate which acts as a duplex nut, enables the repair man to renew the collector rings quickly and easily. ***Keep drums tight on shaft*** (fig. 8,581); a socket wrench should be used for this purpose. ***Resetting brushes*** (fig. 8,582) use fingers as shown.

There are several ways of operating these signs. The border is generally working continuously, while the center can be flashed or not, as may be desired. Flashing the wording reduces the current expense, which offsets in a measure the extra cost of the sign. The border, although working continuously consumes very little current.

Combination Flashers.—Many of the more complicated signs require a combination of flashing effect to attain the highest degree of attractiveness and drawing power.

The leading manufacturers design their various flasher units so that any combination of units may be made with each other with either synchronous operation or varying shaft speeds.

Control or Master Flashers.—When it is desired to darken the effects at intervals, *master or control brushes are provided on the flasher*. A border or circle revolving first in one direction, then in the reverse, requires four controls, as shown in fig. 8,606. To give the *standing still* effect, four controls are necessary.

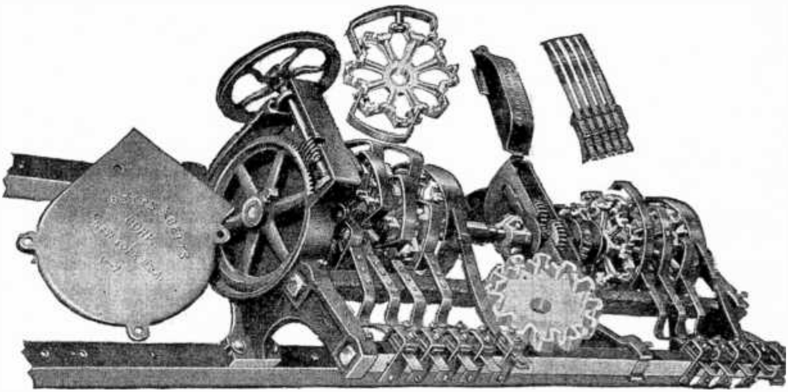


FIG. 8,583.—Betts & Betts combination flasher showing general construction.

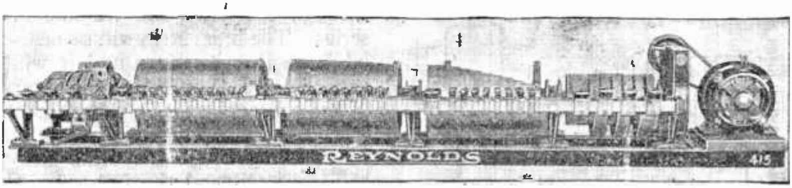


FIG. 8,584.—Reynolds combination flasher consisting of a combination of the following units. 1, on and off; 2, speller, and 3, script.

Fig. 8,585 shows method employed when it is desired to darken the border effects periodically. In this case the neutral wires from both sides are *broken* by the control brushes (this section of the flasher runs at one-eighth of the speed of the border section).

Thermo-Flashers.—The operation of these flashers is based upon the *heat expansion principle;* that is, the *movement of the contact points of the flasher necessary to open and close the circuit is obtained automatically by the alternate heating and cooling of the metal of the flasher, which causes it to expand and contract.*

The principle of a thermo flasher is illustrated in the elementary diagram fig. 8,586.

The device has a tongue consisting of two metal strips, one of brass and the other of iron. The brass strip is provided with a winding of fine wire over asbestos, and the two strips are connected to the base as shown.

In hook up, the flasher is connected at L and G, in series with the lamp it is to flash; and D, adjusted so that the contact clears the plate E about 1/32 inch when no current is flowing in the winding.

In operation, when the switch is turned on there will be a current through the lamp and winding in series. The brass strip will be heated more than the iron and it will expand more, thus forcing the point of the contact screw D, down upon the brass plate, which will result in the winding about the brass strip being shorted and the full voltage

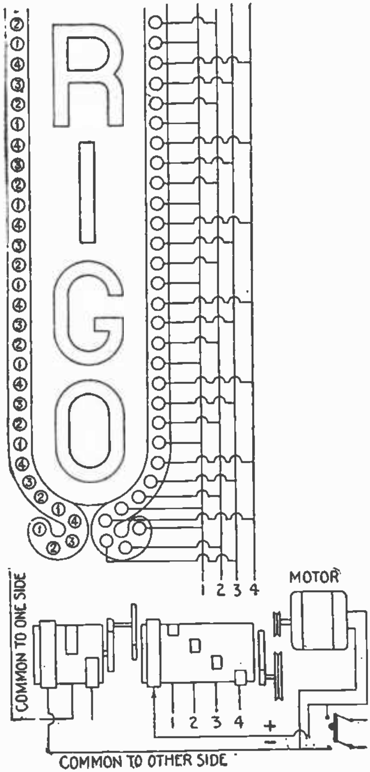


FIG. 8,585.—Reynolds control or master flasher and hook up to sign for darkening the border effect periodically.

will be impressed upon the lamp and it will burn at normal candle power. When the coil is shorted there will of course be no current in its winding and the brass strip will cool down, the screw D, will finally be drawn away from contact with the brass plate, and the winding again connected in series with the lamp. The lamp will apparently go out when the winding is in series with it, as the total resistance of the iamp and winding combined will not permit sufficient current to pass through the lamp to make its filament glow.

The time the lamp is on and off may be varied to a certain extent by adjusting the screw D.

Neon Tube Signs.—To gain the full advertising value of a Neon tube sign, it is just as essential that it be flashed as that a bulb sign be flashed, and the flashing of the Neon tube sign

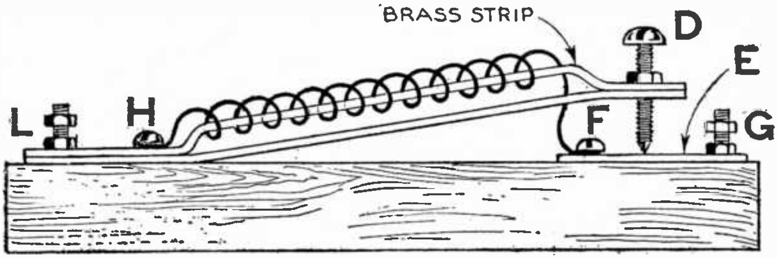


FIG. 8,586.—Elementary thermo flasher to illustrate principle of operation as explained in the text. D, adjustable contact; E, contact plate; H and F, winding terminals; G and L, external circuit connections,

is no more complicated than the bulb sign. As it is necessary to flash the primary side of the transformer, each section of the sign that flashes independently of the other sections must be on a separate transformer.

In determining the number of transformers that can be controlled by one brush, take the input rating as shown on the name plate of the tranformer. This is given in amperes. Any number of transformers may be used on a particular brush as long as the total number of amperes is not greater than the capacity given for that brush.

To Determine Flasher Capacity for Neon Tube Signs.—Consider the transformer volt ampere rating as a rating in watts. Where more than one transformer is used, the sum of their ratings in volt amperes will give the capacity in watts required of flasher. The volt ampere rating may be obtained by multiplying the voltage rating by the ampere rating.

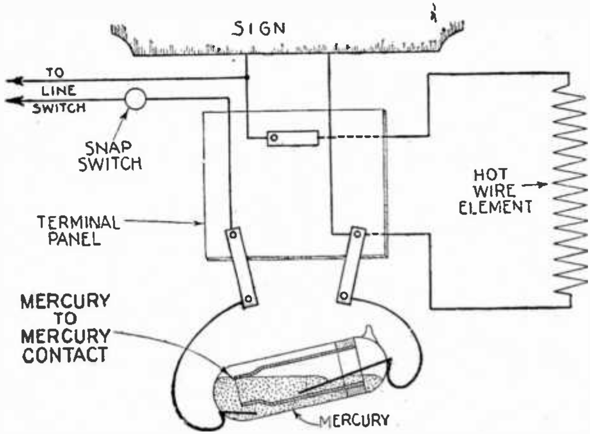


FIG. 8,587.—Wiring diagram of Time-O-Stat universal (*d.c.* or *a.c.*) thermo-flasher for single on and off circuit. *In operation,* when the switch to the sign is turned on, the current flows through the Hywatt mercury to mercury contactor which is in the *on* position, heating the hot wire element and lighting the sign. Thus, as the hot wire element becomes heated, it expands and tilts the contactor through the mechanical connection to the *off* position, cutting out the hot wire element and sign simultaneously. The hot wire element then cools and contracts, allowing the contactor to drop back to the *on* position again, completing the cycle.

It is not advisable to multiply the tubing length by a power factor to obtain the flasher capacity. This power factor cannot always be the same because it varies with the length and size of the tubing.

Radio Interference from Electric Sign Flashers.—This interference is of two kinds. One kind of disturbance is caused by oscillations or disturbing impulses set up by the flasher in the same supply line. The other kind is that picked up by the receiving aerial.

When the flasher is located at some distance from the sign, the wires connecting the two act as an aerial to radiate the disturbance set up by the flasher. Obviously one solution of this type of interference is the installation of the flasher as close as possible to the sign.

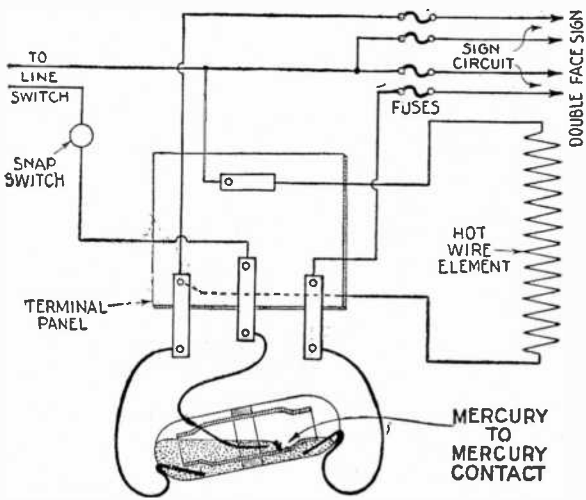


FIG. 8,588.—Wiring diagram of Time-O-Stat thermo-flasher for 2 alternating circuits. A hot wire element is mechanically connected so that its expansion and contraction tilts a Hywatt double action mercury contactor. As the switch to the sign is turned on, the current flows through the flasher, closing the circuit into the hot wire element and one side of the sign, as they are in parallel. This causes the hot wire element to heat and expand. When the element expands, by means of its mechanical connection it tilts the tube to the other position, closing the second sign circuit and opening the first. Now the hot wire element cools and contracts, allowing the mercury tube to drop back to its original position, completing the cycle.

To determine which kind of interference is being picked up, proceed as follows:

Disconnect the aerial and ground. If the interference be still audible, this indicates that it is coming in over the supply line. If no disturbance be audible, it would indicate that disturbance is being picked up by the aerial and ground system of the radio set. It may usually be remedied by the use of radio eliminators. However, if the disturbance be still audible, one or more of the following suggestions should be tried:

1. Connect condensers from each of the four circuits to ground instead of across each of the four circuits of the sign.

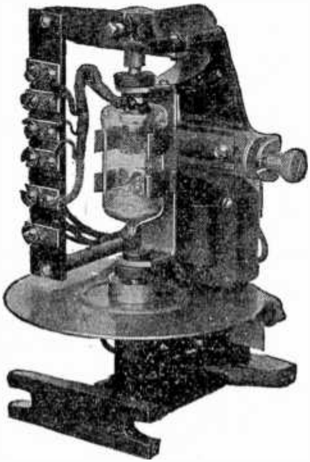
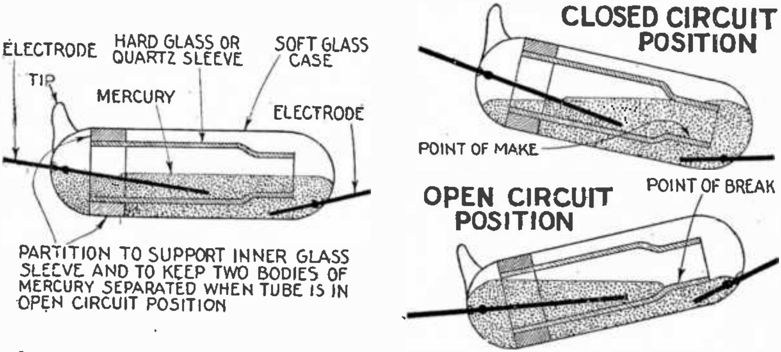


FIG. 8,589.—Time-O-Stat rotary speed flasher for 110 volt, 60 cycle *a.c.* only. ***It is operated*** by means of an induction disc, similar to that used in the watt hour meter. A single Hy-watt contactor containing all the contacts is given a rotary motion so as to flash the circuits in rotation, producing the standard speed effect. The contacts as in the other types of this make of flasher are from mercury to mercury.

2. Connect two condensers in series across the main line connection to the sign, and ground the center point. These connections should be made close to the flasher.

3. Make up choke coils using No. 10 or No. 14 insulated wire jumble wound on a spool and connect them to each of the flasher circuits. The number of turns is variable depending on local conditions. Sometimes 25 turns are enough and other times 100 turns are required. These of course, will be connected right in series with the line to the flasher contact. Until the exact make up of the coil is determined it is best to disconnect three of the circuits and concentrate on one.

4. Connect condensers across the choke coils and the flasher contacts, making a sort of tuned circuit. In this case, as in all others, the condenser capacity should be somewhere between .25 *mf* and .50 *mf*.



FIGS. 8,590 to 8,592.—Time-O-Stat mercury to mercury contactor. ***It consists of*** a hard, heat resisting sleeve mounted rigidly within a soft glass case. ***In operation*** as it is tilted with a clockwise motion to the *on* position, the mercury flows down the inside sleeve, making positive contact with the mercury pool covering the electrode in the case at the point as shown in fig. 8,591. When it is tilted back with a counter clockwise motion, to the *off* position, the mercury in the sleeve and case separate, breaking the contact at the point as shown in fig. 8,592. The mounting material for the sleeve, as shown in fig. 8,591, acts as a partition to prevent the mercury making contact between the two electrodes when the contactor is in this position.

TEST QUESTIONS

1. *What is a sign flasher?*
2. *Give a classification of sign flashers.*
3. *Describe a brush flasher.*
4. *How does a simple on and off flasher work?*
5. *What is the construction of a high speed flasher?*
6. *For what service is a speller or script flasher adapted?*

7. *What is the construction of a script flasher?*
8. *How does a chaser flasher work?*
9. *What is a combination flasher?*
10. *Explain the operation of a control or master flasher.*
11. *What is the basic principle on which a thermo flasher works?*
12. *What are the features of Neon tube signs?*
13. *How is flasher capacity for Neon tube signs determined?*
14. *What two kinds of radio interference are encountered from electric sign flashers?*

CHAPTER 220

Wiring Diagrams for Sign Flashers

The Wiring.—Usually conduit or lead covered B.X. cable is used to connect the sign to the service mains. Difficult bends around building cornices may be made by use of Greenfield cable with lead covered wires inside.

The wires are usually brought out from the frame of the sign in porcelain bushings, but on the larger types the conduit is usually brought directly into the sign. Sheet metal used in electric signs must not be less than No. 28 U. S. metal gauge. All metal must be galvanized, enameled or painted over three times with black asphaltum or tar paint to prevent rust. Only rubber covered wire is permissible on the inside of the sign. All wires must be soldered to the terminals of all receptacles. After the wires have been soldered to the terminals they should be painted over (the terminals) with black asphaltum or any other good insulating paint to prevent rust.

Special receptacles must be used for sign work and must be so installed as to prevent their turning. When wiring the interior of signs great care should be taken to see that the wires are at least one inch from the entire surface wired over. Where the receptacles are placed over 4½ feet apart they must be supported on cleats or knobs, where the receptacles are placed not over one foot apart and wires are secured to these receptacles, a support every 4½ feet will not be required as above.

Not over 1,320 watts lamp load should be placed on any circuit.

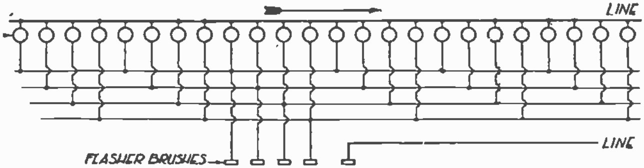


FIG. 8,593.—The number of sockets must always be a multiple of 4, 6, or 8, otherwise at some point a jump will occur.

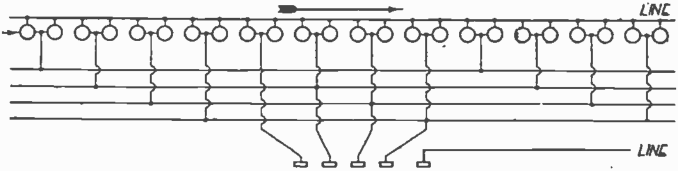


FIG. 8,594.—By grouping two lamps as shown, motion appears faster.

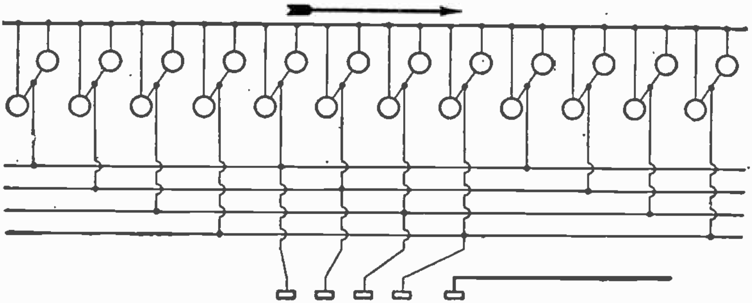


FIG. 8,595.—Number sockets 1-2-3-4. Connect all No. 1 to circuit No. 1 and to flasher brush No. 1. Nos. 2, 3, and 4 likewise. Keep in mind, that the direction of the numbering determines the direction of movement of the shadows.

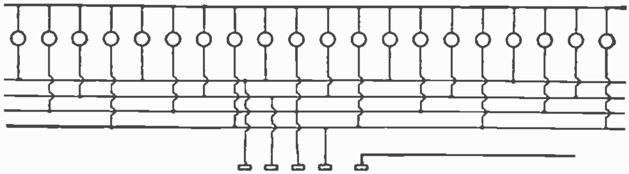


FIG. 8.596.—Pulsating, twinkling or shimmering effects are accompiished by transposing leads (hooking lead No. 2 to flasher brush No. 4, lead No. 3 to brush No. 1, etc.).

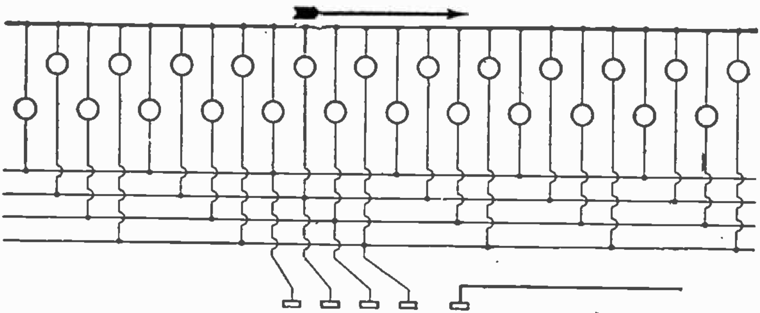


FIG. 8,597.—Borders of irregular outline or particular shape require lamps more closely spaced than standard.

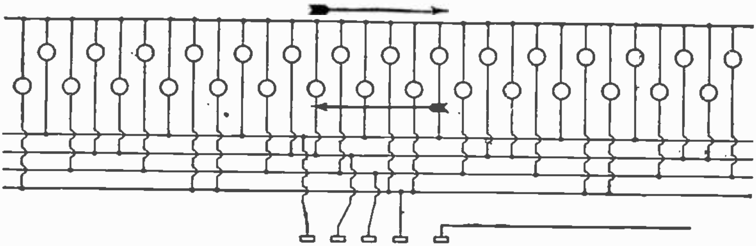


FIG. 8,598.—Two motions traveling in opposite directions. Effective when rows are spaced more than lamp centers. Borders. Although most borders are made on the style of the accompanying illustrations it is not because of the lack of possibility that more unusual patterns are not more popular. Unusual form and variation in color as well as distinctive motions depend largely upon the imagination and ingenuity of the designer.

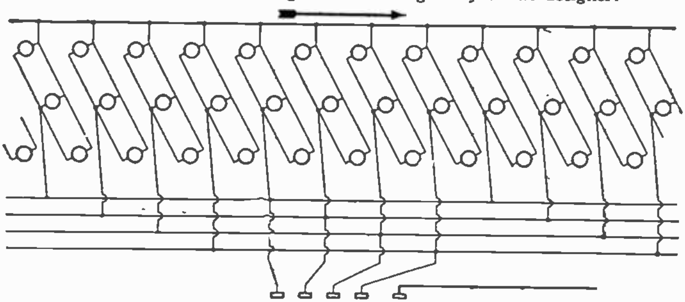


FIG. 8,599.—An arrangement for border and speed effects where a heavy border is necessary or where dark colors are used. Many variations and novel effects are possible by special arrangement of lamps and connections.

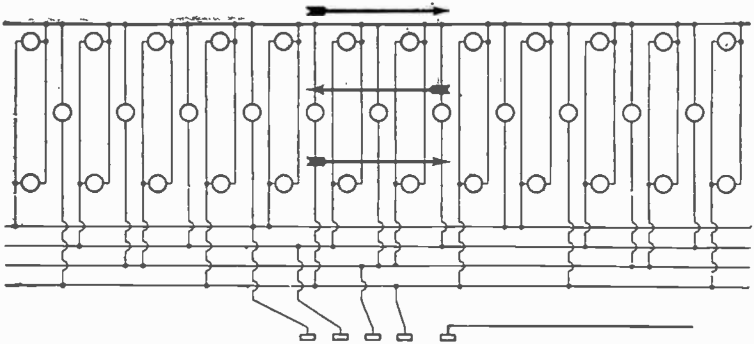
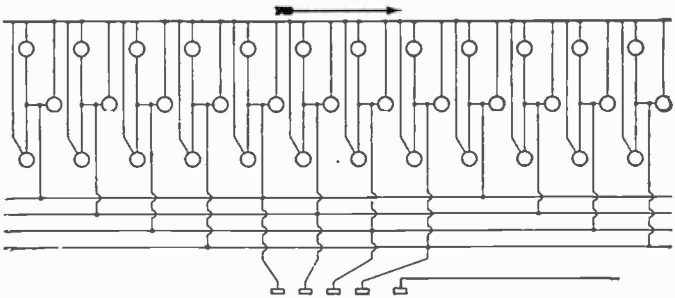
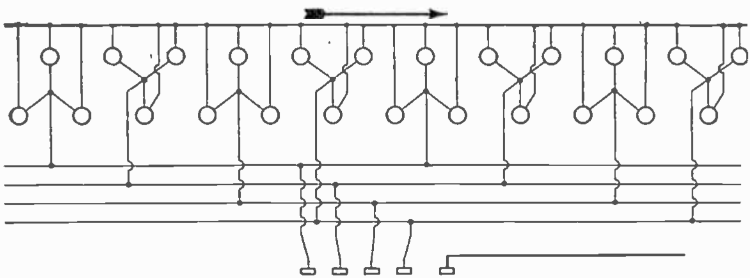


FIG. 8,600.—Simple, yet unusual motion. Outside rows travel to the right while inside row travels oppositely. Here again lamp centers should be less than row centers to clarify directions of both motions.





FIGS. 8,601 and 8,602.—Fig. 8,601, heavy border of running design. Fig. 8,602 shows traveling triangular shadow, changing shape continuously.

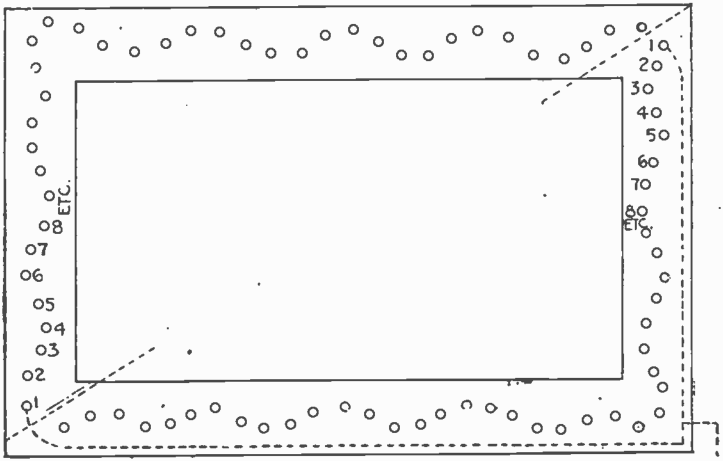


FIG. 8,603.—Chaser wiring diagram for two snakes. Draw a line diagonally through the sign (as shown in dotted line) so that one-half the total lamps will be on either side. Begin to number from one consecutively from the line. Over the line commence again at 1, and number as before. For three snakes, divide total lamps into three parts and number as before. *In each case,* connect all lamps of the same number to the same wire whether the sign be single or double face. The wire containing all the No. 1. lamps goes to the No. 1 switch on the flasher, and the remaining sets are connected similarly.

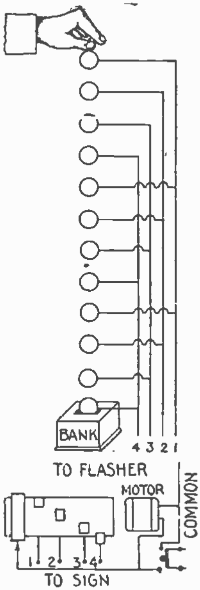


FIG. 8,604.—Dropping coins, juggling clowns, flying sparks. These and similar effects are wired 1-2-3-4 as here shown. This method gives a realistic action and is inexpensive, as it takes only a four brush flasher. The contacts on the flasher are set so that only one brush is in circuit at one time.

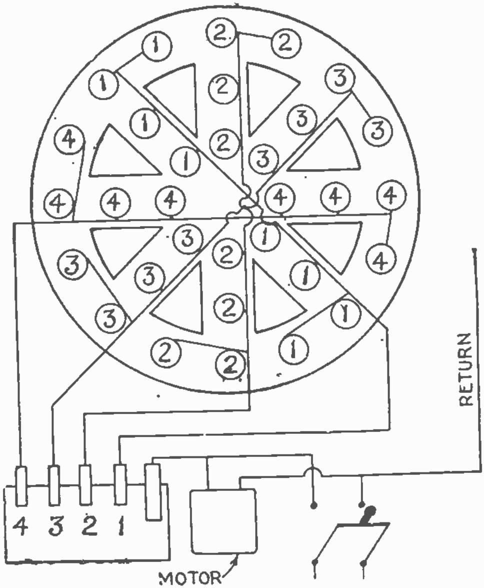


FIG. 8,605.—Wiring for revolving wheel.

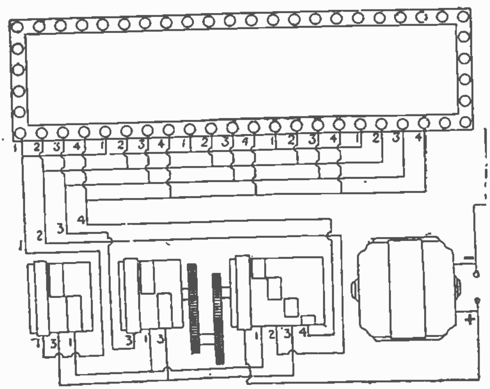


FIG. 8,606.—Standard reversing traveling or running border. It travels first to the right, then to the left, reversing approximately every three seconds. Requires four brush speed flasher with four controls.

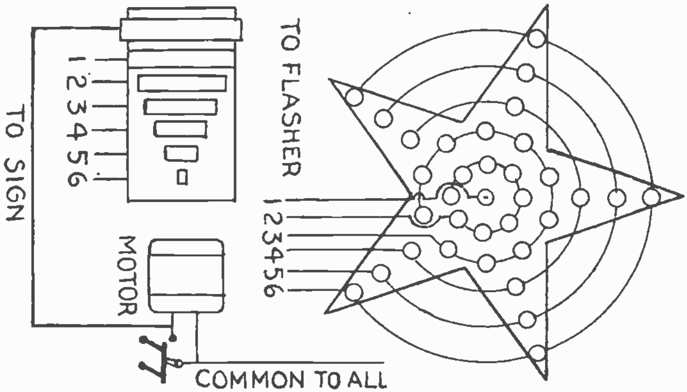


FIG. 8,607.—Expanding and contracting effect (building up and down). Sockets are wired in circular circuits. The flasher brushes coming on in successive steps cause the star to expand gradually, going out the same way.

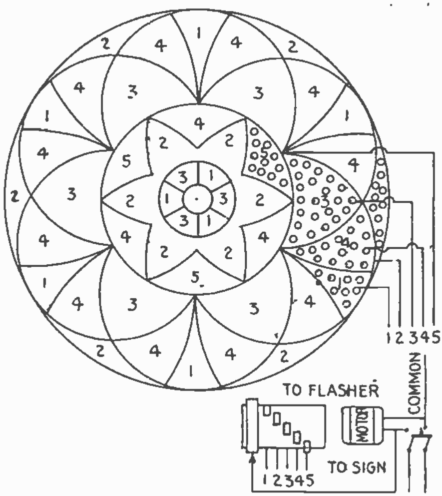


FIG. 8,608.—Chromatic or kaleidoscopic effects. These are usually wired in five circuits as shown.

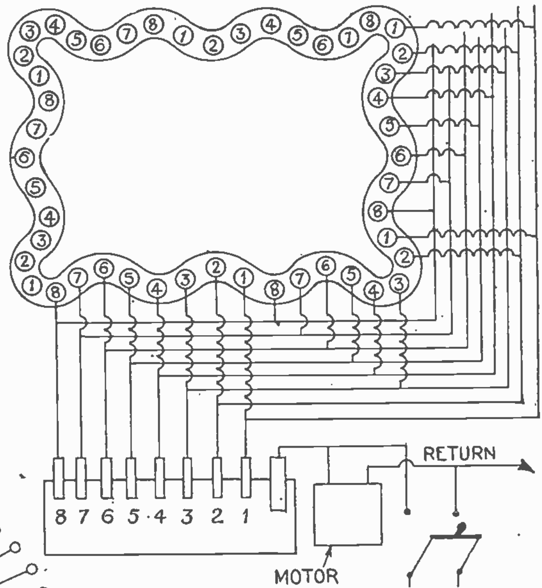


Fig. 8,609. — Crawling or chaser effect. For two chasers, divide the total number of lamps by two; that is, 60 lamps divided by 2 equals 30 circuits, and number sockets 1 to 30 and 1 to 30. This will require a 30 brush flasher. For three chasers divide by three and number from 1 to 20, 1 to 20 and 1 to 20, which requires a 20 brush flasher. For four chasers, divide by four and number from 1 to 15, etc. When sockets are wired in multiples of two, half as many brushes are required as given above. The average border will accommodate two chasers; larger border, three, four or more. The length of the chaser is governed by the number of brushes in contact, usually one third of the total number of brushes.

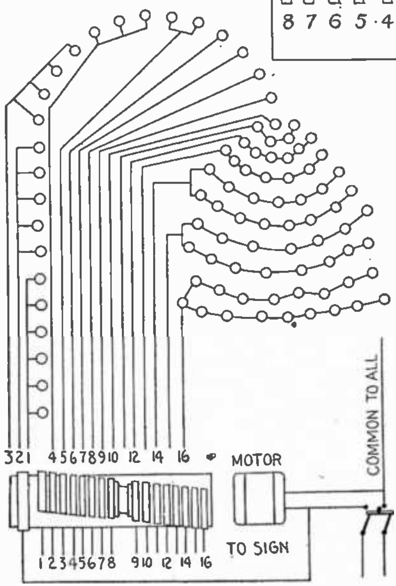


Fig. 8,610.—Fireworks, rockets, roman candles. These and other imitations of pyrotechnic displays are very attractive. The first circuit at the base of the rocket consists of six lamps, the next five, etc., and at the curve, single sockets. This will show acceleration at the start and slowing up as the burst is reached. The burst is wired in three circuits, and the streamers in double rows as shown. This diagram gives the general idea and it may be expected that different designs and greater number of lamps require modifications or variations.

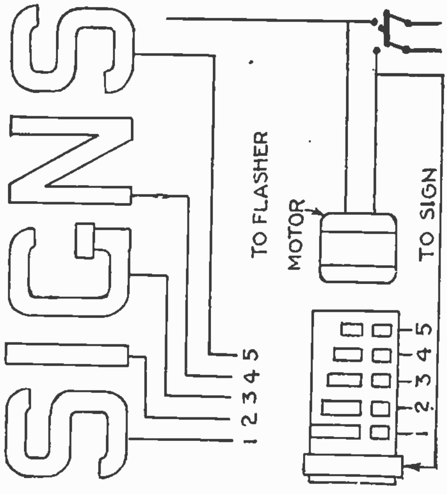


Fig. 8,611.—Standard speller effect. One letter after another till all are lighted, all out, all on together, all out and repeat. Speller effects require a circuit for each letter and a flasher brush for each circuit.

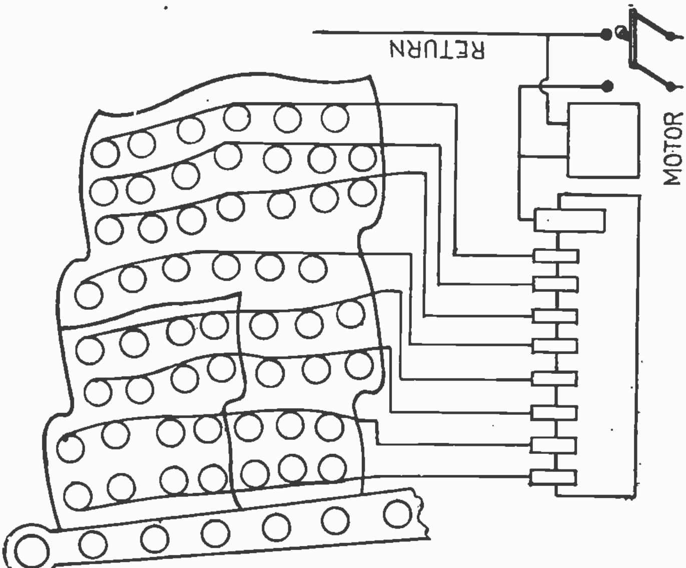


Fig. 8,612.—Waving flags, pennants, etc. Flags are wired in staggered rows as here shown, and require a flasher brush for each row.

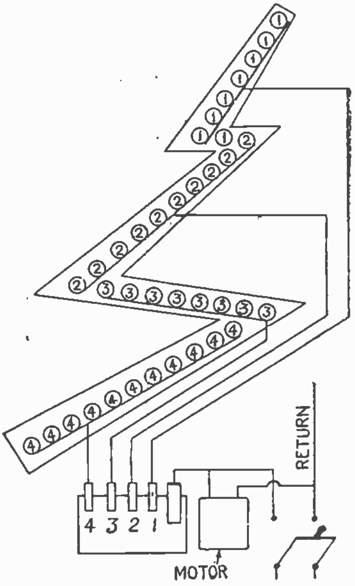


FIG. 8,613.—Lightning effects. Each hook or streak is wired in one circuit. Four streaks require a four brush flasher. Either chaser or speed type. If lightning be not continuous, but is required to synchronize with reading matter or spectacular effect, a control flasher is necessary.

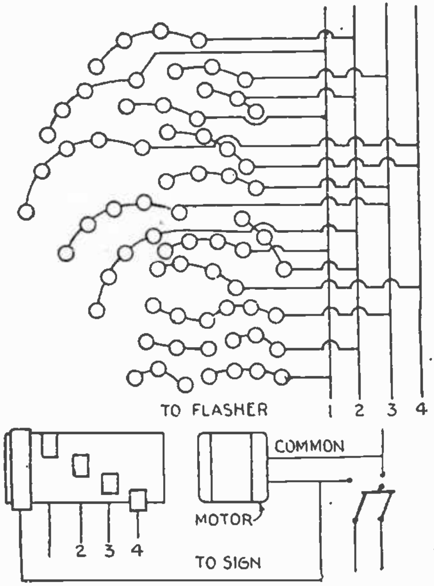


FIG. 8,614.—Smoke, steam, etc. These effects are wired in crescent form. The shapes, sizes and lengths being irregular; semi-circles are numbered 1-2-3-4 in an upward and outward direction. A speed type flasher is used for this work.

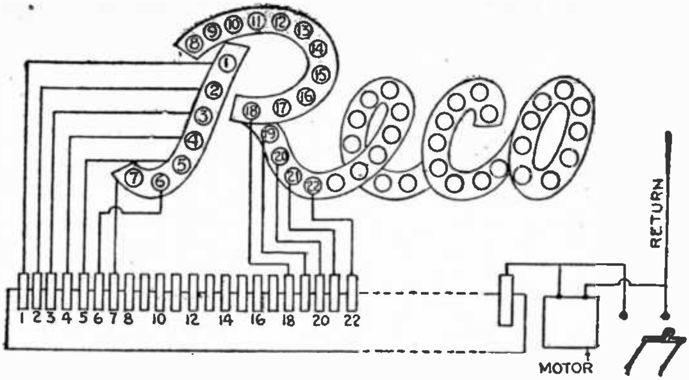


FIG. 8,615.—Reproducing invisible handwriting effect in script letter signs. Script letters are usually wired two sockets to a circuit; thus if the total number of sockets be 100, 50 circuits and 50 brushes on the flasher are required. The flourish or tail (if any) can be flashed as one, to save wiring. Letters of large size can be wired 4, 6, 8 or more sockets to a circuit without impairing the effect.

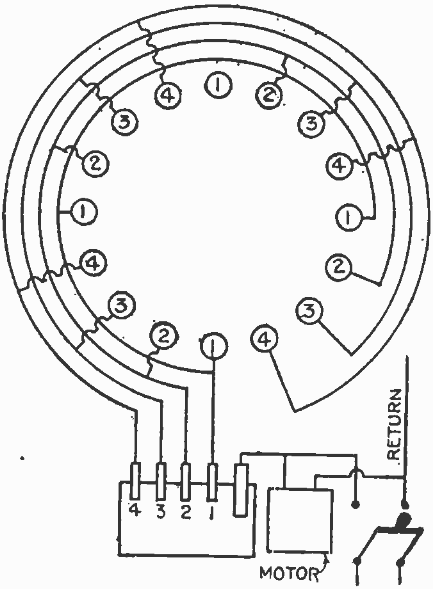


FIG. 8,616.—Traveling borders, circles and movements in general. The number of sockets must always be a multiple of 4, otherwise at some point a jump will occur.

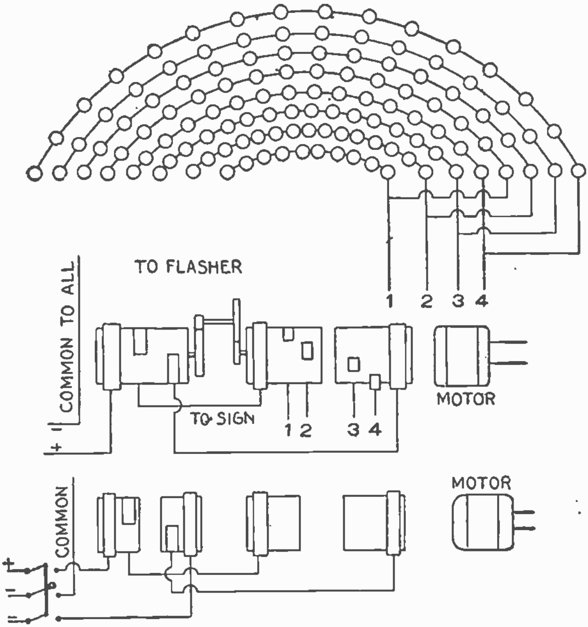


FIG. 8,617.—Rays, sunrise. These and similar effects are wired in semi-circular rows. For rays wire 1-2-3-4 and use four brush speed type. For sunrise wire in eight circuits and use eight brush speller type, provided there be eight circular rows in design. If more or less, flasher will require a corresponding number of brushes.

REFRIGERATION

Points on Dry Ice

Dry ice is solidified carbon dioxide, and is sometimes called **carbice.**

Carbon dioxide, like many other gases, has the capacity of existing in three separate states, namely, gas, liquid and solid. Like many other gases, it may be liquefied by the application of pressure produced by compression, using a gas compressor for the purpose, then subsequently cooled to remove the heat of compression and the latent heat.

The liquid may then be converted to the solid state by reducing the pressure below its condensing pressure and allowing same to escape through a control valve into a suitable container where approximately 75 to 80% forms snow and the remainder passes off in the form of low temperature and low pressure gas to be recovered and reconverted to the liquid state.

The snow thus formed is compressed into dense cakes which resembles somewhat a cake of closely packed fine snow. As produced for the trade, a cake of dry ice is more dense than water ice and its weight per cubic foot is approximately twice that of water ice, depending upon the pressure used for compressing the snow. Not all commercial dry ice has the same density.

There are numerous uses for dry ice: its principal application is in the shipment of ice cream, quick frozen foods of various kinds, and for maintaining low temperatures in refrigerators where such commodities are sold as well as for refrigerating delivery trucks used for transporting such low temperature commodities.—*E. Gilbert.*

Refrigeration

CHAPTER 221

Numerous definitions have been given for refrigeration. It is *the process of removing heat from a confined space* for the purpose of reducing and maintaining the temperature of the enclosed space below that of the external atmosphere.

Refrigeration is usually accomplished by a "*change of state*" of the *refrigerant* or *refrigeration medium*, that is:

1. By fusion.

As when ice changes from a *solid* to a *liquid* state by melting.

2. By evaporation of liquids having a low boiling point.

When a liquid evaporates or boils it changes from a liquid to a gaseous state.

Another method of refrigeration in which a change of state does not occur is

3. By expansion of a gas.

The first method utilizes

the latent heat of fusion

the second,

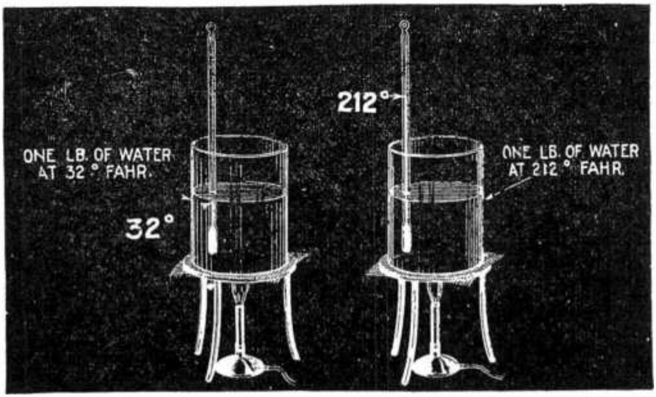
the latent heat of evaporation

and the third,

the heat due to external work of expansion

Heat.—By definition heat *is a form of energy known by its effects.*

These effects are indicated through the touch and feeling, as well as by the expansion, fusion, combustion or evaporation of the matter upon which it acts.



FIGS. 8,618 and 8,619.—Experiment illustrating the British thermal unit. Place one pound of water at 32° Fahr. into a beaker over a Bunsen burner as in fig. 8,618, assuming no loss of heat from the water. It will, according to the definition, require 180 heat units to heat the water from 32° to 212° Fahr. as in fig. 8,619. If the transfer of heat take place at a uniform rate and it require, say five minutes to heat the water to 212°, then one heat unit will be transferred to the water in $(5 \times 60) \div 180 = 2$ seconds.

Ques. What is temperature?

Ans. That which indicates how hot or cold a substance is; a measure of *sensible heat.*

Ques. What is sensible heat?

Ans. That heat which produces a rise of temperature as distinguished from *latent heat.*

Ques. What is latent heat?

Ans. The quantity of heat required to change the *state* or condition under which a substance exists without changing its temperature.

Thus a definite quantity of heat must be transferred to ice at 32° to change it into water at the same temperature.

The Unit of Heat.—The present generally accepted heat unit, called the British thermal unit (*B.t.u.*) is defined as 1/180 *of the heat required to raise the temperature of water from* 32° *to* 212° Fahr.

Transfer of Heat.—When bodies of unequal temperatures are placed near each other, heat leaves the hot body and is absorbed by the colder body until the temperature of each is equal.

The rate by which the heat is absorbed by the colder body is proportional to the difference of temperature between the two bodies. The greater the difference of temperature, the greater the rate of flow of the heat.

When ice is placed in an ordinary ice box the temperature of the interior is reduced below that of the external atmosphere.

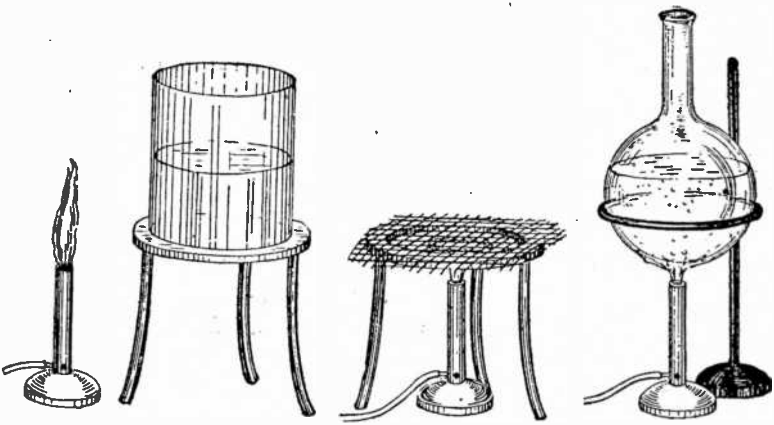
This occurs because the ice, in melting, absorbs heat from the heat laden air in contact with it and this heat is carried away from the box in the water produced by the melting of the ice. The reason for this is that heat always seeks the coldest places, that is, it moves from the warmer to the colder object and when the colder object absorbs and removes this heat, in the form of water in the example of the ice box, a cooler temperature is naturally produced.

Transfer of Heat.—A transfer of heat takes place by

1. Radiation;
2. Conduction;
3. Convection.

Thus, in a boiler, heat is given off from the furnace fire in rays which radiate in straight lines in all directions being transferred to the crown and sides of the furnace by radiation; it passes through the plates by conduction, and is transferred to the water by convection, that is, by currents.

In the case of the ice box relatively warm objects as food transfer their heat to the surface of the ice by *radiation*, also on account of the unequal



FIGS. 8,620 to 8,622.—Three ways in which heat is transferred; fig. 8,620, by radiation; fig. 8,622, by conduction; fig. 8,622, by convection. In fig. 8,620, the water in the beaker is heated by *heat rays which radiate in straight lines in all directions from the flame.* In fig. 8,621, the flame will not pass through the wire gauze, because the latter conducts the heat away from the flame so rapidly that the gas on the other side is not raised to the temperature of ignition. In fig. 8,622, the water nearest the flame becomes heated and expands. It is then rendered less dense than the surrounding water, and hence rises to the top while the colder and therefore denser water from the sides flows to the bottom thus *transferring heat by convection currents.*

temperature of the food and ice air currents are produced which carry heat from the food to the ice by *convection*.

Finally, the heat penetrates the ice by *conduction* causing it to melt and be carried off in the water.

NOTE.—*Convection.*—In convection, heat is carried from one place or object to another by means of some agent such as air or water or any moving gas or liquid. The food in a refrigerator is cooled mostly by convection. The circulating air is the medium used to transfer the heat from the food and compartment walls to the ice.

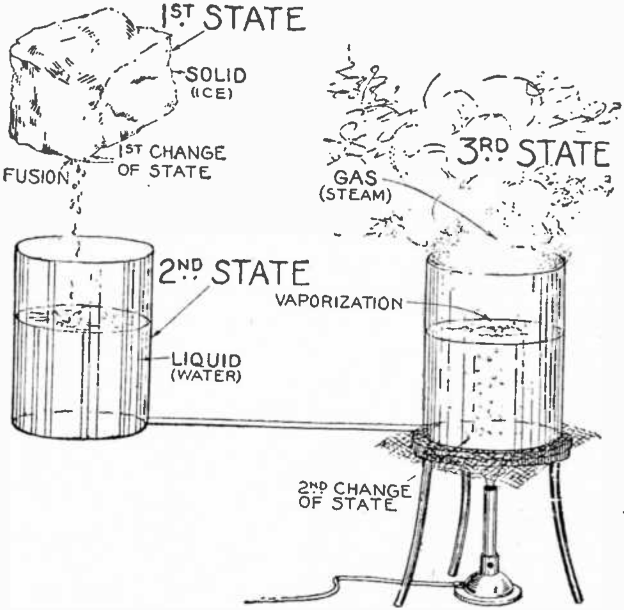


FIG. 8,623.—The three states: solid, liquid and gas. The cake of ice represents a substance in the solid state. If the temperature of the surrounding air be above the freezing point (32° Fahr.) *the ice will gradually melt*, that is to say, *change its state from solid to liquid*, this process being known as *fusion*. If sufficient heat be transferred to the liquid, *it will boil*, that is to say, *change its state from liquid to gas*, this process being known as *vaporization*. Very interesting phenomena take place during these changes, which are explained in the accompanying text.

NOTE.—*Conduction.*—In conduction, heat is carried by means of molecular vibration set up through the substance itself. Heat may be transferred between different parts of the same body or between two separate bodies in actual contact by conduction. All substances have, to a greater or less extent, the power of allowing heat to flow through them. This property is called *conductivity* and a substance that offers little obstruction to the flow of heat is called a *good conductor*, while a substance which offers great resistance is called a poor conductor or an *insulator*. When one end of a bar of iron is held in a fire, the other end will soon become too hot to hold in the hand. The heat is transferred from one end to the other by conduction. One end of a stick of wood can be held in a fire without the other end becoming warm. Wood is a poor conductor of heat as compared to iron. A vacuum is an extremely poor conductor, while air is about 40 times better as a conductor.

NOTE.—*Radiation.*—In radiation, heat energy is transferred from one body to another by ether vibrations without the assistance of any material medium. The heat of the sun is transferred from the sun to the earth in this way.

The Three States of Matter.—The three forms in which matter may exist are known as

1. Solid;
2. Liquid;
3. Gas.

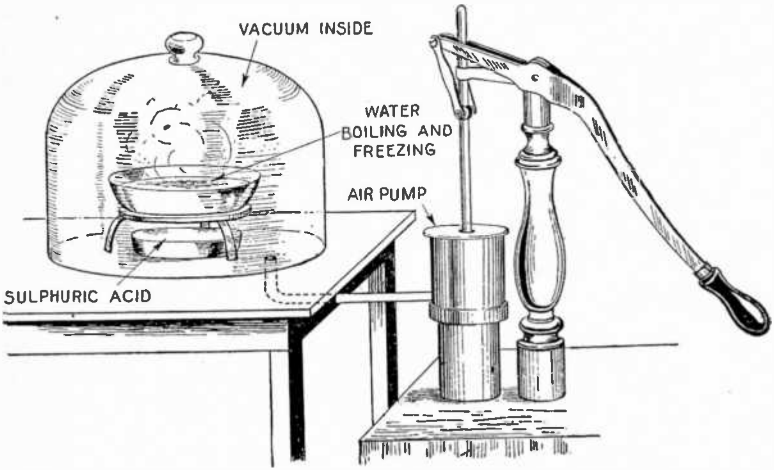


FIG. 8,624.—*Change of state* as illustrated by Leslie's experiment showing water freezing as it boils. A small pan containing some water is placed over a dish filled with sulphuric acid, and the air removed with an air pump. On removal of the air the water evaporates rapidly and begins to boil, being greatly facilitated by the sulphuric acid which absorbs the vapor almost as rapidly as formed. The temperature of the water is quickly reduced and it finally solidifies, thus the liquid is frozen while in the act of boiling.

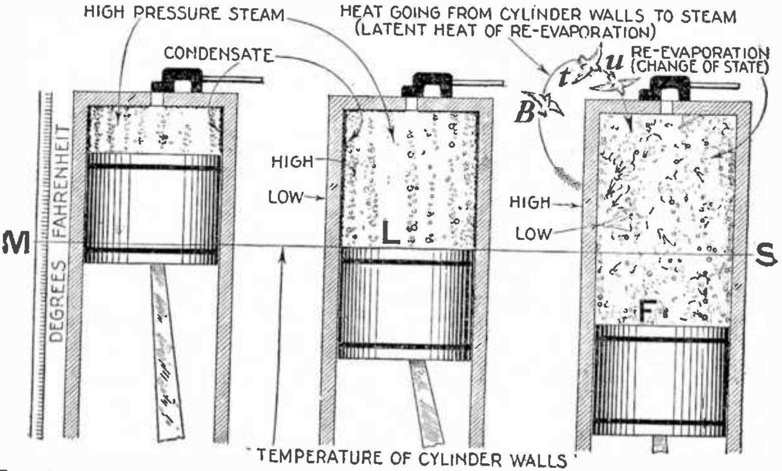
A familiar example of one substance existing in the three states is

1. Ice;
2. Water;
3. Steam;

as shown in fig. 8,623.

Change of State.—By sufficiently increasing the temperature, solids are converted into liquids, and liquids into vapors. While either change is taking place the temperature of the mass is found to remain constant till the change is completely effected.

Thus, if a vessel full of broken ice be placed over a lamp, the ice will gradually melt, but the temperature of the whole mass will not alter till the



FIGS. 8,625 to 8,627.—Steam engine analogy illustrating *cooling by change of state*. Let **MS** equal average temperature of cylinder walls. *In operation*, when steam is admitted to the cylinder and during a portion of the stroke its temperature is higher than that of the cylinder walls. Assume **L**, to be piston position of equal temperatures. Evidently up to position **L**, condensation will take place. The temperature of the steam being *lower* than that of the cylinder walls while the piston is traveling from **L**, to **F**, the excess heat will cause the condensate to boil, that is, a *change of state* takes place as it robs the cylinder walls of an amount of heat, corresponding to the *latent heat of re-evaporation*.* Similarly in refrigeration, when the refrigerant leaves the expansion valve, a *change of state* occurs which robs the metal of the expansion coils of an amount of heat corresponding to the latent heat of evaporation of the refrigerant, thus producing the refrigerating effect.

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*NOTE.—***Re-evaporation.** Numerous students of the steam engine have a wrong conception of the effect of re-evaporation. Since re-evaporation increases the area of the indicator card during a portion of the stroke up to pre-release, it represents, considered alone, a *gain* in power. It is the cost of this gain which offsets the economic result. Considering the excessive amount of condensation it causes, re-evaporation results in a loss in economy.

melting is completed. The heat received is employed in changing the state of the substance, in converting it from solid ice to liquid water.

If the supply of heat be still continued, the liquid will rise in temperature and ultimately begin to boil. When this point is reached, the temperature again remains stationary. The liquid simply passes into vapor, and the heat supplied during this process is used up in changing the state of the substance from that of liquid to that of vapor.

FIG. 8,628.—Method of judging the heat of a soldering bit or so-called "iron," illustrating *sensible heat*.

Heat and Work.—Heat develops *mechanical force, and motion*, hence *it is convertible into mechanical work.*

As already explained, heat is measured by the British thermal unit (*B.t.u.*). Work is defined as *the overcoming of resistance through a certain distance by the expenditure of energy*. Work is measured by a unit called the *foot pound*.

Ques. What is a foot pound?

Ans. It is *the amount of work done in raising one pound one foot*, or in overcoming a pressure of one pound through a distance of one foot.

Thus, if a 5 pound weight be raised 10 feet, the work done is $5 \times 10 = 50$ foot pounds.

Ques. What is the relation between the unit of heat and the unit of work?

Ans. It was shown by experiments made

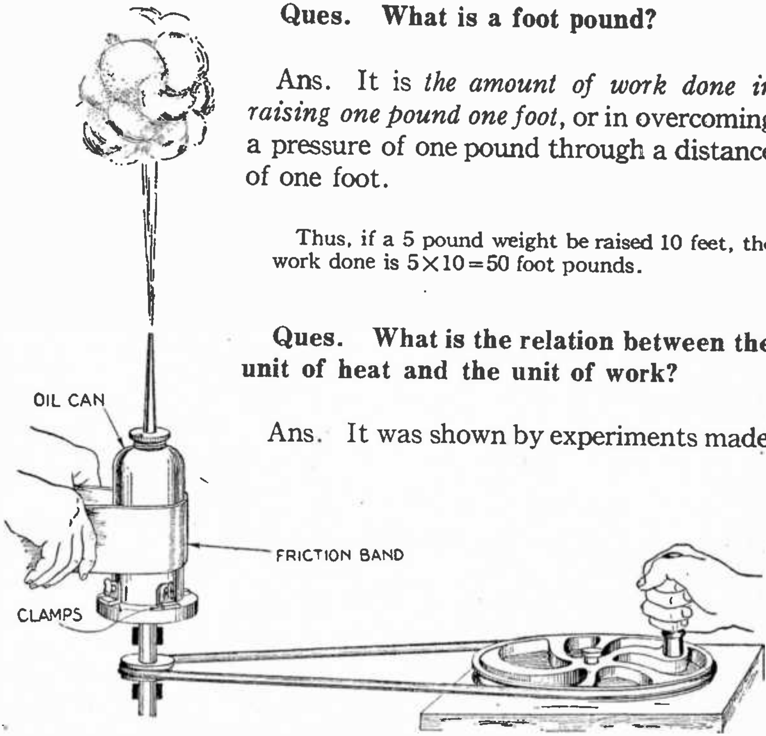


Fig. 8,629.—Experiment showing relation between heat and work. Take a brass oil can, attached to a spindle geared to rotate rapidly and partly fill the can with water and insert a cork. Apply a friction band, and rapidly rotate the can by turning the large wheel. The energy expended in overcoming the friction due to the band and rotating the can, causes the water to heat and finally boil; if continued long enough, the steam generated will pass out through the tip as shown. During the operation *work has been transformed into heat.*

by Joule (1843–50) that 1 *unit of heat* = 772 *units of work*. This is known as the "mechanical equivalent of heat" or Joule's equivalent.

More recent experiments by Prof. Rowland (1880) and others give higher figures; 778 is generally accepted, but 777.5 is probably more nearly correct, the value 777.52 being used by Marks and Davis in their steam tables.

The value 778 is sufficiently accurate for ordinary calculations.

Latent Heat of Fusion.—The term "fusion" signifies the change of state of a substance from the solid form to the liquid form. This is popularly known as melting.

If heat be applied to ice it will gradually melt, but during the melting process the temperature will remain unchanged.

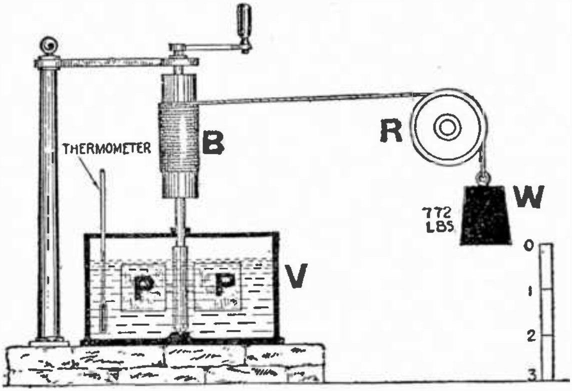


FIG. 8,630.—The mechanical equivalent of heat. In 1843, Dr. Joule of Manchester, England, performed his classic experiment, which revealed to the world the mechanical equivalent of heat. As shown in the figure, a paddle was made to revolve with as little friction as possible in a vessel containing a pound of water whose temperature was known. The paddle was actuated by a known weight falling through a known distance. *A pound falling through a distance of one foot represents a foot pound of work.* At the beginning of the experiment a thermometer was placed in the water, and the temperature noted. The paddle was made to revolve by the falling weight. When 772 foot pounds of energy had been expended on the pound of water, the temperature of the latter had risen one degree, and the relationship between heat and mechanical work was found; the value 772 foot pounds is known as Joule's equivalent. More recent experiments give higher figures, the value 778, is now generally used but according to Kent 777.62 is probably more nearly correct. Marks and Davis in their steam tables have used the figure 777.52.

The heat required to melt the ice is called the *latent heat of fusion.*

It requires 143.57 *B.t.u.* to melt one pound of ice at 32° Fahr. The value given is ordinarily taken at 144 *B.t.u.*

Latent Heat of Evaporation.—By definition the latent heat of evaporation of a substance is *the amount of heat necessary to convert a unit quantity of the liquid into saturated vapor at the same temperature and pressure.*

Example. If one pound of water be taken at 212° Fahr. (boiling point) and heated, the temperature will remain the same (212°) until it has been completely evaporated (or boiled off) into steam. This has been found to

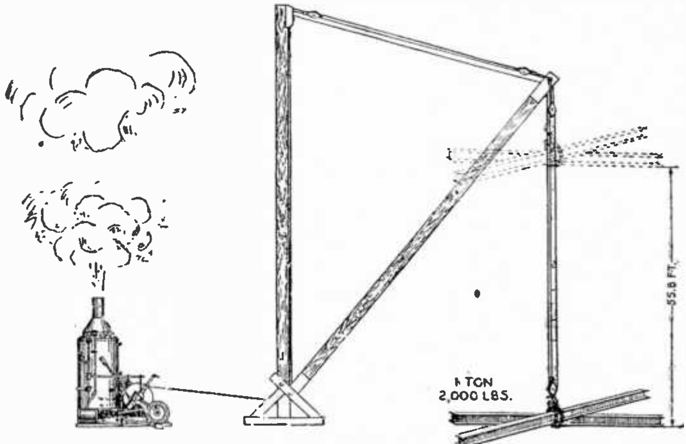


FIG. 8,631.—The fusion of ice, illustrating the *work done when the pound of ice at 32° Fahr. is melted or converted into water at the same temperature.* The latent heat of fusion being 143.57 heat units, and since one heat unit is equivalent to 778 ft. lbs. the work done during the fusion of one pound of ice is 778×143.57 = 111,698 ft. lbs. This is approximately equivalent to the work done when a hoisting engine hoists 2,000 lbs. a distance of 55.8 ft. as shown in the illustration.

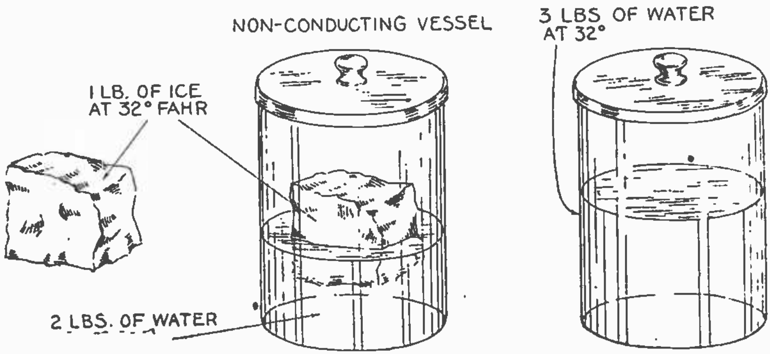
require 970 *B.t.u.* and is known as the *latent heat of evaporation for water.* That is, when water is at a temperature of 212° (and atmospheric pressure) it takes 970.4 times as much heat to change the water to vapor as it would to raise the water one degree in temperature at any temperature between 32° and 212°.

The Boiling Point.—By definition the boiling point is *the temperature at which a liquid boils.*

The boiling point depends upon

1. The pressure upon the liquid, and
2. The liquid.

Water in an open vessel boils at a temperature of 212° F. when the barometer reads 30 inches. Now, if the vessel be closed, and the supply of heat be continued, the pressure of the steam will gradually rise, and the temperature of the liquid also; that is to say, the boiling point is elevated above



FIGS. 8,632 to 8,634.—Experiment illustrating the *latent heat of fusion*. ***It requires*** 144 heat units to "melt" a pound of ice at 32° Fahr., that is, to convert it into water of the same temperature. Accordingly, if a pound of ice (fig. 8,632) be placed in a non-conducting vessel with two pounds of water at 104° Fahr., it will be found that when all of the ice has been melted by the transfer of heat from the water to the ice the temperature of the mixture (fig. 8,634) of melted ice and the water will be the same as the original temperature of the ice, 32°. ***The reason*** for this is because the total heat above 32° in the water at 104° was the same as the latent heat of the ice, or 144 heat units, that is to say, the total heat above 32° in the water was (104 − 32)2 = 144 heat units. ***It should be understood*** that the term non-conducting vessel implies one which allows no heat to pass through its sides. Such a vessel is not possible to construct, but by covering an ordinary vessel all over with a thick layer of asbestos very little heat will be lost.

212° when the pressure is increased above 14.7 pounds, *there being a definite temperature or boiling point corresponding to each value of pressure;* in other words, there is one temperature only for steam at any given pressure; at any other pressure, the temperature has some other value, but always fixed for that particular pressure.

The popular idea is that a liquid must be hot to boil. This is a wrong conception.

Water, for instance, in a 28 in. vacuum will boil at 100° Fahr.; if the vacuum be increased to 29.74 in. it will boil at 32°, the temperature at which it would freeze at atmospheric pressure.

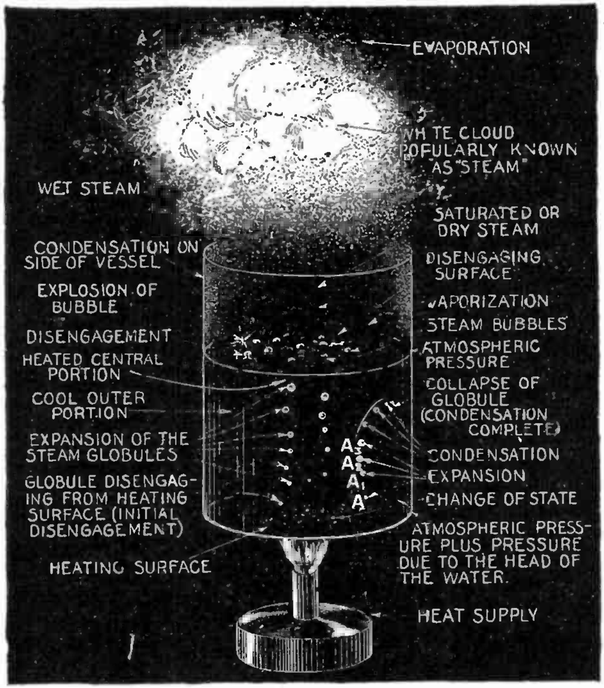
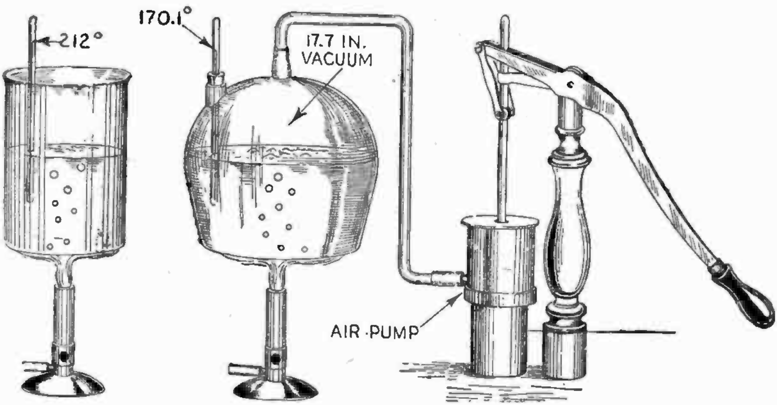


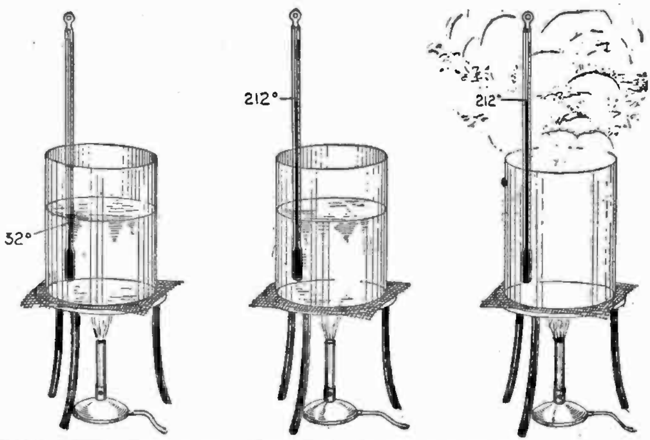
FIG. 8,635.—Vaporization or the process of boiling as illustrated by the boiling of water.

Again, different liquids have different boiling points.

For instance, methyl chloride boils at 11° below zero Fahr. at atmospheric pressure. This means that in an open vessel and not under pressure (other than normal atmospheric pressure) methyl chloride would rapidly evaporate into the air at a temperature of 11° below zero just as a pan of water placed on a hot stove will boil at 212°.



FIGS. 8,636 and 8,637.—***The boiling point.*** The temperature at which a liquid boils depends upon the pressure. Thus, at atmospheric pressure, as in fig. 8,636, water boils at 212° Fahr. but under say a 17.7 inch vacuum (at 6 lbs., absolute pressure) it boils at 170.1°.



FIGS. 8,638 to 8,640.—Experiment illustrating the ***latent heat of evaporation*** or *the considerable amount of heat which must be added to a liquid at its boiling point to convert it into vapor at the same temperature.* Taking water for illustration, suppose the glass vessel to contain one pound of water at 32° Fahr., and heat be transferred to it, as indicated by the Bunsen burner, at such rate that its temperature is raised to the boiling point 212° in five minutes. In this time the water has received 212 – 32 = 180 heat units. Now, if the heat supply be

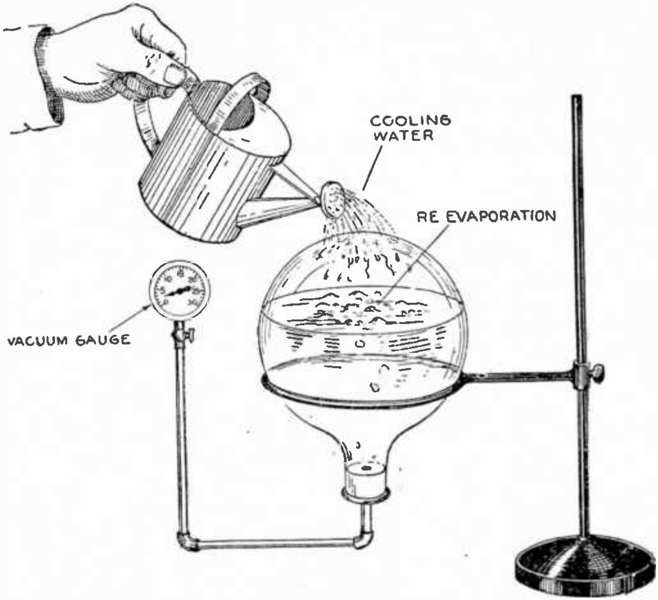
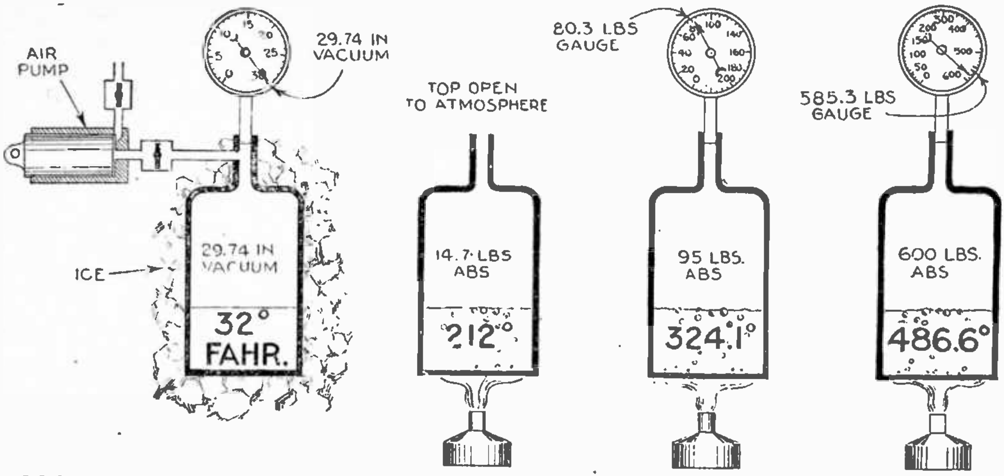


FIG. 8,641.—Lowering the boiling point by diminishing the pressure. Put some water in a round bottomed flask and boil. After it has boiled some time, until the air has been drawn out of the flask by the steam, insert a rubber stopper, having fitted to it a connection leading to a vacuum gauge and invert the flask as shown. The vacuum gauge will now read zero. Now, if some cold water be poured over the flask, the temperature will fall rapidly and some of the steam will condense, thus lowering the pressure within the flask, that is, the vacuum gauge will read 5 or 10 inches indicating a vacuum. The reduced pressure disturbs the equilibrium between pressure and temperature and the water will boil until equilibrium is again restored. The operation may be repeated several times without reheating, the pressure gradually falling each time. At the city of Quito, Ecuador, water boils at 194° Fahr., and on the top of Mt. Blanc at 183°. Again, in a steam boiler in which the pressure is 200 lbs., the boiling point is 387.7°.

FIGS. 8,638 to 8,640.—*Text continued.*

continued at the same rate, it will require (since the latent heat of steam at atmospheric pressure is 970.4 heat units) 970.4 ÷ 180 = 5.39 times as long, or 5.39 × 5 = 26.95 minutes to convert the pound of water at 212° (fig. 8,639) into steam at the same temperature as indicated by the empty beaker in fig. 8,640. *That is to say, it takes over five times as much heat to convert water at 212° into steam at the same temperature as it does to raise the same amount of water from the freezing point 32° to 212°.* In the well remembered *naphtha launch* and *alco-vapor launch*, naphtha and alcohol were used respectively in the boilers in the place of water because of the excessive latent heat of the latter. Thus with a given heating surface or weight (an important factor in marine construction) more power could be developed with the



FIGS. 8,642 to 8,645.—Variation of the boiling point with change of pressure. Taking water to illustrate, when the pressure is

29.74 in. vacuum	14.7 lbs. absolute	80.3 lbs. gauge	585.3 lbs. gauge

the water will boil at a temperature (Fahr.) of

32°	212°	324.1°	486.6°

Highly different values are obtained for other liquids.

FIGS. 8,638 to 8,640.—*Text continued.*

liquids just mentioned than with water, because of their relative low latent heat of evaporation. For instance, for alcohol the latent heat is 363.3 heat units or only a little over one-third of that of water. From experiments made by the Gas Engine and Power Co., builders of *naphtha launches*, it was claimed that the power obtained on the brake was in the ratio of about 5 to 9 for water and naphtha, that is, the same quantity of heat was turned into nearly twice as much work by the expansion of naphtha vapor as by the expansion of steam under the same conditions. Some of the results obtained during the tests were: *1*, with ***steam***, mean pressure 37.99 lbs., *r.p.m.*, 312.6; *2*, with ***naphtha***, mean pressure 55.8, *r.p.m.*, 552.2.

The important fact to know is that *in vaporizing or boiling, the heat surrounding the vessel is carried away by the gas or vapor which is formed.*

If the vessel of methyl chloride were placed in an ice box and means were provided for carrying the gas away, the liquid would continue to boil (drawing heat from the interior of the box) until the liquid was exhausted or

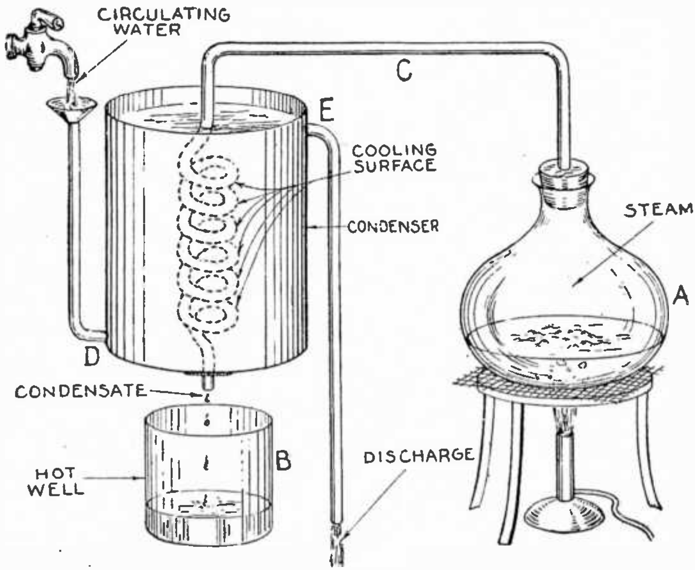


FIG. 8,646.—Experiment illustrating *condensation*. If water for instance be boiled in a flask A, and the steam thus produced led off through pipe C, having a coiled section surrounded by cold water, it will here be cooled below the boiling point and will therefore condense, the *condensate* passing out into the receptacle B, as water. The cooling or "circulating" water enters the condenser at the lowest point D, and leaving at the highest point E.

until, if the box were perfectly insulated, the temperature of the surrounding air was 11° below.

The following are the approximate boiling points, Fahr., at atmospheric pressure of various liquids used as refrigerants.

Ammonia	Ethyl chloride	Methyl chloride	Carbonic acid (carbon dioxide)	Sulphur dioxide	Sulphuric ether
−28	+55	−11	−110	+14	+94.1

Condensation.—By definition condensation is the change of state of a substance from the gaseous to the liquid form. It is caused by a reduction of temperature below that corresponding to the boiling point.

The boiling point as has been explained *depends on the liquid and the pressure to which it is subjected.*

Refrigerants.—The word *refrigerant* means *a heat transfer medium*, that is, a substance which removes heat from an enclosed space or substances to be cooled. The refrigerants commonly used are

1. Ammonia;
2. Ethyl chloride;
3. Methyl chloride;
4. Carbonic acid (carbon dioxide);
5. Sulphur dioxide;
6. Sulphuric ether;
7. Air;
8. Water.

A refrigerant to be suitable for domestic or commercial refrigeration should possess the following properties:

1. High latent heat;
2. Low boiling point;
3. Low condensing point;
4. Non-inflammable;
5. Non-explosive;
6. Non-corrosive on metals;
7. Non-injurious and non-offensive odor;
8. Easily detected in small quantities;
9. Low cost.

Adaptation of Refrigerants.—Each of the various refrigerants just mentioned is, on account of its characteristics, adapted to some particular service as follows:

Ammonia.—More than 90% of the large commercial refrigerating plants use this refrigerant. It is not suitable, however, for use in the types of small refrigerating systems frequently used in apartment house and dwellings. It has an offensive and penetrating odor which is very irritating to any of the membranes of the body and especially to the eyes. Accordingly a slight leak in a confined space would be objectionable if not dangerous.

Ethyl chloride.—This is well adapted to household refrigerators. More than 75% of these refrigerators use ethyl chloride.

Methyl chloride.—Being non-explosive, non-inflammable and having a low toxic hazard methyl chloride is especially adapted to household machines. Methyl chloride can be breathed with no serious effects for an hour in concentrations two-thirds as great as those of carbon dioxide, which gas is thrown off from the lungs during respiration.

Carbonic acid.—On account of safety, in case of accident or fire, carbonic acid is extensively used in marine practice. Used in Europe for household machines and in the United States for cooling theatres and public buildings.

Carbonic acid is also used to a considerable extent abroad, partly because it is made cheaply as a by-product in German breweries; in this country it has found favor, principally in hotels and restaurants, because in case of a leak no harm would be done to perishable goods; then, too, the presence of one-half of one per cent of ammonia in the atmosphere would be decidedly dangerous, while air containing as high as eight per cent of carbonic acid could be breathed for a short time without any serious results.

Sulphur dioxide.—This refrigerant (also called sulphurous acid) has the advantage of requiring only comparatively low pressures, and is a good lubricating medium. This fact simplifies the mechanical details of the machine and it is in use extensively for household and small plants where the service of a skilled engineer is not practicable.

The main objection to its use is the great tendency of sulphurous acid to take up moisture and change to sulphuric acid, consequently great precautions must be taken to avoid leaky joints.

A disadvantage is that a compressor of nearly three times the capacity of an ammonia compressor is required. Sulphur dioxide even in small concentrations in air, is very unpleasant to breathe, but it is not considered poisonous because its very presence is so suffocating that one will immediately seek fresh air.

Sulphuric ether.—On account of the relatively large compressor necessary and more especially the inflammability of ether and the great liability to explosion, sulphuric ether (usually called just "ether") has not come into extensive use.

Its chief advantage is that it requires only a low pressure in the condenser, which is of no little importance in warm climates, and which has led to its use by the British military authorities in several campaigns in Africa.

The low pressure is also favorable for the maintenance of tight joints, and

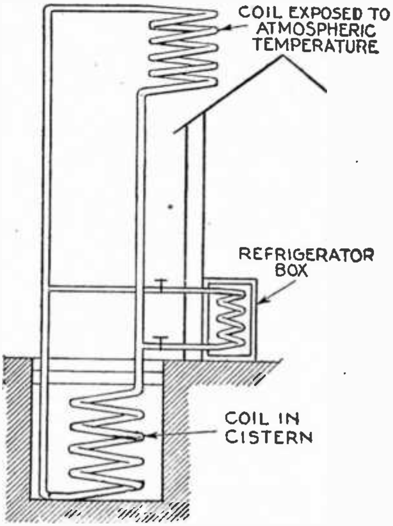


FIG. 8,647.—Natural refrigeration without labor suggested by Prof. Elihu Thomson. A radiator placed on the roof of the house is connected to a coil of pipe in an underground cistern. On cold days the wintry weather would cool the brine in the radiator, causing it to circulate downward into the coil in the cistern, which would gradually collect a thicker and thicker coating of ice. On warm days, the brine in the radiator would be lighter than the brine in the cistern coil and there would be no tendency to circulate. Thus, during the winter each cold day would add to the layer of ice being gradually stored in the cistern. In the summer, a motor operated brine pump could be used to circulate the brine from the cistern to the refrigerator box, and the heat abstracted from the box would be absorbed by the gradual melting of the accumulation of ice in the cistern.

the simplicity of the working parts. Another important fact in connection with military operations is that as ether is in a liquid state under ordinary conditions of temperature and pressure, it can be drawn out of the plant at any time and stored in drums, thus making this type of machine easily and quickly portable.

Properties of Refrigerants.—On account of the fact that different refrigerants have different physical characteristics or "properties" the selection of the type of machine to use and the design will depend largely on the properties of the refrigerant.

The cylinder displacement of the compressor will depend on the refrigerant. Those refrigerants which have high refrigerating effects with corresponding low specific volumes of vapor, will require the minimum cylinder displacements, while those which have low refrigerating effects, and correspondingly large specific volumes of vapor, will require the maximum cylinder displacements.

The properties of the various refrigerants are here given as an aid to selection and design.

Classification of Refrigeration Systems.—The numerous systems of refrigeration may be classified according to several points of view as:

1. With respect to the refrigerant as:

   a. Ammonia;

   b. Ethyl chloride;

   c. Methyl chloride;

   d. Carbon dioxide (carbonic acid);

   e. Sulphur dioxide;

   f. Ether.

2. With respect to the working of the heat absorbing medium or cooling agent as:

   a. ***Compression*** {wet, dry}

   b. ***Absorption***

3. With respect to the manner of applying the refrigeration as:

a. Direct expansion;

b. So called indirect expansion or brine circulating;

c. Semi-indirect expansion or brine congealing;

d. Cold air;

e. Pipe line.

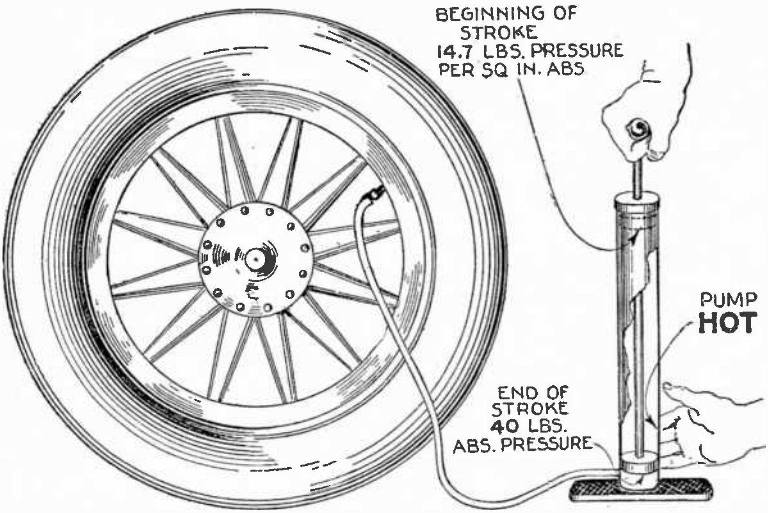


FIG. 8,648.—The heat of compression as illustrated by the familiar operation of pumping up an automobile tire.

4. With respect to service, as:

a. Commercial;

b. Domestic.

Compression System.—In this method *a compressor is used to subject the refrigerant to a pressure during a portion of the operating cycle.*

Briefly stated, mechanical refrigeration by a compression system is accomplished by the condensation of a gas or vapor under pressure and it's revaporization will take place at a lower pressure.

Under these conditions the revaporization will take place at a lower temperature than the condensation and heat will be extracted from surrounding objects.

The object of compressing the vapor of the refrigerant *is to* **raise** *its boiling point.*

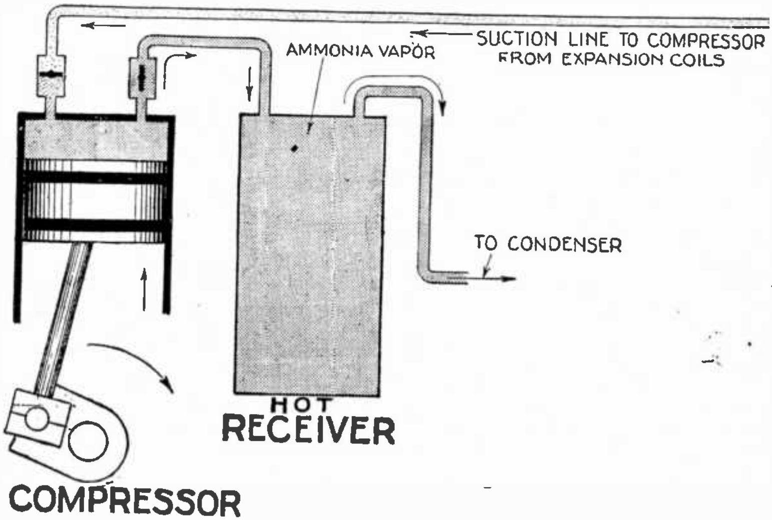


FIG. 8,649.—***How an ammonia compression system works. 1.*** The compressor pumps the ammonia vapor from the expansion coils into the *receiver* compressing it to about 150 lbs.

Similarly, the reason for expanding the refrigerant is *that when the pressure is* **reduced**, *the temperature of the boiling point is also lowered.*

The reduction of pressure on the refrigerant *causes it to vaporize.*

In order to do so it must be supplied with a certain amount of heat known as its *latent heat of vaporization* or simply latent heat. *This heat is absorbed from the surrounding substances or bodies*, thus producing the refrigerating effect.

The compression system cycle is briefly as follows:

1. Compression

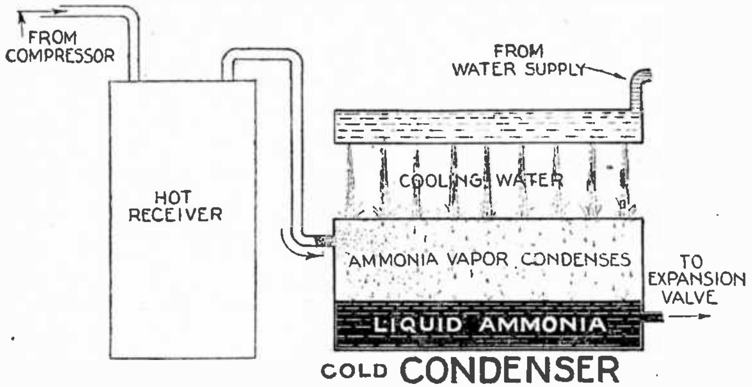


FIG. 8,650.—***How an ammonia compression system works, 2.*** The ammonia vapor compressed to 150 lbs. passes from the receiver to the condenser which being cooled by a continuous supply of cooling water causes the ammonia to condense, the liquid falling to the lower part of the condenser.

Refrigerant subjected to maximum pressure.

2. Condensation

Refrigerant cooled and liquefied under pressure.

3. Expansion

Pressure greatly reduced causing vaporization and absorption of heat producing the "refrigeration effect."

Ammonia Compression System.—In this system *anhydrous ammonia* (ammonia containing no water) *is used as the refrigerant.*

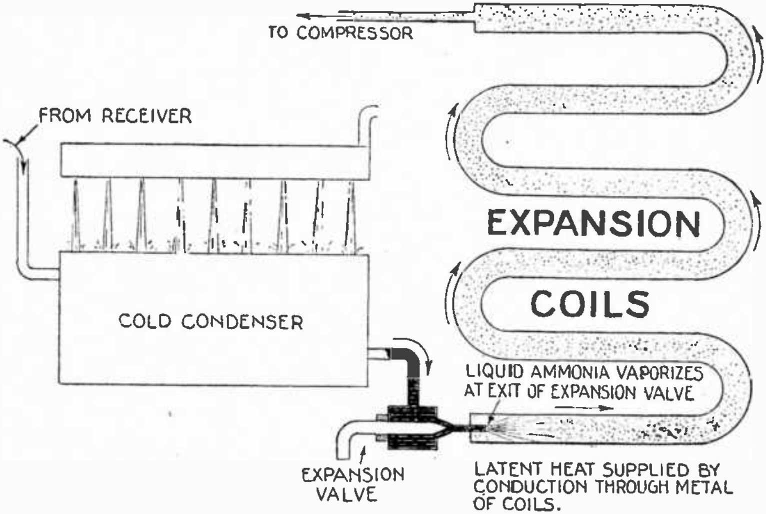


FIG. 8,651.—***How an ammonia compression system works, 3.*** Liquid ammonia at 150 lbs. pressure passes from the condenser through the very small outlet of the expansion valve into the expansion coils. The liquid ammonia thus injected into the expansion coils "flashes" into vapor because the pressure in the expansion coils is much less than in the condenser. During the change of state (liquid to gas) the temperature of the ammonia is greatly reduced thus giving the refrigerating effect. In passing through the expansion coils the vapor absorbs heat which it receives by *conduction* through the metal of the coils thus cooling the space surrounding the coils. Due to the operation of the compressor there is a continuous circulation of vapor through the expansion coils.

At atmospheric pressure and ordinary temperatures, anhydrous ammonia is a gas. Its adaptability to mechanical refrigeration is due to its high latent heat (heat absorbing quality) and also to the relatively low pressures required for liquefaction after having been evaporated and compressed.

Another factor favoring the use of anhydrous ammonia is its non-corrosive effect on ferrous metals.

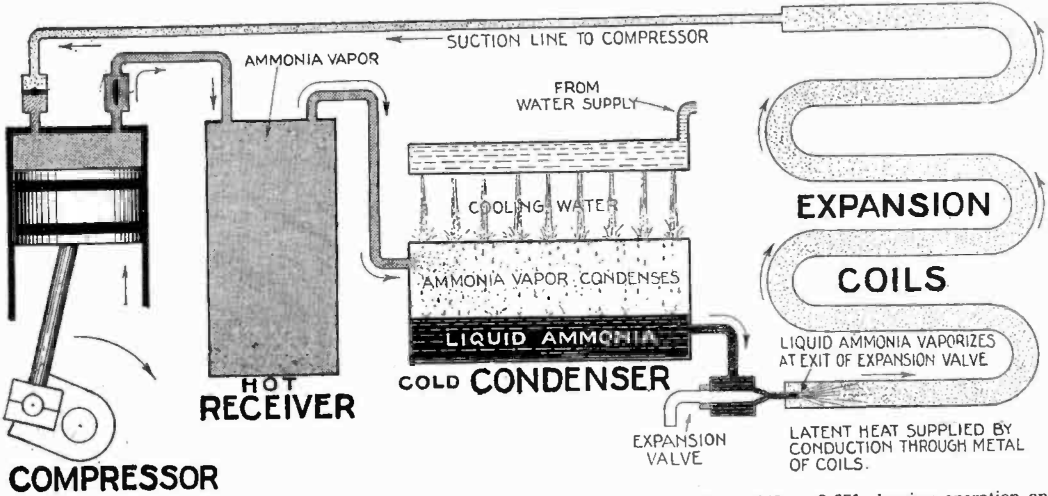


FIG. 8,652.—***How an ammonia compression system works, 5.*** Assembly of figs. 8,649 to 8,651 showing operation and connections of the various parts.

The refrigerating process takes place *while the ammonia is changing from a liquid to a gas.*

This is accomplished by allowing the ammonia, which has been compressed and liquefied, to pass through a special valve (known as the expansion valve) to the expansion piping.

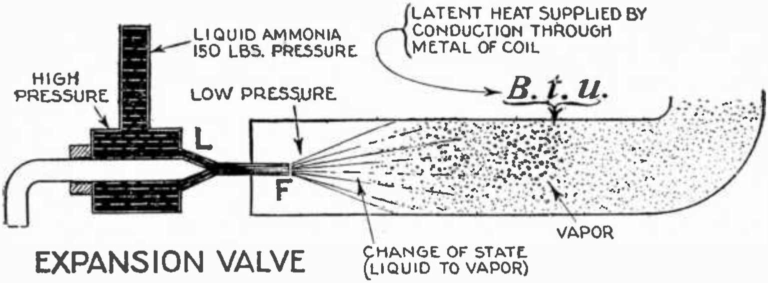
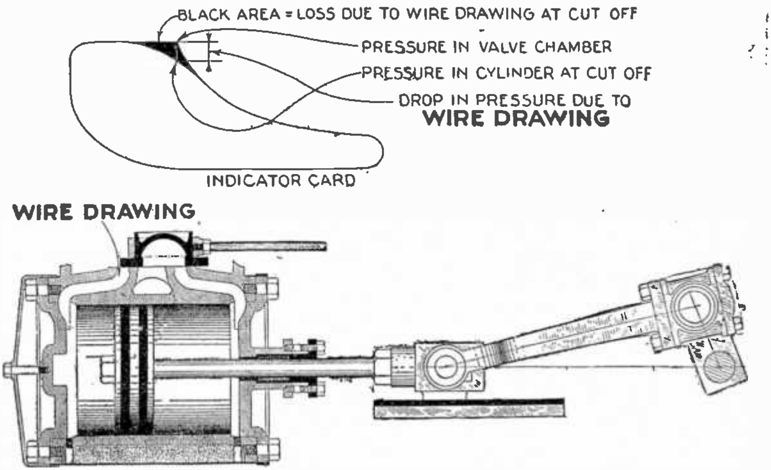
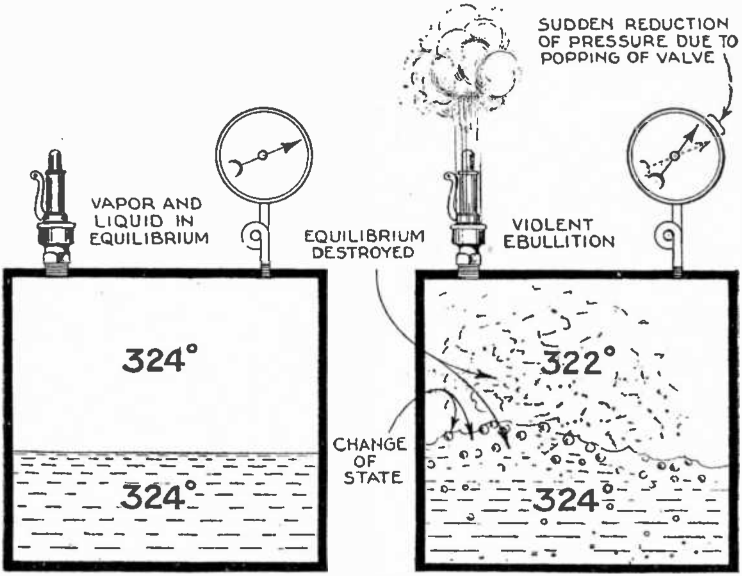


FIG. 8,653.—Effect of the expansion valve. *When the equilibrium between pressure and temperature of a liquid or gas is disturbed a change of state occurs, accompanied by a transfer of heat.* In the diagram, if the temperature and pressure at **L**, be such that the ammonia is in the liquid state a sudden reduction of pressure at **F** (exit of expansion valve) will cause a change of state, the liquid flashing into vapor, a considerable amount of heat being transferred to the ammonia to accomplish this change of state. The heat thus supplied being known as the *latent heat* of the ammonia.



FIGS. 8,654 and 8,655.—*Steam engine analogy* illustrating *effect of the expansion valve.* The familiar "D" slide valve has an inherent defect of traveling slowly at and near the point of cut off. The restricted passage thus presented "chokes" or "wire draws" the supply of steam to the cylinder thus causing the pressure to drop considerably below the pressure in the valve chamber as indicated in fig. 8,654. *Similarly,* the refrigeration system expansion valve wire draws or chokes the supply of ammonia (steam) from the receiver (valve chamber) to the expansion coil (cylinder) thus causing a drop of pressure as the ammonia (steam) enters the expansion coil (cylinder).

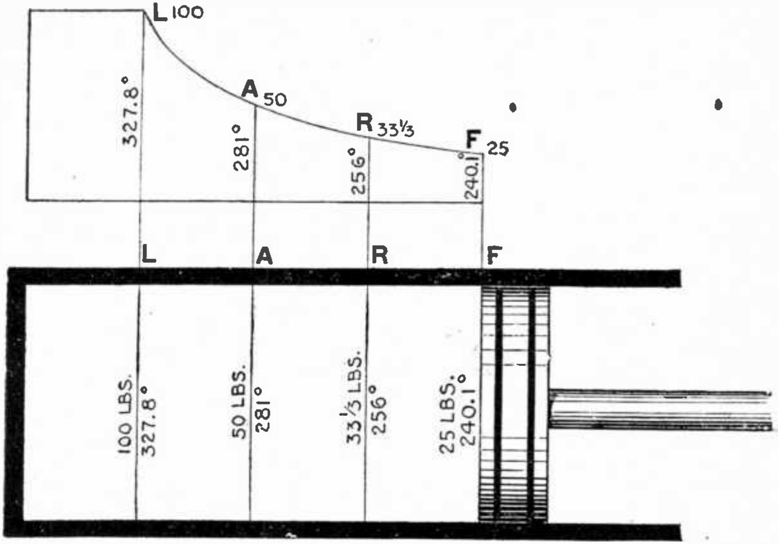
The vaporization and expansion of the gas takes place inside the cooling pipes or coils and the absorbed heat is extracted from the surrounding air or products to be cooled.



FIGS. 8,656 and 8,657.—Boiler analogy of expansion valve effect. When the conditions are as in fig. 8,656 the water and steam are in equilibrium and no change of state occurs. If more heat be supplied causing the safety valve to pop as in fig. 8,657, the pressure is reduced destroying the equilibrium of water and steam. Some of the water flashes into steam to restore equilibrium thus a *change of state* occurs which involves a transfer of heat in amount corresponding to the latent heat of evaporation. *Similarly,* when liquid ammonia passes through the expansion valve equilibrium of pressure and temperature of the liquid ammonia is destroyed and a change of state occurs (liquid to vapor) involving a transfer of heat by conduction through the metal of the expansion coil in amount corresponding to the latent heat of the ammonia.

The vaporized ammonia having absorbed its maximum amount of heat during its passage through the coils in the cold storage rooms, is drawn through a connecting pipe to the compressor. The function of the compressor is to circulate and apply pressure to the vaporized ammonia, compressing and pumping it through the condenser through which water is also circulated.

Here it is condensed and drains to a receiving tank, when it is again ready to repeat its cycle. As the ammonia passes through the water cooled condenser, the heat extracted from the cold storage room, and generated during compression, is absorbed by the circulating water which flows through the condenser tubes.



FIGS. 8,658 and 8,659.—Steam engine analogy illustrating *cooling due to expansion*. As the piston moves from the point of cut off **L**, to the point **F**, the pressure falls as the steam expands as indicated by the card (fig. 8,658). During the expansion (**L** to **F**) heat in the steam is converted into work by the piston, the temperature falling as shown in fig. 8,659, which results in cooling the cylinder walls. *Similarly*, in the dense air type refrigerating machine the "expander" is similar to the familiar cut off steam engine. The expansion of the air lowers its temperature and cools the refrigerating pipes in the same way that expanded steam cools the cylinder walls.

The extraction of heat in the cold storage room may be accomplished either by

1. Direct expansion method.
2. Brine circulation method.

In the direct expansion method the coils, in which the expansion of the refrigerant takes place, are placed in the room with the materials to be cooled as shown in fig. 8,660

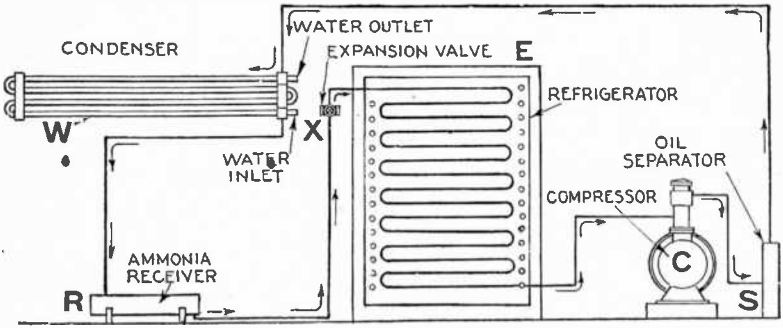


FIG. 8,660—*Ammonia compression system;* 1, *direct expansion method. In operation*, liquid ammonia stored in receiver **R**, passes through expansion valve **X**, into coils or piping located in the refrigerator **E**, to be cooled. After expanding, it returns to the compressor **C**, where it is compressed and pumped through the oil separator **S**, to the condenser **W**, where, by water circulation, the ammonia is condensed and drains in liquid form to receiver **R**.

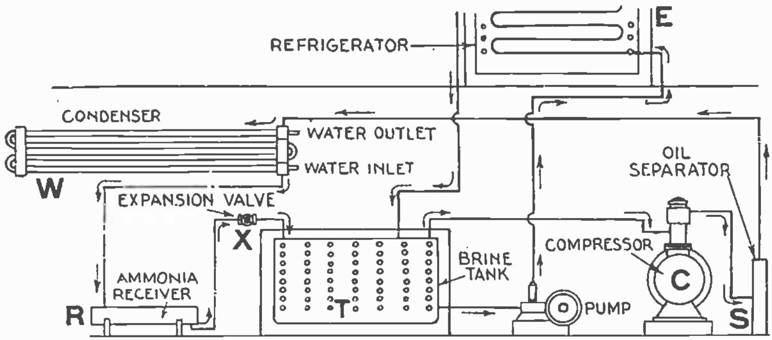


FIG. 8,661.—*Ammonia compression system;* 2, *brine circulating method. In operation*, ammonia is expanded through piping submerged in a brine tank, or through a special cooler or evaporator. The brine, after being reduced to a low temperature, is pumped through piping placed in the compartments to be chilled. **C**, compressor; **E**, refrigerator; **R**, receiver; **S**, oil separator; **T**, brine tank; **W**, condenser; **X**, expansion valve.

In the brine circulation method, the brine temperature is reduced by ammonia expansion coils placed in a tank filled with brine, or, where very low temperatures are essential, a device known commercially as a "brine cooler" is employed. This method is shown in fig. 8,661.

In the direct expansion method *the refrigerant absorbs heat direct from the materials to be cooled.*

The principal advantages of the direct expansion method generally employed in small units are simplicity, economy, ease of operation and compactness.

The motive power and compression side, which includes the compressor, condenser, ammonia receiver and oil interceptor, all placed outside of the cooling chamber may be located in a comparatively small space.

The direct expansion method is adapted to either intermittent or continuous operation.

Where operation by day only is desired, brine storage or congealing tanks are installed to maintain low temperatures in the refrigerators when the compressor is not operating.

Part of the expansion piping is placed in the tanks, which are then filled with a solution of brine, made either from calcium chloride or common salt.

A brine solution is employed because during the day it may be frozen to a semi-solid condition. When the compressor is not in operation, the salt in the solution causes the ice to melt at a low temperature, and absorbs the heat which enters through the refrigerator walls.

In rooms where it is necessary to place the coils and tanks on the side walls, the tanks are flat; center flue tanks are used in rooms where the cooling chamber is overhead. These center flue tanks are built in various sizes and are designed to give the maximum amount of cooling surface without having a great mass of inefficient or inactive brine.

In the brine system, *the refrigerant absorbs the heat that the brine absorbs from the materials to be cooled.*

This is an indirect system and obviously it is not necessary for the expansion coils to be in the cold storage room.

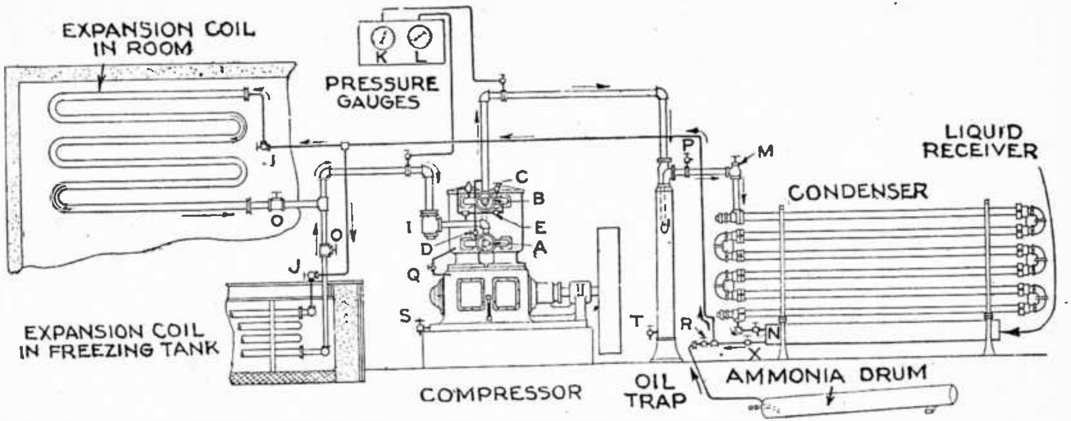


FIG. 8,662.—***Ammonia compression refrigeration plant*** employing both *direct expansion* and *brine circulation* methods. ***In operation,*** liquid ammonia in the ammonia receiver is permitted to escape through a very small opening (expansion valve) into coils located in the space to be cooled. As the ammonia escapes, its pressure is reduced and its boiling point lowered. It expands and vaporizes, absorbing heat from the metal which in turn absorbs heat from the air, water, milk, brine or whatever substance surrounds the coil. Thus refrigeration is produced. Having expanded in the coils and produced refrigeration, the ammonia gas must be removed either by allowing it to escape to the atmosphere, or by converting it again into a liquid. As ammonia is rather expensive, the latter course is followed, hence the need for the compressor. The compressor is essentially a pump which draws ammonia gas from the expansion coils, compresses it and delivers high pressure gas to the ammonia condensing coils. Here cool water passing over the coil takes up the excess heat and the ammonia again becomes a liquid and passes to the receiver ready for use again. The working cycle consists of: 1, compression; 2, condensation; 3, expansion. In expansion, the ammonia takes up heat; in condensing, heat is taken from it. The system is roughly divided into two parts, the high pressure side consisting of compressor, oil trap, condenser and liquid receiver, being more or less standardized, while the low pressure side comprises the expansion coils, brine cooler, etc., and is designed and proportioned for the particular plant where installed.

NOTE.—***The parts are*** (in fig. 8,662): **A**, suction stop valve; **B**, discharge stop valve; **C**, blow off valve (relief valve); **D**, high pressure by pass; **E**, low pressure by pass; **I**, suction strainer (scale trap), **J**, expansion valve; **K**, high pressure gauge; **L**, low pressure gauge; **M**, condenser valve; **N**, receiver inlet valve; **O**, room valves; **P**, air valve; **Q**, crank case pump-out valve; **R**, charging valve; **S**, oil drain valve; **T**, drain valve; **X**, king valve.

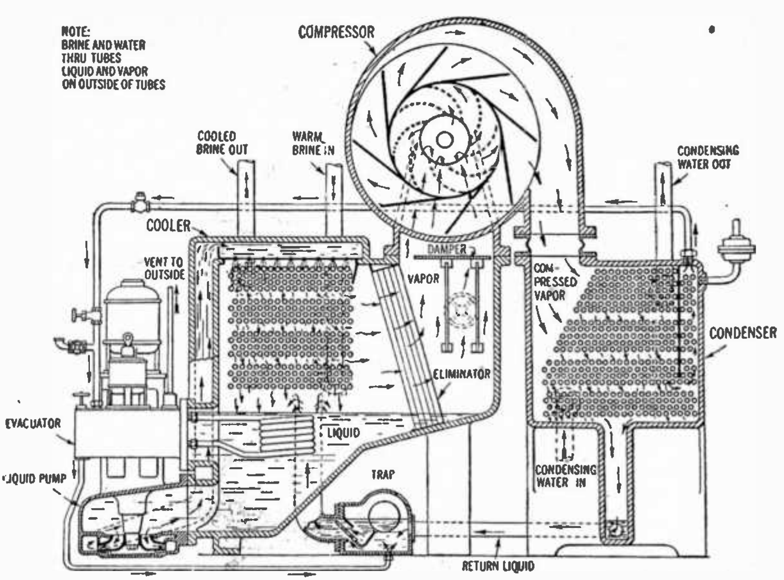


FIG. 8,663.—Carrier compression type refrigerating machine with centrifugal compressor. The cycle is as follows: Starting with the liquid in the base of the evaporator or cooler, through the tubes of which is flowing the water or brine it is desired to cool. The minus pressure in the cooler is maintained, by the centrifugal compressor, at, say 26 ins. of mercury vacuum (−12.77 lbs., per sq. in gauge). As the arrows indicate, the centrifugal liquid pump, enclosed within the base of the cooler, lifts the liquid to the space above the tubes from which, through a distributer plate, it falls over the tubes. At the low pressure (*i. e.*, high vacuum) the liquid boils or evaporates rapidly, as in a flash boiler, quickly absorbing its latent heat of evaporation from the brine or water flowing through the tubes, thus performing the objective cooling thereof. Then the resulting vapor passes through the stationary eliminator plates, which remove any entrained liquid, enters the centrifugal compressor wherein the pressure is increased (or, so to put it, the minus pressure is reduced) to, say 5 ins. of mercury vacuum (−2.46 lbs., per sq. in. gauge), a difference between the evaporating and condensing pressures of but 21 ins. of mercury (10.3 lbs., per sq. in., gauge), although the condenser pressure is still minus, that is, below atmospheric. At its relatively higher pressure, corresponding to the 5 ins. of mercury vacuum, the vapor enters the condenser and circulates about the tubes through which the condenser cooling water flows, as indicated. In the condenser the vapor, negligibly heated by its very slight compression, gives up to the cooling water this small quantity of compression heat and also its latent heat of liquefaction. Thus the vapor becomes a liquid again, falls into the space beneath the condenser and from there it passes through an ordinary float trap back into the cooler, thus completing the very simple cycle. The trap serves merely to avoid short circuiting in case the liquid level in the condenser should fall below that required to seal the return riser. Note that there is no *expansion valve*. The control is automatic.

Where the plant is designed for operation by day only, the brine tank is made large enough to afford ample storage of cold brine. When the compressor is shut down, the compartment temperature is maintained by continuing the circulation of brine with the pump. The brine circulating method is recommended for large installations or where the various compartments to be cooled are widely scattered.

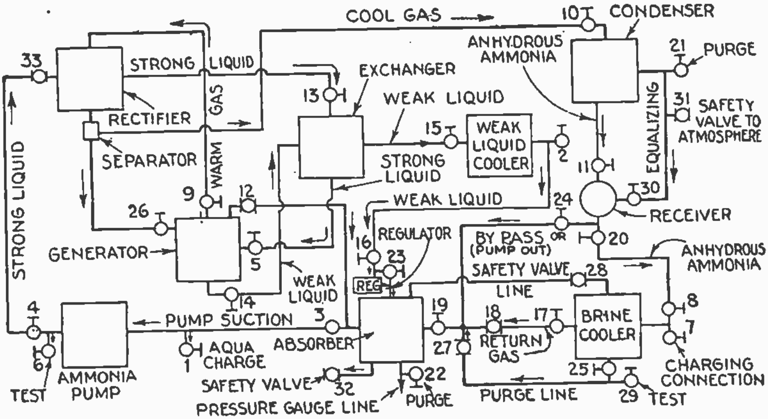


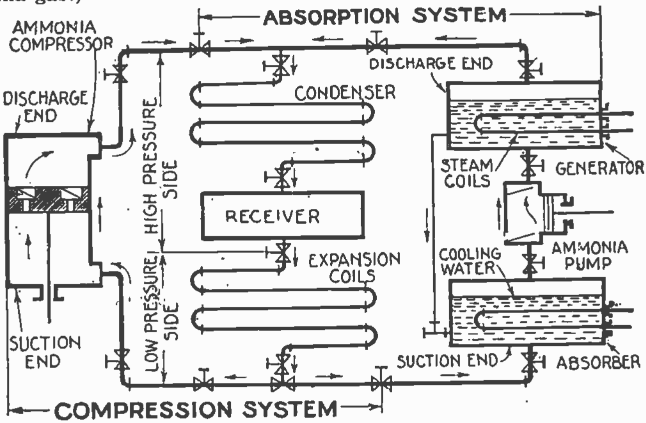
FIG. 8,664.—Piping diagram of the absorption system showing the flow of liquids and gases. *The valves are:* 1, aqua charge; 2, weak liquid drain; 3, pump suction; 4, pump discharge; 5, strong liquid to generator; 6, sample valve; 7, charging valve; 8, expansion valve; 9, gas from generator; 10, gas to condenser; 11, liquid to receiver; 12, safety valve from generator; 13, strong liquid to exchanger; 14, weak liquid from generator; 15, weak liquid to weak liquid cooler; 16, weak liquid to regulator; 17, return gas on brine cooler; 18, check valve return gas line; 19, return gas to absorber; 20, liquid stop valve; 21, purge from condenser; 22, purge from absorber (in pressure gauge line); 23, weak liquid by-pass around regulator; 24, by-pass of condenser pump out; 25, purge valve from brine cooler; 26, drain from separator; 27, check valve in purge line; 28, safety valve from brine cooler; 29, drain or test valve from brine cooler; 30, equalizing line condenser and receiver; 31, safety valve on receiver; 32, safety valve on absorber; 33, check valve in pump discharge line.

A combination of the two methods in one plant is shown in fig. 8,662, and the accompanying description, although it contains some repetition of principles will be found helpful.

The diagram shows the simplest form of compression plant. The same elements are used in every plant regardless of size or capacity.

Ammonia Absorption System.—The principle of the absorption system may be stated as *the alternate repulsion and absorption of ammonia gas by the alternate heating and cooling of ammonia water.*

A system working on this principle takes advantage of the property of water or a weak ammoniacal liquor (called the "weak liquor") to dissolve ammonia gas. (At 59° Fahr. water absorbs 727 times its volume of ammonia gas.)



Figs. 8,665.—Elementary combined compression and absorption machines showing that each system has in common a condenser, receiver and expansion coils.

A commercial absorption machine consists essentially of six parts three of which are present in the compression machine as will be seen from the following.—

Compression Machine	Absorption Machine
1. Compressor	1. Absorber
	2. Ammonia pump
	3. Generator
2. *Condenser*	4. *Condenser*
3. *Receiver*	5. *Receiver*
4. *Expansion coils*	6. *Expansion coils*

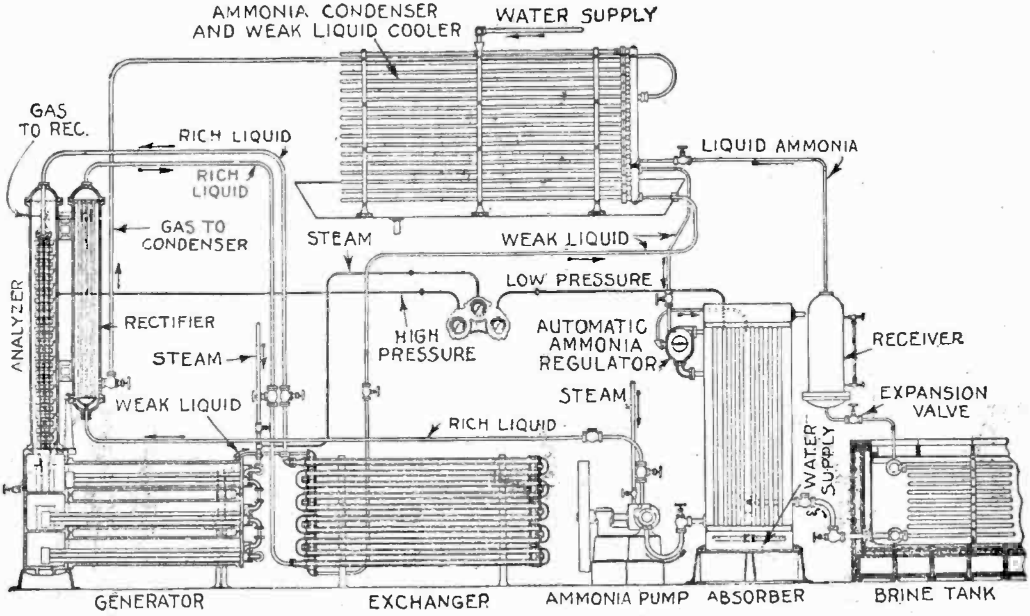


FIG. 8,666.—Large absorption plant. ***In this system*** the rich liquor is circulated through the rectifier before passing through the exchanger, thus some of the heat which would otherwise be carried off in the condensing water is saved.

It is seen from the two lists that the condenser, receiver and expansion coils are common to both systems. This is further shown in fig. 8,665. The figure further shows that the compressor is replaced by an absorber, ammonia pump and a generator.

In the absorption system the gas, returning from the expansion coils, enters the absorber (corresponding to the suction end of the compressor). is transferred to the generator (corresponding to the discharge end of the compressor) by a pump, through the valves of which it passes just as it flows through the valves of the compression piston.

In the absorption plant the ammonia (liquor) pump can be made much smaller than the compressor gas pump used in the compression system, because the actual work of compressing the ammonia gas to the point at which it can be liquefied by the cooling water in the condenser is performed by the direct heat of steam rather than by the heat generated by the expenditure of energy behind the compressor piston.

Briefly the operation of the absorption system is as follows:

The cooling agent (ammonia water mixed in proportions of about one and two respectively), is placed in the *generator*, where it is heated by steam coils containing low pressure steam, usually the exhaust from the circulating pump, and due to this heat, ammonia gas under pressure is liberated from the water and passes on to the condenser where it is cooled and liquefied.

The liquid ammonia then passes into the receiver and thence to the expansion coils, where it vaporizes and absorbs heat from the surrounding substances thus providing the refrigerating effect, and the warm gas from these flows into an absorber, a tank containing the weak ammonia water (called the "weak liquor"), that is, that which has previously given up its gas in the generator.

In the absorber are coils containing cold water, and the ammonia vapor coming from the expansion coils is absorbed by this weak liquor, and the heat given up by the gas in the absorption process is carried off in the cooling water.

The strong liquor or strong aqua ammonia resulting from the absorption of the ammonia gas is pumped into the generator where it is again driven out of solution by the heating coils, thus completing the cycle.

The elements necessary for performing this cycle are shown in fig. 8,667.

In modern practice various refinements (additional parts) are introduced and the description of the operation of the Carbondale ice machine accompanying the chart, fig. 8,676 will

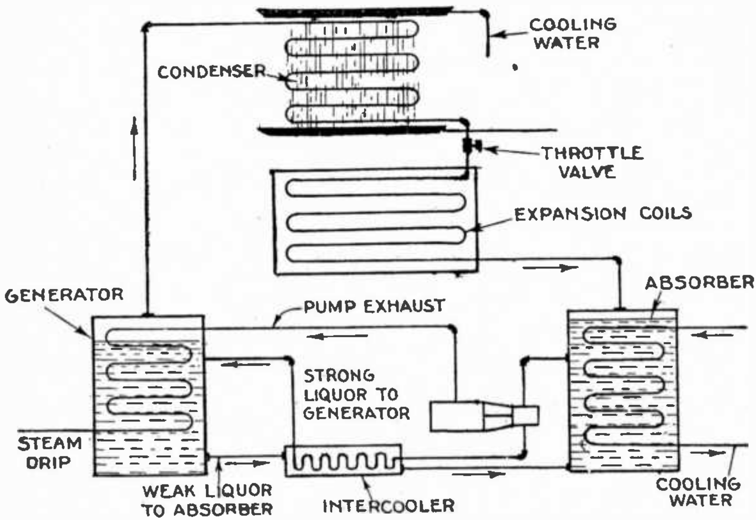


FIG. 8,667.—Elementary *ammonia absorption system; direct expansion cooling.* The essential parts are: 1, generator; 2, condenser; 3, expansion coils; 4, absorber; 5, pump; 6, exchanger. As compared with the compression system the absorber takes the place of the compressor. *Cycle of operation:* 1, the strong liquor vaporizes in generator; 2, ammonia gas produced in generator passes to condenser and condenses; 3, liquid ammonia from condenser passes through expansion valve and vaporizes in the expansion coils which produces the cold or refrigerating effect; 4, ammonia gas from expansion coils is absorbed by the weak liquor in the absorber, producing strong liquor; 5, the strong liquor is pumped from the absorber to generator via the exchanger, where the hot weak liquor passing from generator to absorber gives up some of its heat to the strong liquor, thus completing the cycle.

give a good idea of how the absorption cycle is effectively carried out.

Carbondale absorption refrigerating machines are made in various types. The "Atmospheric" and "Double Pipe" types are shown in figs. 8.668 and

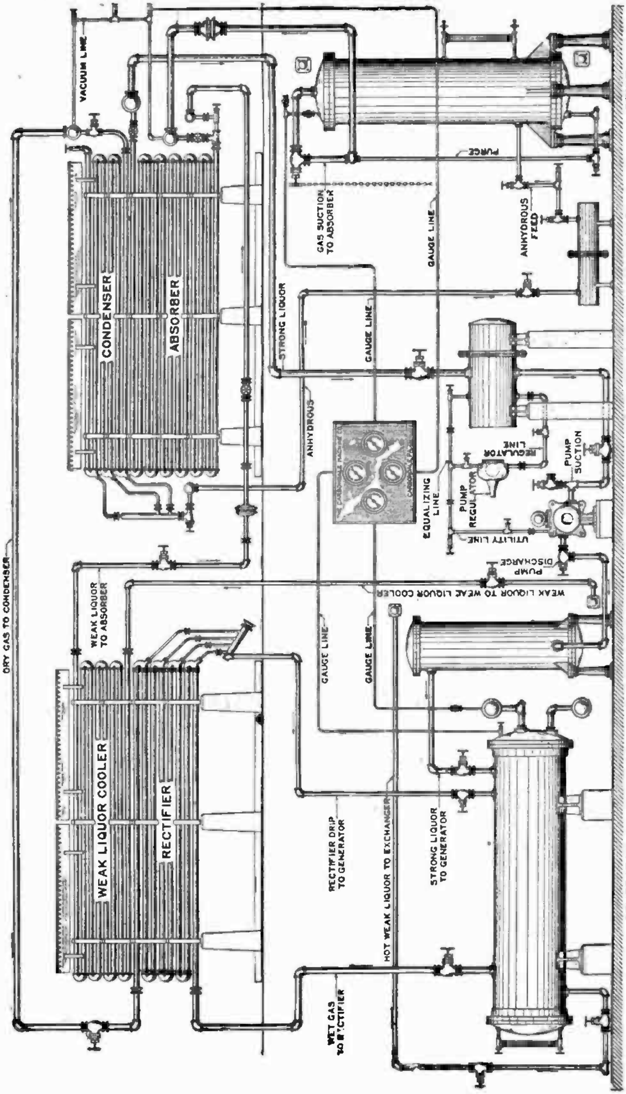


Fig. 8,668.—Carbondale atmospheric type absorption refrigeration machine.

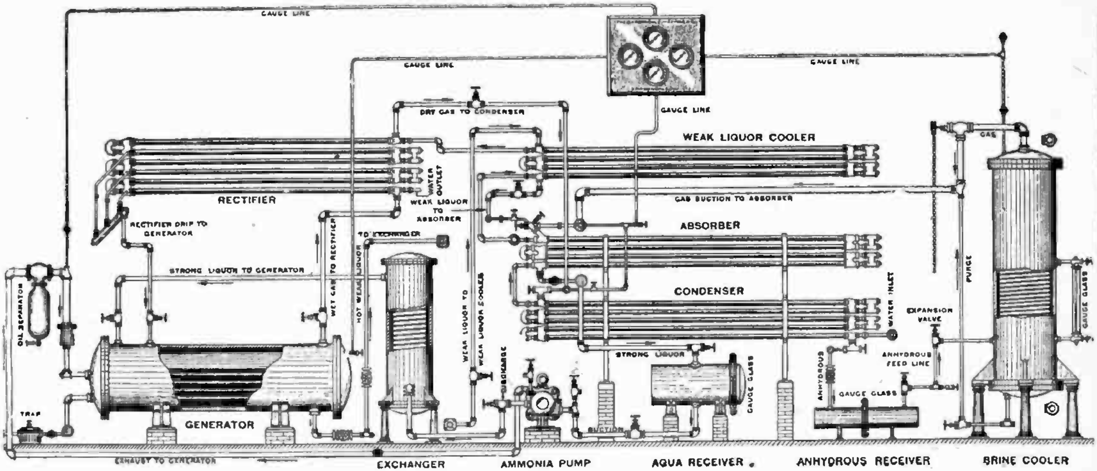


FIG. 8,669.—Carbondale double pipe type absorption refrigeration machine.

8,669. The difference lies merely in construction details of the various component parts.

In the absorption system the exchanger acts much as a feed water heater in a steam boiler plant. In it hot weak liquor from the generator heats the cool strong liquor from the absorber, before it enters the generator.

The cooling water enters the condenser, passes through it and goes to the absorber. After leaving the absorber, it divides, a portion of the water entering the rectifier and the rest going to the weak liquor cooler. In this way the water is used four times, each at a somewhat higher temperature than the preceding. A great saving in water results.

Choice between the types of absorption machines must be governed by space and the characteristics of cooling water available.

Where the cooling water is warm or muddy, the atmospheric type is recommended. In this machine the exchanger is either the double pipe or shell type.

Where it is necessary to use sea water or water that is at all corrosive, extra heavy galvanized pipe in the rectifier, weak liquor cooler, condenser and absorber should be used. However, if the water be non-corrosive, but of high temperature, full weight pipe will be satisfactory and, if properly painted, will last for years.

Carbon Dioxide System.—The chemical carbon dioxide, variously called carbonic-anhydride, carbonic acid gas or simply CO_2, and used as the refrigerant in this system, is made up of molecules containing one atom of carbon and two atoms of oxygen and has the chemical symbol CO_2.

The boiling point of water being far above the atmospheric temperature, heat must be applied to bring it to the boiling temperature. The boiling point of liquid carbonic anhydride being much lower than the temperature of the atmosphere, it absorbs from its surroundings the necessary heat to cause it to boil or evaporate.

Carbonic anhydride is supplied in steel cylinders and can be procured almost anywhere at a cost of a few cents per lb.

Ether System.—This method of refrigeration has never come into extensive use owing to the relatively large compressor necessary, but more especially to the inflammability of ether and its great liability to explosion.

The great advantage of ether is that it requires only a low pressure in the condenser, which is of no little importance in warm climates. The low pressure is also favorable for the maintenance of tight joints, and the simplicity of the working parts.

The compressor required is very much larger than in an ammonia machine of like capacity, and its generally massive construction, and larger consumption of coal and water, added to the great fire risk, have seriously handicapped the ether machine for ordinary commercial use.

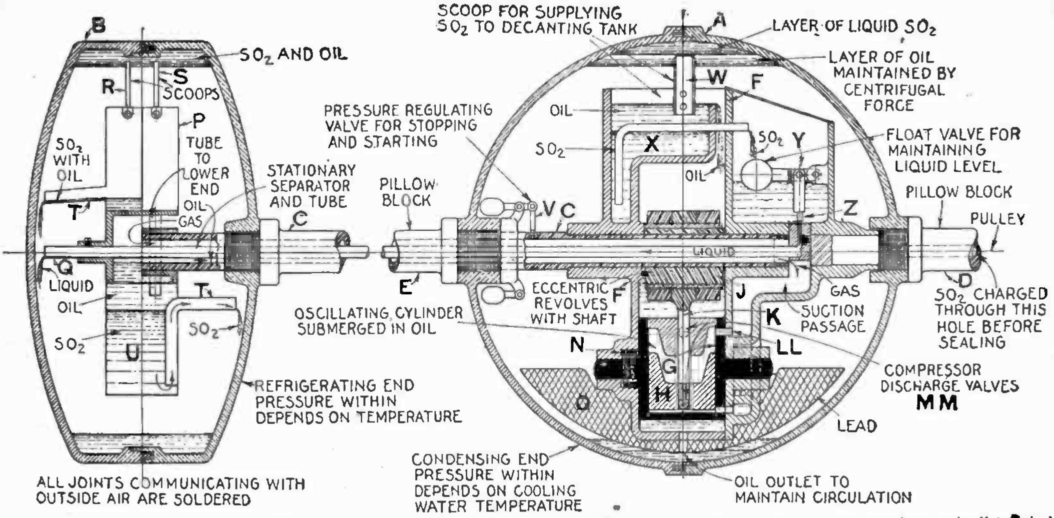


FIG. 8,670.—Sectional view of Audiffren ice machine showing mechanism. ***In construction,*** bells A and B, are hermetically sealed at all seams. Machine is charged at factory, after evacuation of air, with SO_2 and pure mineral oil. ***In operation,*** bells A and B, revolve with hollow shafts DE and C. Carrier F, is held stationary by counter-weight O, the shaft revolving within it. Carrier supports two oscillating compressors G. Compressors are double acting and driven by eccentric F. Vapor is drawn by motion of piston H, through hollow shaft and port LL, into cylinder. Return stroke compresses vapor, expelling it through spring valves MM, into the surrounding space. Vapor condenses upon walls of A, and collects with surplus oil at rim. Scoop W, carries mixture to decanting box X, oil overflows over bearing surfaces, and liquid SO_2 is delivered to reservoir Y. Expansion valve admits liquid to central tube Q, which is stationary with carrier F. Liquid is delivered to interior of evaporator B, and expands again to vapor under suction of the compressors. Spent gas returns through hollow shaft. Separator U and P, collects surplus oil carried over with liquid SO_2 and returns it in the stream of spent gas, to the condenser end. There is no chemical action, and no deterioration of the gas or oil. When machine is stationary, pressure in both bells is equalized through valve V, which closes by centrifugal force, isolating the condenser from the evaporator when running. Power required to compress the gas is derived through the shaft and eccentric. Torque created is resisted by weight of carrier assembly and counterweight, which rises about 15° from vertical. Variation in condenser pressure (and temperature) and variation of evaporator

Compressed Air System.—In this system air is compressed to a pressure of ten to fifteen atmospheres, and its temperature raised from 75° to 500 or 600°.

This heat is conducted off by the compressed air being held in a coil surrounded by water, or in long pipes passing through the atmosphere as when used for rock drilling machinery. The heat may be reduced by conduction to 75°, but the pressure is still, say, fifteen atmospheres. If this should be allowed to escape into the atmosphere a temperature of zero to 10° Fahr. would be produced, part of the low temperature being due to the energy required to force itself into the air again against an atmospheric pressure of 14.7 lbs. per sq. in.

The basic principle is that: *When a gas is allowed to expand while doing work, the amount of heat given out by the gas is equal in mechanical energy to the work done.*

The main objections to air machines are: The large space required, the high cost, comparatively, of operation, and the amount of moisture in the air which interferes not only with the working of the machinery but also in the form of ice or snow deposited over goods, otherwise the safety of the refrigerant is greatly in its favor.

Water System.—Several machines have been developed, using water as the refrigerant.

The boiling point of water depends on the pressure. Although it requires a temperature of 212° Fahr. to boil water at atmospheric pressure, water will boil at 32° under a 29.74 in. vacuum; at 40° for 29.67 in. vacuum, etc.

Sulphuric acid is used to absorb the water in some systems of this kind. A pump must be used to remove the air. Small hand made machines are made in Europe to operate on this system. They will cool a carafe of water in a few minutes, or make a few pounds of ice in less than half an hour.

It is difficult, however, to produce a commercial pump to obtain such a high vacuum. The air in the water must also be discharged.

FIG. 8,670 —*Text continued.*

pressure (and temperature) directly affect torque required. If either brine temperature or condenser temperature become excessive counter-weight will revolve and automatically prevent building up of dangerous pressures.

Mechanical Ice Making.—The term "mechanical ice making" as here used relates to the apparatus and methods employed in freezing ice into cakes for distribution by ice wagons. There are two methods known as

1. The can method;
2. The plate method,

the former being the more extensively used.

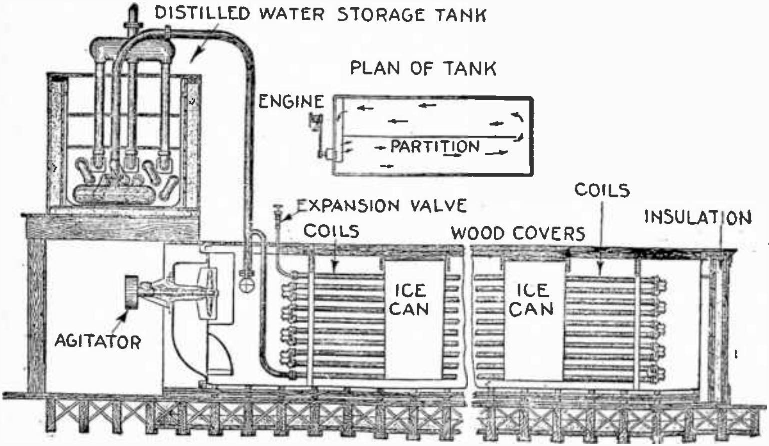
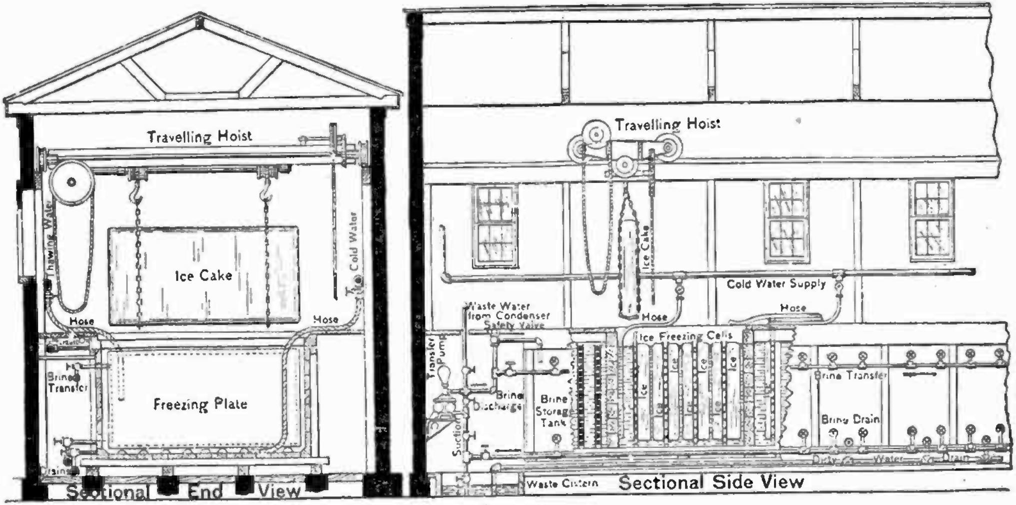


FIG. 8,671.—Detail of freezing tank of an Eclipse ice plant, showing the arrangement of the cans with covers, also the brine agitator. The agitator is in the shape of a propeller which keeps up a continuous circulation of brine between bottom and top of tank.

Ques. Describe the can method.

Ans. Galvanized cans or moulds are filled with water, after they have been suspended the proper depth in a tank of brine the brine being cooled by a direct expansion system in the freezing tank, as shown in fig. 8,671.



FIGS. 8,672 and 8,673.—Sectional views of plate ice plant showing freezing plates and cells. The ice plates are hoisted by means of the traveling hoist after being thawed off the freezing plates by passing hot brine through the coils. The freezing plates with their coils are shown in fig. 8,673 in heavy black lines with the ice forming on both sides of them.

The time required for freezing varies from 40 to 60 hours, depending on the thickness of the cakes. The longer the time a given thickness is allowed to freeze the better the quality.

In removing the cakes from the cans, the cans are drawn out of the brine and sprayed with, or dipped into, warm water which loosens the ice so that when the can is inclined on its side the cake of ice slides out, the can being make tapering in shape so as to facilitate the movement.

In domestic refrigeration the can method is used on a miniature scale in freezing *ice cubes* with the exception that the tray which corresponds to the can is not placed in brine, but is surrounded by a cooling coil.

Ques. Describe the plate method.

Ans. Several vertical hollow iron walls are built in a large tank. The tank is filled with pure well water so that the iron walls are entirely submerged. The hollow iron walls are placed parallel with each other at a distance of from two to three feet. The freezing fluid, consisting either of cold brine or ammonia, is passed through the hollow walls, with the result that the water will freeze on the outside of the walls; the water is kept in agitation either by means of a propeller or pump, or by compressed air, so that the water is kept continually on the move; carrying the air with it prevents it being frozen in the ice. After the ice is frozen on the walls to the required thickness the freezing fluid is shut off from the walls and a warm fluid passed through instead until the ice is loosened and taken out of the tank.

This method is shown in figs. 8,672 and 8,673.

TEST QUESTIONS

1. *What is the basic principle of refrigeration?*
2. *Give definitions for: 1, heat; 2, temperature; 3, sensible heat; 4, latent heat.*
3. *How does the transfer of heat take place?*
4. *What are the three states of matter?*
5. *How is a change of state accomplished?*
6. *Give steam engine analogy of change of state.*
7. *What is the latent heat of evaporation?*
8. *Upon what does the boiling point depend?*
9. *How is heat carried away in vaporizing?*
10. *Describe an experiment illustrating condensation.*
11. *What is a refrigerant?*
12. *Name the various refrigerants used.*
13. *Give the properties of the various refrigerants.*
14. *Give a classification of refrigeration systems.*
15. *Describe the compression system.*
16. *What refrigerant is generally used with the compression system?*
17. *What is an expansion valve?*
18. *Give steam engine analogy of the effect due to expansion valve.*
19. *What is the difference between the direct expansion and the brine circulation methods?*

escribe in full detail the ammonia absorption system.

21. *Describe the: 1, carbon dioxide; 2, ether; 3, compressed air; 4, water systems.*

22. *Describe the can method.*

23. *How is ice made by the plate method?*

CHAPTER 222

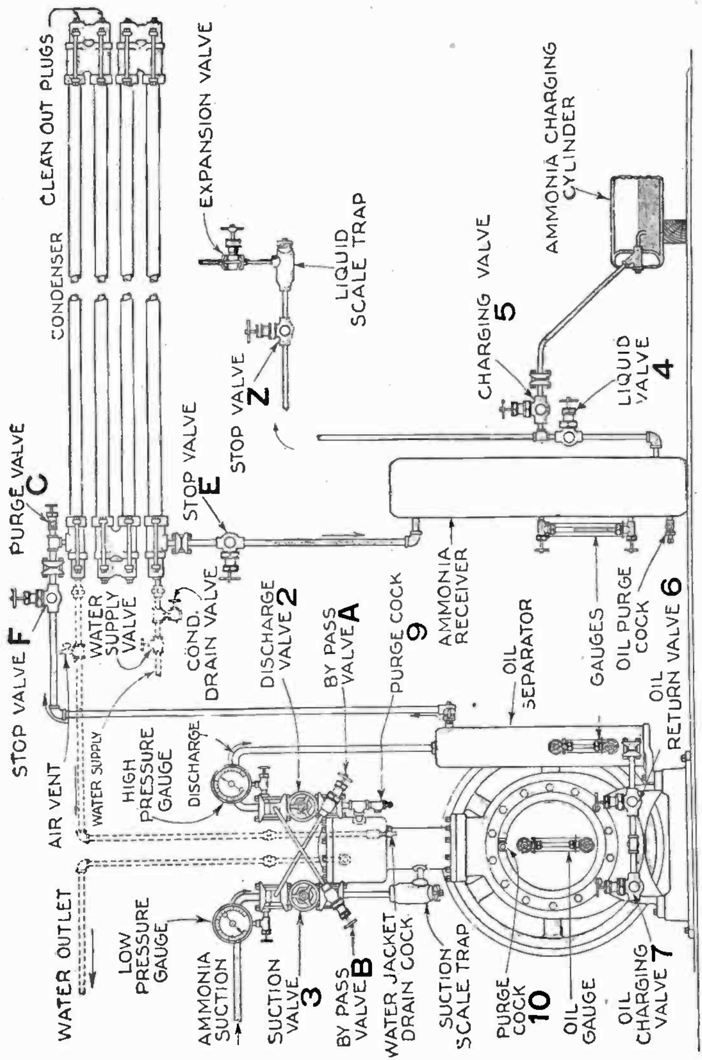
Refrigeration Machine Operation

The following instructions for the operation and maintenance of refrigeration plants, will be found helpful to the practical man who intends to be put in charge. Directions are given in this chapter for the operation of plants of both the compression and the absorption types.

Small Compression Machine Operation.—To illustrate the running of a small refrigeration plant of the *compression* type, directions are here given for operating the Brunswick refrigerating machine, as shown in figs. 8,674 and 8,675.

To start machine.—1, Open water supply valve. *Be sure water is running.* 2, open wide by-pass valve A; 3, turn fly wheel back to compression point (opposite to operating direction); 4, turn on power; 5, open discharge valve No. 2; 6, close by-pass valve A. (Never close by-pass valve A, until discharge valve No. 2 is open); 7, open suction valve No. 3 (Suction valve No. 3 should be open only one quarter turn and system pumped down until suction or low pressure gauge registers 25 lbs. pressure, then slowly open wide and run machine until low pressure gauge registers 10 lbs. pressure; 8, open liquid valve No. 4; 9, regulate expansion valve until low pressure gauge registers proper pressure.

To stop machine.—1, close liquid valve No. 4. (After liquid valve No. 4 is closed, keep machine running until low pressure gauge registers between zero and 5 lbs.); 2, close suction valve No. 3; 3, turn off power; 4, close discharge valve No. 2. (Never close discharge valve No. 2 until machine is stopped); 5, close water supply valve.



FIGS. 8,674 and 8,675.—Brunswick compressor type refrigeration machine. Its operation is explained in the accompanying text.

Expansion valve.—This valve controls the *suction* or as it is called low pressure. Suction pressure gauge *should never register above* 30 *lbs. or below zero* when compressor is running. Expansion valve being very sensitive, care should be taken in regulating it.

It is impossible to designate the exact suction pressure at which each plant should be operated, since it depends on the actual work to be done by the machine. The best rule to follow however, is to operate with *suction pressure as low as possible, still frosting through all the pipes*, since the lower the suction pressure, the colder is the ammonia gas and therefore a lower temperature is obtainable.

If frost come back to cylinder on compressor to the extent that discharge pipe gets cold, there is too much ammonia going through expansion valves, which should be slightly closed. The best results are usually obtained in the following way: after machine is started, open expansion valve a little more than usual until frost comes back to suction scale trap; then close slightly, operating at usual working suction pressure.

Water.—*There cannot be too much water used.* This however does not mean that water should be wasted. The *high* or *condensing* pressure is controlled *not only by the amount of condensing water* that is used, *but also by the temperature of it*. Therefore, if condensing water be cool, it is not necessary to use as much as when water is warm.

The average condensing pressure (high pressure gauge) with water say 65° Fahr. to 75° Fahr. should be 160 lbs. to 180 lbs. As the temperature of the water rises, the condensing pressure increases, but should not exceed 200 lbs. unless water is exceptionally warm.

With plenty of cool water, the condensing pressure may be lowered to 150 or even 125 lbs. with correspondingly lower power consumption and increased refrigerating effect, but there is little economy in carrying condensing pressure much below 150 lbs. since the gain in refrigerating effect and power saved by the compressor is offset by increased water consumption.

Condenser.—*In cold weather when machine is not running all water should be drained out of condenser and also water jacket on compressor, to prevent freezing. When draining condenser be sure that air vent at top of water piping is open.* Keep water tubes of condenser clean and free from sediment.

Unusually high pressure indicates the presence of air or foreign gas which may be drawn off through purge valve C, on condenser as follows: attach pipe to purge valve C, and submerge end in pail of water. Slightly open purge valve C. Allow air to escape through water. When foul gas is purged out and ammonia appears causing a cracking noise, immediately close purge valve C.

Never purge condenser unless machine has been stopped several hours.

Dirty water tubes in condenser.—These should be cleaned once a season or oftener if necessary. To do this, remove bends and scrape tubes with tube cleaner after which tubes should be thoroughly washed out and bends replaced.

Oil.—*Oil gauge on compressor case should show about quarter full when compressor is shut down. If oil level be too high, an excessive quantity of oil may be carried over into the oil separator.* When the oil level gauge on the separator shows a considerable quantity of oil in the separator it should be blown back into the case of the compressor as follows: First open gauge cocks on oil separator and compressor case, then slightly open oil return valve No. 6, on bottom of compressor case, watching fall of oil in gauge glass on separator.

When oil disappears from gauge glass on separator, close oil return valve No. 6 tight, at once. If valve No. 6 be not closed tight immediately after oil disappears from separator gauge, ammonia will pass through return pipe, causing excessive pressure in compressor case.

Never blow back oil except when machine is running.

To recharge with oil.—*Compressor case should be supplied with new oil about once in six months.* This may be done as follows: Close liquid valve No. 4 and run compressor until low pressure gauge shows 5 ins. vacuum, then close suction valve No. 3, and stop compressor. Next close discharge valve No. 2, and then open slowly purge cock No. 9 and purge cock No. 10. Draw old oil out of compressor case through oil charging valve No. 7. When old oil is drawn out, connect piece of ½ in. pipe, with funnel attached to valve No. 7 and pour in new oil until gauge glass is quarter full. Close valve No. 7, and purge cock No. 10 and start machine pumping air out through purge cock No. 9. After all air is pumped out, close purge cock No. 9, then open discharge valve No. 2 at once and operate machine as usual.

Important.—*Nothing but special ice machine oil should be used in crank case, since ordinary lubricating oil will freeze and become sticky.*

General care of plant.—Keep all ammonia and oil gauge cocks closed, except when examining level of liquids. *Gauge cocks on compressor case should be opened each day to make sure that there is sufficient oil in the compressor.*

Always keep stuffing boxes on valves and compressor shaft just tight enough to prevent any leak of ammonia. When stuffing boxes are drawn up as far as possible, packing should be replaced with good grade of ammonia spiral packing. Shaft stuffing box is packed with special metallic packing.

All valves, except gauge cocks, expansion valve, purge valve C, oil return valve No. 6, and charging valves No. 5 and No. 7, must be repacked when wide open in order not to lose ammonia.

Gauge cocks, purge valve C, and charging valves Nos. 5 and 7, must be closed while being repacked.

When repacking oil return valve No. 6, close it and relieve pressure on crank case as when recharging with oil.

Important.—Never open by-pass valve B, unless it is necessary for some reason to pump ammonia out of high pressure side into coils. Never close stop valves F and E, unless there be a leak in some part of the high pressure side. Stop valve F, is omitted on machines up to and including 6 tons refrigerating capacity. Stop valve E, is omitted on compressors up to and including 1¾ tons capacity. Stop valve Z, is omitted where expansion valve is installed close to receiver. Never close stop valve Z, except when it is necessary to take expansion valve or scale trap apart.

Pressure must be taken off both sides of expansion valve while it is being repacked, by closing liquid valve No. 4 or stop valve Z, and pumping down low pressure.

Keep all valve stems well oiled to prevent rust.

Clean oil well on outboard bearing with gasolene every two or three months, and keep this bearing filled with good grade of motor oil.

Once each year suction and discharge valves in compressor should be reground and scale traps cleaned. This may be done conveniently when renewing oil in crank case as machine is then pumped down.

Compressor can be taken apart easily when pumped down and valves reground without loss of ammonia.

To recharge with ammonia.—1, connect ammonia charging cylinder to charging valve No. 5, using charging pipe furnished; 2, start plant in usual manner, leaving liquid valve No. 4 closed; 3, open slightly valve on ammonia cylinder, testing connections to see if they be tight; (*Caution:* Stuffing box nut on ammonia charging cylinder has left hand thread and must be turned to left to tighten stuffing box); 4, if connections be tight, open valve on cylinder and open charging valve No. 5, which will allow the ammonia to flow from charging cylinder to expansion valve; 5, regulate system with expansion valve to normal operating conditions and charge until gauge glass on ammonia receiver shows half full; 6, *before disconnecting, close the valve on ammonia charging cylinder and also close charging valve No. 5*; 7, disconnect charging cylinder, making sure that charging valve No. 5, and valve on cylinder are both closed tight.

Caution.—Never leave ammonia cylinder connected to system.

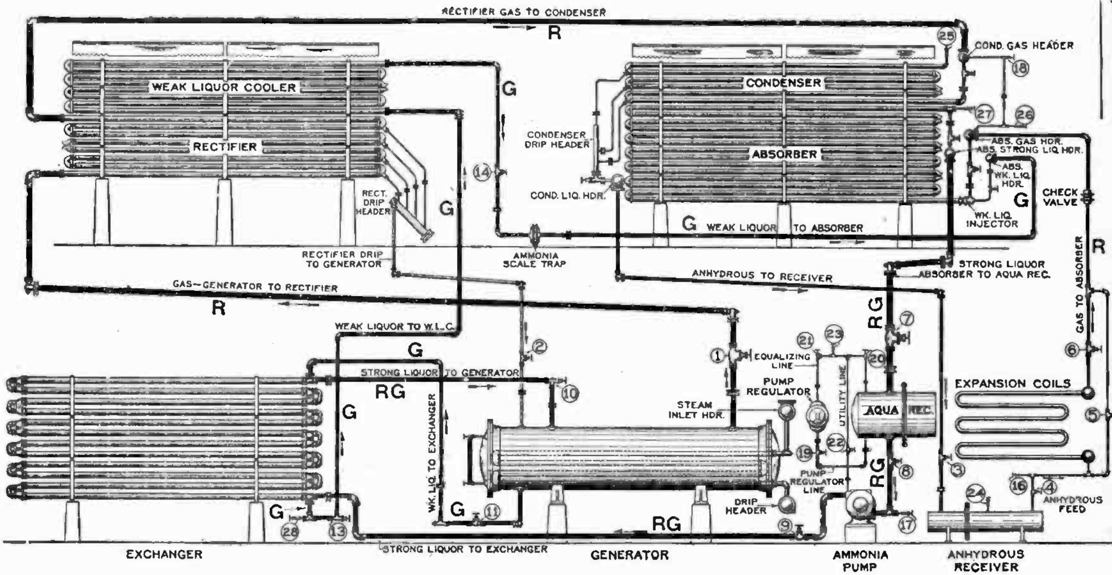


FIG. 8,676.—Carbondale absorption type refrigerating machine.

Absorption Machine Operation.—To illustrate the running of a refrigeration plant of the *absorption* type, directions are here given for operating the Carbondale refrigerating machine as shown in fig. 8,676.

1. The operation of the Carbondale Absorption Refrigerating Machine is based on the fact that pure water readily absorbs ammonia gas. Pure anhydrous liquid ammonia boils at 28½ deg. below zero Fahr. under atmospheric pressure, while water boils at 212 deg. Fahr. above zero. A mixture of ammonia and water will have a boiling point somewhere between, depending on the strength of the aqua ammonia solution.

2. The quantity of ammonia that water will absorb depends on the pressure under which the absorption takes place, the temperature of the solution, and the efficiency of the absorber.

3. A strong solution of aqua ammonia is pumped thru the Exchanger into the Generator. Steam Heating coils in the Generator heat the solution and drive off the ammonia gas, thru the Rectifier, or moisture separator. into the Condenser.

4. From the Condenser the liquid anhydrous ammonia is conducted to the Expansion Coils or Brine Cooler, thru the feed valve (4). There it evaporates, gathering the heat from, and thus cooling the objects to be refrigerated.

5. Since strong aqua ammonia is continually pumped into the Generator at the rate of about one half gallon per minute per ton of refrigeration, and the gas driven off from this aqua into the Condenser, a continuous supply of weak liquor leaves the Generator thru the Exchanger and Weak Liquor Cooler to the Absorber, where it absorbs the ammonia gas liberated by the Cooler or Expansion Coils. The resultant strong aqua ammonia is taken from the absorber by the aqua Ammonia Pump, forced thru the Exchanger into the Generator again, ready to repeat the cycle.

6. This information and diagram is useful to owners and operators, who wish to learn the method by which the Carbondale Exhaust Steam Machine operates. The diagram is of value to experienced engineers, breaking in green operators. It shows a typical Carbondale Atmospheric Type Absorption Refrigerating Machine. We build other types but the principle is the same.

7. Ammonia Gas Connections are shown by Lines R.

8. Ammonia Weak Liquor Connections are shown by Lines G.

9. Ammonia Strong Liquor Connections are shown by Lines RG.

10. Mark the valves in your plant to correspond to the valves on the diagram. It will help the engineer in case of fire or accident to close the necessary ones promptly, minimizing ammonia loss and preventing other damage.

11. The following instructions, condensed from our Instruction Book, are for handy reference.

12. TO START THE MACHINE. Assuming that the machine has a normal charge, proceed as follows:—

13. Start water circulating thru the machine.

14. Start brine pump, making sure that the proper quantity of brine of the proper specific gravity is circulating.

15. Turn steam on generator. Do so gradually.

16. Open the cooler gas valve (6). Slowly.

17. Immediately thereafter start the ammonia pump making sure that valves (8) (9) (10) are open.

18. Open and set the weak liquor valve (13).

19. When the generator pressure is raised to that usually carried, open the gas valve (1) and drip valve (2).

20. Open and set the expansion valve (4). The machine is now in regular operation.

21. TO STOP THE MACHINE: Shut the steam off the generator. During short shut downs leave a little steam on to prevent undue cooling, and leakage thru coil tail packing when starting up.

22. Close the expansion valve (4).

23. Stop the ammonia pump, closing suction valve (8).

24. Close the weak liquor valve (13).

25. Close the cooler gas valve (6).

26. Close the rectifier drip valve (2) and gas valve (1).

27. Stop the brine pump.

28. Shut off water supply.

29. For short shut downs, items 25 and 26 may be omitted. All valves should be opened very slowly.

30. WATER SUPPLY: To secure full capacity it is essential that ample water at proper temperature be provided. Consult the specification or the Carbondale Machine Company to ascertain the correct amount of water.

31. As a general rule the absorber outlet water should not exceed 95 deg. Sufficient water should be used on the rectifier, to maintain the outlet gas from 20 deg. to 30 deg. F. warmer than the ammonia condensing temperature due to the generator pressure.

32. Under proper operating conditions, and water supply, the shortest drip pipe on the rectifier will be very hot, the intermediate pipes successively cooler and the longest pipe fairly cool to the touch.

33. STEAM: Consult the specification as to the proper steam pressure to be employed. In general, the steam pressure must be increased if the brine temperature is lowered or the cooling water temperature raised

34. Ordinarily the steam pressure should not exceed one third of the

generator pressure. Thus with 150 pounds generator pressure, 50 pounds steam pressure is maximum.

35. Keep the air cock on the lower generator header open slightly which frees the coils of air, and indicates if the trap is working properly.

36. AMMONIA CHARGE: With the machine in regular operation and a normal charge the proper liquid levels, as indicated by gauge glasses on the various shells, will be as follows:

37. The Generator liquor level will be from one to two inches above the coils.

38. Atmospheric and Double Pipe Absorbers will have at least 12" of aqua in the receiver, above the pump suction connection. Shell Absorbers will run practically empty.

39. Shell Condensers will show 4" to 6" of anhydrous in the gauge glass and the receivers of Atmospheric or Double Pipe Condensers will show a similar amount above the outlet to expansion valve.

40. The Brine Cooler should contain enough anhydrous ammonia to frost both gauge cocks, with the cocks closed, and show a flash of soapy liquid in the glass, when the cocks are opened. The gas line should be slightly frosted back to the absorber. This, however, should never frost sufficiently to show frost on the purge line which indicates that liquid ammonia is being carried out of the cooler.

41. EVAPORATING OR COOLER PRESSURE: With a normal charge, the cooler gauge pressure should correspond to an ammonia temperature from 5 to 10 deg. lower than the temperature of the outgoing brine. The following table shows approximately the pressures corresponding to different outlet brine temperatures.

TEMP. OUTLET BRINE DEG. FAHR.	COOLER GAUGE PRESSURE LBS. PER SQ IN.
—20	2½" vac. to 0 lbs.
—10	3 lbs. " 6 "
0	8 " " 12 "
10	15 " " 19 "
20	23 " " 27 "

42. If Expansion Coils are used, instead of a Brine Cooler, the normal Evaporating Pressures will be slightly lower than those for a Brine Cooler.

43. A BRINE COOLER PRESSURE BELOW that given in the table for the corresponding temperature indicates:—

44. Insufficient ammonia (see par. 40).

45. Cooler needs purging (see par. 64).

46. Brine being circulated with insufficient rapidity (see specification).

47. If BRINE COOLER PRESSURE IS TOO HIGH it is probably due to one of two causes:—

48. Feeding Anhydrous too heavily (see last two lines par 40).

49. Air or foul gas in absorber (see par. 71).

50. It is unnecessary to know the strength of the strong and weak aqua to determine if the machine is sufficiently charged. If the conditions outlined in par. 36 to 40 inclusive are met, the strength of the strong and weak aqua will take care of themselves.

51. CONDENSING PRESSURE: With clean coils and a good water supply, the generator pressure should not exceed that shown in the table below:—

WATER TEMP. DEG. FAHR.	GENERATOR GAUGE PRESSURE. LBS. PER SQ IN.	TEMP. GAS LEAVING RECTIFIER DEG. FAHR.
50	105	86 to 96
60	125	95 to 105
70	145	102 to 112
80	166	109 to 119
90	192	118 to 128

52. A Generator pressure higher than given in this table, indicates one of three things:

53. Insufficient water supply.

54. Air in the high pressure side of machine.

55. Dirty condenser coils.

56. LACK OF CAPACITY: Is usually attributable to

57. Insufficient water supply. (see par. 30—31—32).

58. Insufficient steam pressure (see par. 33—34—35).

59. Insufficient flow of brine (see specification).

60. Insufficient ammonia charge (see par. 36 to 40 inc.)

61. Air or non-condensable gas in machine (see par. 69—70—71).

62. Dirty Condenser, Absorber or Rectifier coils.

63. Cooler in need of purging. (see par. 64).

64. PURGING THE COOLER: If some aqua has worked into the Cooler it is usually indicated as follows:—

65. A lack of capacity not attributable to other causes, the gauge cocks on the Cooler being frosted as with a normal charge and the cooler pressure below that shown in table.

66. If on opening the Cooler gauge cocks the liquid looks watery and sluggish, and the Cooler pressure is below normal.

67. To remove this aqua, or "Purge" the Cooler, close expansion valve (4) and in about 15 minutes close gas valve (6) and open purge valve (5):

68. After thoroughly draining the Cooler open expansion valve (4) for about half a minute, repeat this several times and when the pressure drops to 5 to 10 pounds below that on the absorber before purging was begun, the cooler has been completely purged and operation can be resumed.

69. REMOVING AIR OR FOUL GAS: If with clean Condenser coils and ample water supply the condenser pressure remains high, it indicates Air or Foul Gas in the high pressure side of the machine.

70. Air can be removed from the high pressure side, during operation, by opening expansion valve (4) wide for 10 or 15 minutes at intervals of one or two hours. This empties the liquid receiver periodically and allows gas to blow thru. The rapid flow of gas thus induced carries the Air or Foul Gas to the low pressure side from which it can be removed thru valve (23) see paragraph 71. As soon as evidence of Air or Foul Gas disappears, this process should be discontinued.

71. To remove Air or Foul Gas from the Absorber blow it from valve (23) into a bucket of water until ammonia gas comes. This is indicated by a crackling sound as the ammonia gas is absorbed, also by the heating of the water. When this occurs, close valve (23).

72. LEAKS: Stop leaks the moment they appear.

73. GENERAL: In the season of light load reduce the number of atmospheric or double pipe absorber coils in service to the smallest number required.

74. In cutting out each coil, close the individual controlling valves in the following sequence.

75. Close the weak liquor valve.

76. Close the gas valve.

77. Close the strong liquor valve.

78. In putting the coils back into service the procedure should be reversed.

79. Keep a log of operation, coal, repairs and results. Keep the anhydrous receiver outlet sealed always. Keep the generator coils covered with aqua always and the generator steam pressure as uniform as possible. Keep pipe surfaces clean.

80. For detailed instructions see the complete Instruction Book

TEST QUESTIONS

1. *Describe in full detail the operation of a small compressor machine.*
2. *How is a machine re-charged with ammonia?*
3. *What precautions should be taken in re-charging?*
4. *Describe in full detail the operation of a large absorption type machine.*

CHAPTER 223

Domestic Refrigeration

Domestic Refrigeration.—By definition, domestic refrigeration is *refrigeration on a small scale as accompanied by a self-contained unit with automatic control, fool proof and of suitable size for household use.*

The term electric refrigeration is misleading.

Electricity has nothing to do with the refrigeration cycle, but is used to furnish the power to perform the cycle, that is, to drive the compressor.

Details of domestic refrigeration systems are given in the sections following.

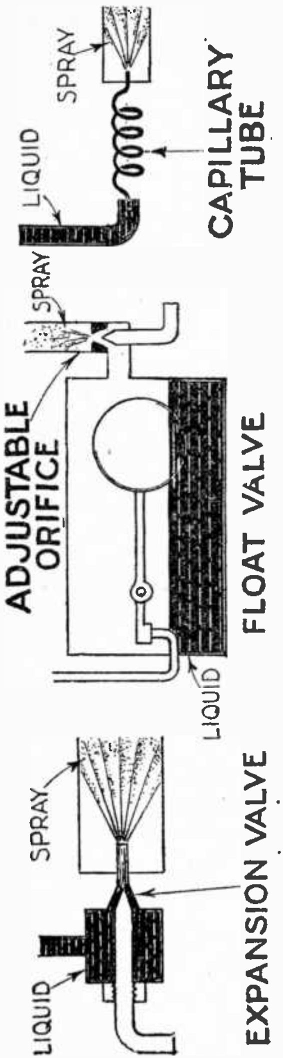
Compression Systems.—There are two general type of compressor apparatus classed according to the method of expanding the refrigerant and known as

1. Dry system.

   a. Expansion valve;

   b. Capillary tube.

2. Flooded system.



Figs. 8,677 to 8,679.—Various methods of expanding the liquid. Fig. 8,677 by expansion valve; fig. 8,678, by combination float valve and adjustable orifice; fig. 8,679, by capillary tube.

In the *dry system*, the refrigerant *is admitted into the expansion coils of the evaporator in a semi-liquid or spray form, which is controlled by an expansion valve actuated by pressures.*

In the *flooded system, a relatively larger amount of liquid refrigerant is held in the evaporator and the proper operating level is maintained by means of a float valve actuated by gravity flow.*

Methods of Heat Transfer.—Two methods are employed to transfer heat from the interior of a cabinet to be cooled, namely,

1. By direct expansion;
2. By brine circulation.

These methods have been fully described and need no further explanation.

Compressors.—There are three types of compressors used:

1. Reciprocating;
2. Oscillating;
3. Rotary.

Reciprocating type compressors are generally either of *single* cylinder or *double* cylinder construction, having discharge and *intake* valves of varied differences of construction. The compressors may be *belt* driven, *gear* driven, or *directly connected to the motor*.

Condensers.—The condensing element is usually one of three types:

1. Water cooled;
2. Air cooled by *natural* air circulation.
3. Air cooled by means of a forced *fan* draft.

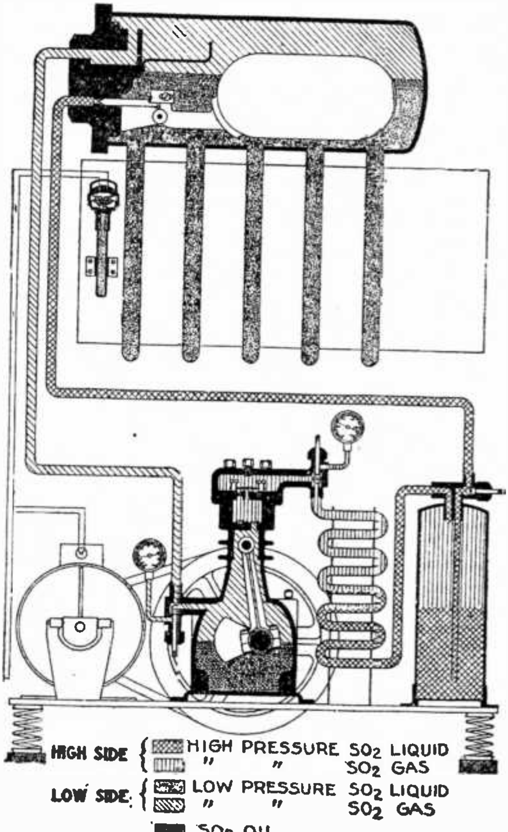


FIG. 8,680.—Kelvinator flooded system cycle.

Motors, Control Mechanism, Valves, Stuffing Box, Etc.— Motors of fractional horse power capacities to 1 *h.p.* and over of various industrial types are the *prime movers* of any electric refrigerator.

Control mechanisms are either of the following types:

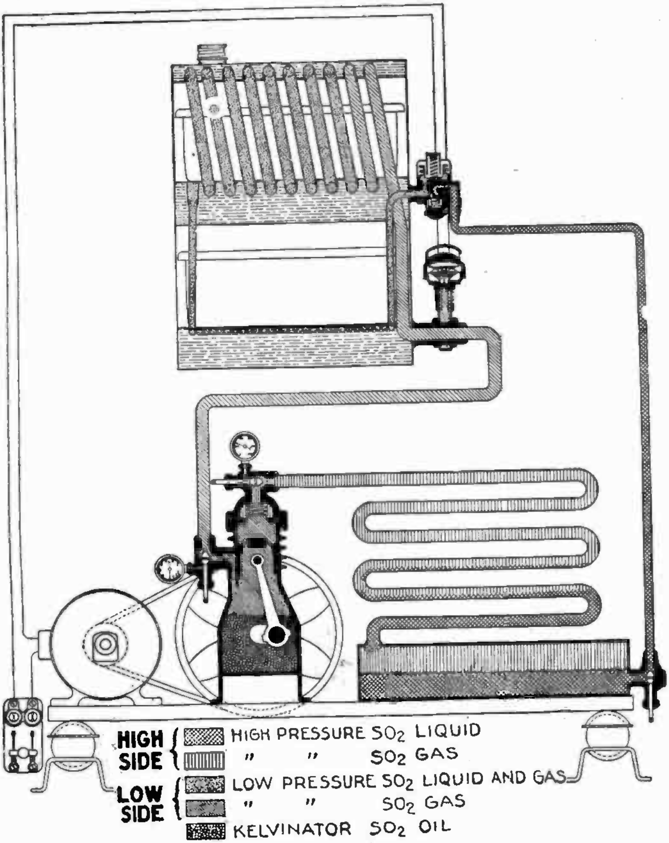


FIG. 8,681.—Kelvinator dry system cycle

1. Pressure type;
2. Thermal type.

Service and shut off valves are usually required on the average refrigerating system. In many compression systems where the drive is by belt or gear involving the use of a compressor drive shaft, a *stuffing box* is a primary element.

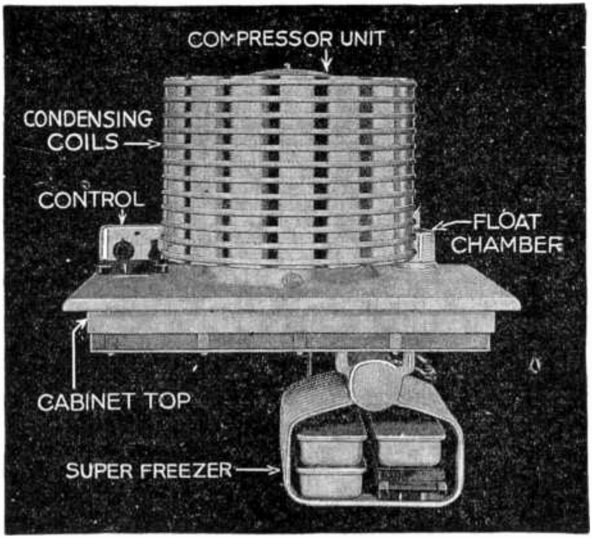


FIG. 8,682.—General electric domestic refrigerator unit. Exterior view showing general appearance. This unit fits on top of the refrigerator.

The function of the stuffing box is that of a packing gland to prevent leakage of the refrigerant by *sealing* the compressor drive shaft.

Typical Compression Type Domestic Refrigerator.—As an example of how the *compression cycle* is applied in a small unit for household duty the following brief description of the General Electric refrigerator is here given.

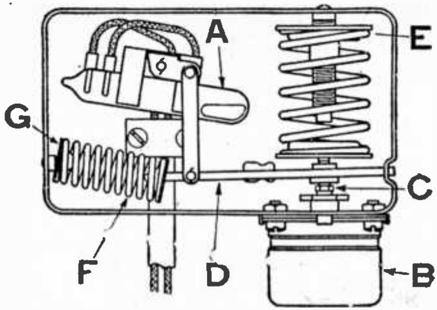


FIG. 8,683.—Rice automatic control by temperature. The electric circuit to the motor is opened and closed by the tilting of the mercoid switch A, which causes the mercury to flow from one end to the other, making or breaking contact with the terminals. The power element B, consists of a metal bellows containing a gas which quickly expands with a slight rise in temperature. When temperature increases, the power element exerts an upward push on the stem C, forcing up the lever D, which rocks the mercoid switch to the left closing the circuit. A decrease in temperature causes the power element to contract and the large adjusting spring at E, throws the switch back, opening the circuit. Spring F, gives the required snap action to the switch and is necessary for the proper operation of the control.

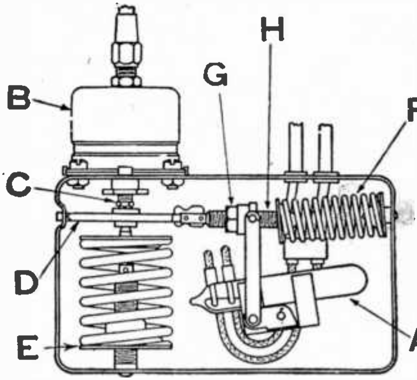


FIG. 8,684.—Rice automatic control by pressure. The electric circuit to the motor is opened and closed by the tilting of the mercoid switch A, which causes the mercury to flow from one end to the other, making or breaking contact with the terminals. The power element B, consists of a metal bellows to which is attached a stem C. The bellows within B, is connected direct to the refrigerant on the low pressure side. Experience has shown that there is a constant relation between the low side pressure and the temperature of the cooling unit. It is, therefore, possible to control temperature by controlling the low side pressure. As the low side pressure increases (unit closed down) the bellows power element expands pushing downward on stem C, and lever D, which rocks the mercoid switch to the right and closes the circuit. Running of the unit causes a decrease in low side pressure allowing the bellows element to contract. The adjusting spring at E, then throws the switch back, breaking the circuit

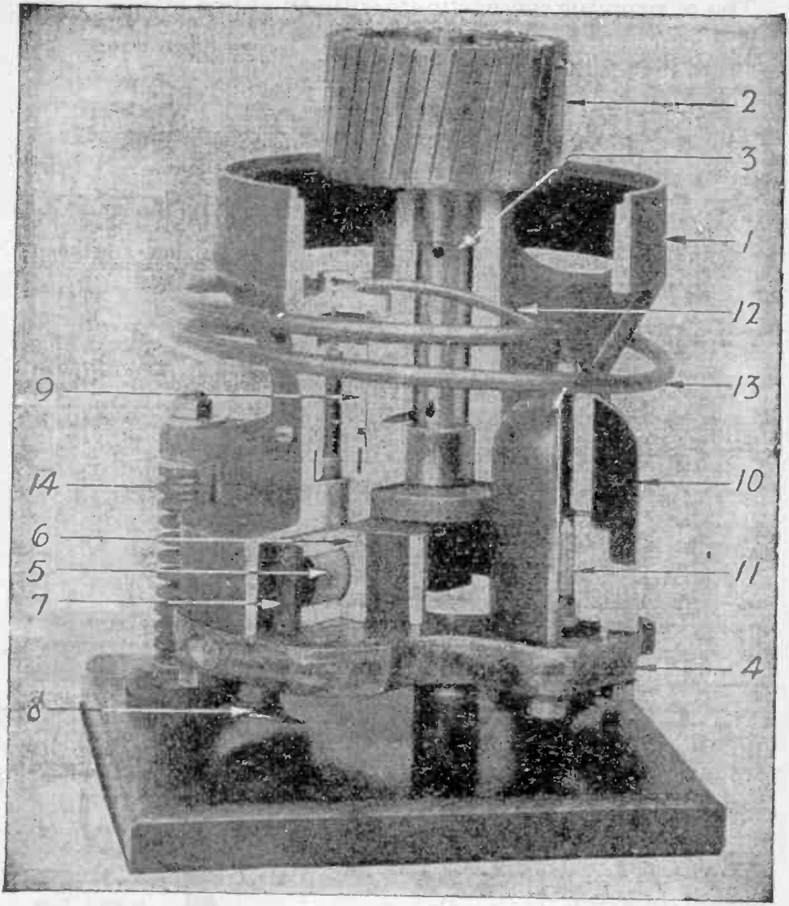


FIG. 8,685.—Cutaway section of General Electric refrigerator machine. The parts are: 1, main frame; 2, rotor; 3, main shaft; 4, bearing plate; 5, piston; 6, cylinder; 7, muffle box; 8, oil screen; 9, unloader; 10, surge chamber; 11, check valve plunger; 12, unloader tube; 13 suction tube; 14, supporting springs.

The General Electric compressor is of the oscillating type. The refrigerator consists in its entirety of two integral parts.

1. Refrigerating unit.
2. Cabinet.

The refrigerating unit consists of five principal parts.

1. Compressor.
2. Condenser.
3. Float chamber.
4. Evaporator (super-freezer).
5. Control.

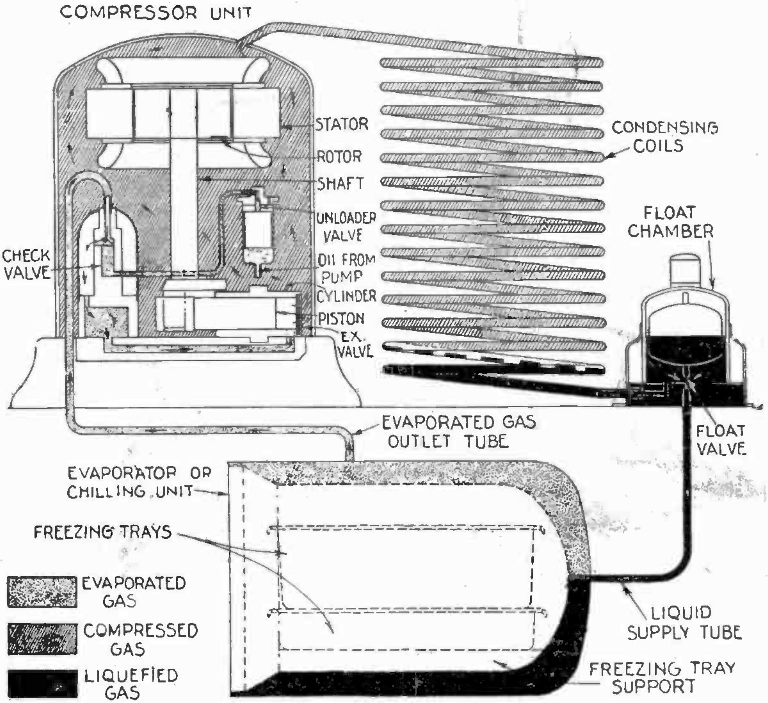
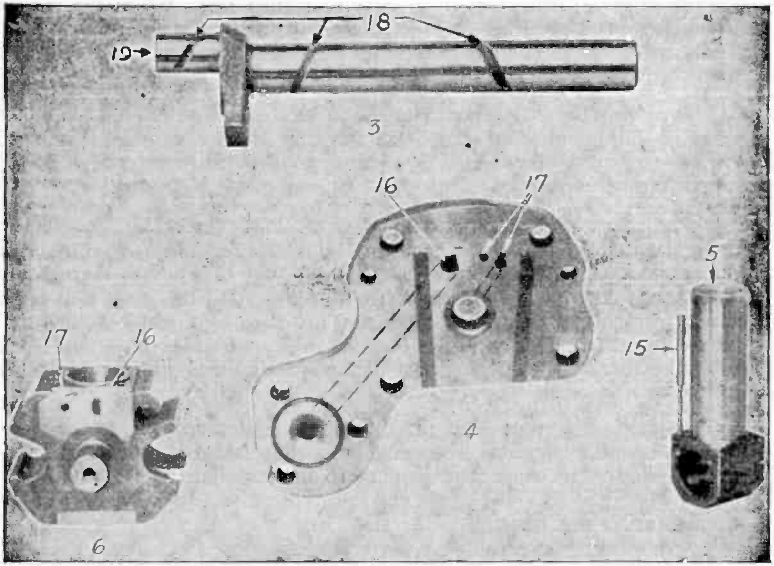


FIG. 8,686.—General Electric refrigerator unit. Diagram showing parts and cycle of operation.

Compressor unit.—This unit consists of the motor and compressor, together with the main frame on which they are mounted. The assembly is mounted on three vertical springs in order to reduce to a minimum the transfer of any noise or vibration to the outside casing.

The motor is of the single phase induction type.

The compressor is of the single oscillating cylinder type on the small units. As the piston is moved in and out by the action of the crank pin, the



FIGS. 8,687 to 8,690.—General Electric bearing plate, crank shaft, piston and compressor of refrigerator. The parts are: 3, crank shaft; 4, bearing plate; 5, piston; 6, compressor; 15, oil piston; 16, gas ports; 17, oil ports; 18, oil grooves; 19, crank pin.

cylinder is made to oscillate about its trunnions. The cylinder rides on the bearing plate and its oscillation opens and closes the suction port. This oscillation also operates the oil ports. The compressor operates at 1,750 revolutions per minute, which is the rated speed of the motor.

The base of the machine in which the mechanism is mounted is shaped like a bowl, which is filled with a permanent supply of high grade mineral oil up to the level of the bearing plate, thus forming an oil sump.

Positive forced feed lubrication is obtained by means of a plunger which is mounted beside the main compressor piston, and the cylinder in which it operates is in the same block as the main cylinder.

The oil plunger operates on the permanent oil supply in the same manner as the main piston operates on the vapor. Since the oil is never overheated, and it cannot become mixed with dirt, and it cannot oxidize or evaporate, there is therefore, no need to replace it.

Condenser.—This consists of circular copper coils, which are rigidly wound on sheet steel fins welded to the outside of the compressor case. These fins serve the double purpose of supporting the condenser coils and dissipating heat from the motor and condenser.

Float chamber.—The float chamber is located on the cabinet top to the right of the compressor case. Its function is to accumulate liquefied refrigerant until there is a sufficient supply to raise the float valve, allowing liquid, but no vapor to return to the evaporator as it is needed.

Evaporator.—This is located on the underside of the cabinet cover as an integral part of the whole refrigerating unit. Its function is to refrigerate the cabinet. It is made of two steel sheets, one of which is corrugated. These are folded into shape, with the upper part of the inner and outer sheets forming a cylindrical header and are then electrically welded and brazed together. This construction gives in effect a series of parallel tubes extending around the outer surface of the evaporator and opening into the header or refrigerant reservoir.

The liquid refrigerant is admitted from the float chamber into the evaporator where it evaporates, absorbing heat from the interior of the cabinet. The interior of the evaporator is made to accommodate ice freezing trays, two of which are set side by side and in direct contact with the floor of the evaporator for fast freezing.

The control.—This is located on the cabinet top at the left of the compressor case and consists of

1. A switch to throw the unit On or Off manually;

2. A thermostat to start and stop the motor in response to temperature changes in the evaporator when the manually controlled switch is On.

3. An overload protective device.

4. A starting relay.

Temperature control is accomplished by a metallic bellows, to which is attached a copper tube, the end of which is fastened to the evaporator. The bellows and tube contain a supply of sulphur dioxide to evaporate with a

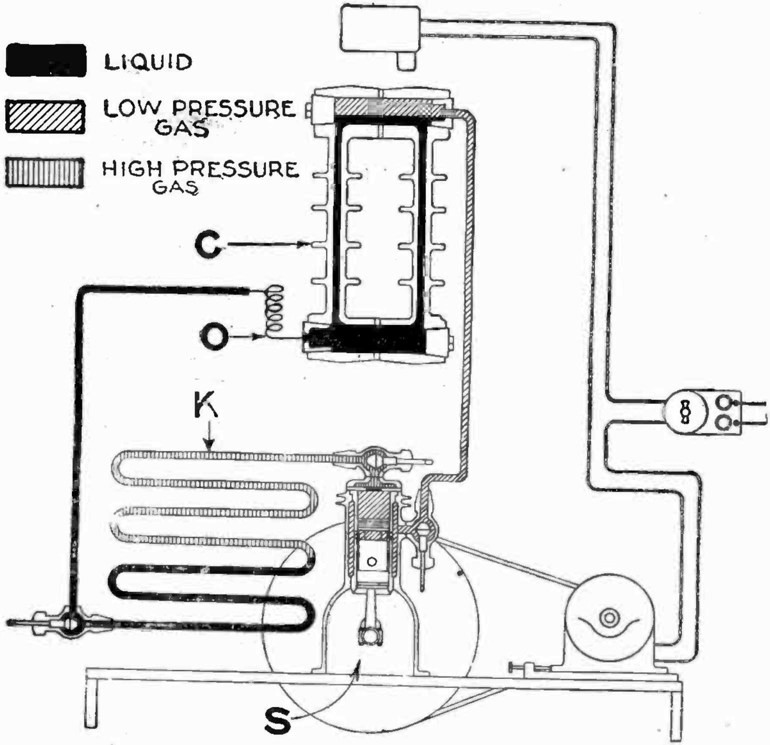


FIG. 8,691.—Operating cycle of Rice methyl chloride direct expansion refrigerating unit. The refrigerating effect is due to the latent heat of vaporization of the methyl chloride, that is, the amount of heat taken out of the surrounding air when the methyl chloride boils. The liquid methyl chloride starts vaporizing when released through the capillary tube O. It then boils or vaporizes in the cooling unit C, taking heat from the surrounding air inside the refrigerator. This vapor is conducted to the suction side of the compressor S, usually reaching it in a slightly superheated condition. The compressor then forces the vapor or gas into the condensing element K, where it is liquefied by cooling by a flow of air over the coils while the vapor inside is under pressure. It collects in liquid form in the bottom of the coils K, and is then allowed to return to the cooling unit C, through the capillary tube O. It should be noted that the resistance due to the constricted opening in the capillary tube O, causes it to act as an expansion valve. The tube builds up a back pressure in liquid feed line or high pressure side, and at the same time relieves it at low pressure into the low pressure side or cooling unit and suction pipe line.

resultant increase in the pressure. This increase in pressure actuates, through the metallic bellows, a switch which starts the motor.

Conversely, a decrease in temperature causes reduction in pressure, which opens the switch and stops the motor. The temperature may be adjusted by increasing or decreasing the tension on the temperature adjusting spring. This may be accomplished by means of the temperature adjusting dial which is on the front of the control. This allows the owner to adjust the cabinet temperature by a simple movement of the dial.

The motor is protected against overload by means of an overload trip which opens the circuit when an abnormal condition arises. The purpose of the starting relay is to close the starting contacts and thereby energize the starting winding, supplying the additional torque necessary to bring the motor up to speed.

In the case of the smaller units, a resistance, located in the control box, is in circuit with the starting winding. In the larger units one point of a capacitor is in circuit with the starting winding. Then when the motor has come up to speed, the starting winding is connected to another point on the capacitor unit and thereafter the motor runs as a polyphase motor. The capacitor on the larger units serves the purpose of increasing the power factor and decreasing the starting and running current.

Cycle of operation.—When the switch is closed and the motor is started, the pump begins to suck the sulphur dioxide vapor from the evaporator through the suction line. This reduces the pressure on the sulphur dioxide liquid and allows it to boil or evaporate freely.

As the sulphur dioxide changes from a liquid to a vapor, it absorbs heat from the interior of the refrigerator. The function of the rest of the refrigerator mechanism is then to reliquefy this vapor and feed it back to the evaporator. The pump, sucking the vapor from the evaporator, compresses it into the steel compressor case. From there the compressed refrigerant gas passes to the condenser coils, where it is cooled and as a result liquefies.

The liquid then drains down into the float chamber. When a sufficient quantity of liquid has accumulated to raise the float, the valve is opened, permitting some of the liquid to run back into the evaporator to complete the cycle.

The moving parts of the unit are liberally oiled by a forced feed system. A small piston plunger, attached beside the main piston, sucks oil from the sump in the base of the unit and forces it up around the piston and main bearings, from whence it drips back into the sump.

The oil pressure also operates an unloader, which equalizes the pressure on both sides of the main piston whenever the unit stops, thereby reducing the starting torque required and permitting the use of a smaller motor than would otherwise be required.

When the unit is running, the oil pressure forces the unloader plunger upward, thereby closing a small by-pass valve. As soon as the unit stops, the oil pressure decreases, allowing the unloader plunger to drop, and thereby opening the by-pass valve. This allows compressed vapor to enter the suction side of the pump. The rush of compressed vapor also closes the check valve, preventing this vapor returning into the super-freezer.

When the unit starts again, the by-pass valve is closed by the oil pressure, the check valve drops open and the unit resumes normal operation.

Multiple Refrigerating System.—Some apartment buildings have instead of individual refrigerating units, *a central plant located in the basement or other remote place, and furnishing refrigeration to each apartment by pipe line.* This is known as a *multiple refrigeration system* and it includes all systems in which the refrigerant is circulated from a common source to two or more separate refrigerator cabinets, each containing one or more evaporators or chilling units.

There are two general classes of these systems, namely

1. Brine piping systems.
2. Vapor piping systems.

The brine piping system comprises one or more commercial compressors placed in a machinery room which is generally located in the basement of the apartment building. A cold brine solution at a temperature of about 9° Fahr. is pumped through heavily insulated pipes into the refrigerator cabinet of each apartment kitchen.

The vapor piping system comprises one or more commercial compressors installed in the basement and a cabinet containing a *cooling coil* placed in each apartment kitchen refrigerator box.

Copper tubing and piping are used to connect the machines in the basement with the coils in the apartments. The refrigerant liquid is circulated through these tubes into the cooling coils of each cabinet, and the refrigerant gas returned to the compressor in the basement.

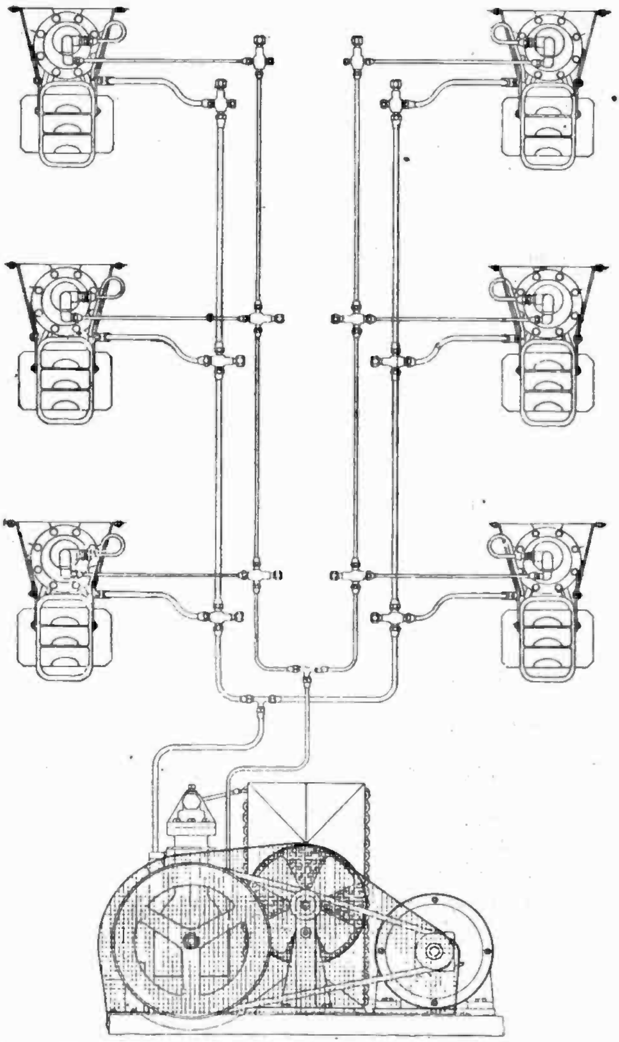


Fig. 8.692.—Servel apartment house installation with *header* and *riser* piping system.

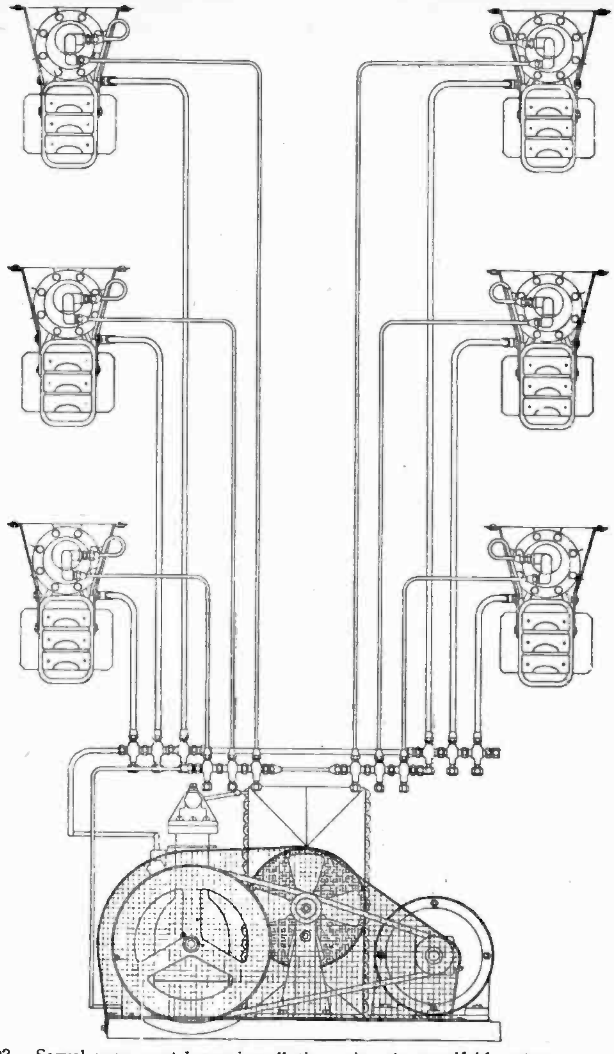


FIG. 8,693.—Servel apartment house installation using the manifold system.

There are two general methods of piping, known as

1. Header and riser system.
2. Manifold system.

These are shown in figs. 8,692 and 8,693.

Typical Absorption type Domestic Refrigerator.—As an example of how the *absorption cycle* is applied in a small unit for household duty, the following brief description of the Servel Electrolux refrigerator is here given.

The strong liquid (distilled water and ammonia only slightly stronger than household ammonia) is heated by the gas flame in the generator. The ammonia vaporizes and passes into the rectifier, where a constant temperature is maintained by the evaporation of ammonia from the previously liquefied ammonia in the bottom of the U tube. The ammonia then passes from the rectifier through the water cooled condenser, where it is cooled and liquified, the liquid ammonia flowing back into one leg of the rectifier.

When the level of the ammonia in the rectifier U tube becomes higher than the inlet pipe into the evaporator (located in the chilling compartment) the liquid ammonia flows from the rectifier through the heat exchanger into the evaporator where it evaporates and absorbs heat from the box.

A hydrogen gas atmosphere in the evaporator causes the ammonia to evaporate, maintaining a constant pressure in the system and requiring no valves or checks of any sort. As the ammonia evaporates into the hydrogen, the mixture being heavier than the hydrogen itself, sinks to the bottom of the evaporator, passes through the gas heat exchanger and into the absorber.

In the absorber the ammonia and hydrogen meet a stream of weak liquid which has been cooled in its passage from the generator. The liquid readily absorbs practically all the ammonia in the gas mixture. Heat is given off when the ammonia dissolves in water, so the absorber must be cooled.

The hydrogen being insoluble in water and being lighter than the incoming mixture of ammonia and hydrogen, rises and flows again to the evaporator, which is at a slightly higher level than the absorber.

The mixture of water and ammonia sinks in the absorber and passes by gravity back to the lower section of the generator. It is lifted from this point to the upper part by means of the thermo-siphon actuated by heat applied at this point. The heat supplied not only lifts the liquid from the lower level in the generator to the higher level in the generator, but also releases ammonia from the strong liquid to repeat its cycle.

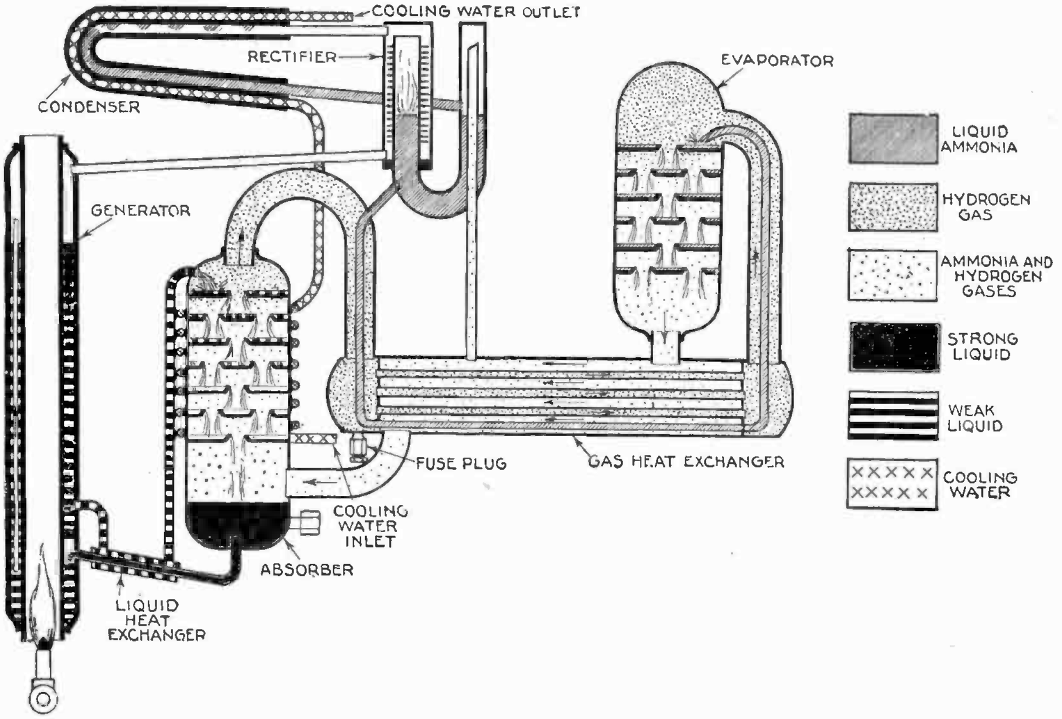


FIG. 8,694.—Sectional view of Electrolux absorption type domestic refrigerator, whose cycle of operation is explained in the accompanying text.

Service Instructions.—First try to locate the source of trouble before tinkering with the plant. By doing this much time and unnecessary labor will be saved. The following are the troubles ordinarily met with.

Frosting Back.—This is the term applied to any condition which frosts the suction line outside of the cabinet.

There are three causes, and they should be checked in the following order to save time:

First, the charge may be low allowing the float to stand in a half open position and a gas and liquid mixture blows through. This can be checked by opening the test cock on the receiver and bringing the reserve charge up to this point. This indicates a full charge and a reserve.

Second, the float may be stuck in an open position by a particle of dirt or scale, or the seat may be damaged. Stop the machine and listen attentively at the head of the float valve. If a continuous hissing be heard with the machine off, it is a clear indication that the needle is not seating. (Note that this test is unreliable unless there be adequate charge in the system.) In many cases, simply shaking or jarring the float valve will seat the needle, or it may be rapped lightly with a hardwood block. If these methods fail to close off the liquid supply, pump out the refrigerant, remove the float head and repair, clean or replace the needle and valve body. Before replacing the head on such a float valve, wipe the interior dry and *heat the head and valve mechanism* until they are too hot to hold in the hands so that no moisture will remain between the needle and valve body.

Third, the oil return orifice may be too small for the machine used on the job. This effect will be apparent as soon as the installation is made, and will persist whenever the machine operates. With an adjustable orifice in the float valve, the remedy is to remove the cap from the orifice body and turn the stem to the left just enough to prevent frosting outside the cabinet. If run out too far, the pull out and oil return will be killed and an oil bound float will result. A quarter turn in either direction near the break over point will make a great deal of difference.

Dead Chilling Units.—If this occur on an installation having only one cabinet on one machine with pressure control, the machine will operate very little or not at all.

If on a multiple system, it is possible to have one or more dead chilling units and yet have the machine operating on the others. Proceed to eliminate the possible causes in the following order:

No current to machine:

Check fuses and machine;
Closed liquid or suction valve.

Stuck float valve.

Treat this as described under "Frosting Back."

Oil Bound Float.—The simplest way to decide whether this is the trouble is to loosen the float or complete chilling unit, and rock it slightly forward and backward.

If the float release periodically due to the undulating motion of the oil, a hiss will be heard and the outlet line of the float will chill slightly due to the release of methyl. This effect is positive indication of excessive oil in the float chamber.

To remedy, loosen two or three of the lower cap screws at the lower part of the float head and drain the oil into a shallow pan. *This affords temporary relief only*. Before leaving the job, determine what caused the trouble and remedy it.

Short Cycle Operation of Machine.—Be sure the suction pressure control is set on a wide range.

Extremely Long Runs at Low Suction Pressure.—This will occur only on overloaded jobs or when sluggish thermostatic control is used instead of pressure control.

It can be overcome to some extent as explained under Improper Orifice Adjustment.

Short Cycling Due to Action of High Pressure Safety Switch.—This will occur only when the water supply is inadequate, or when the machine has an excess of reserve refrigerant in the condenser.

Incorrect Orifice Adjustment.—The smaller the gas orifice in the rear of the float shell body the more oil and refrigerant will be drawn through the oil return tube.

With float valve with adjustable orifice, the stem should be screwed in far enough to completely frost the vaporizer coil at a pressure near 18 lbs. on the suction gauge, for methyl chloride refrigerant, and one or two turns of the vaporizer should be frosting freely when the machine reaches cut off pressure. This means that some oil, methyl mixture will be drawn out all through the run, and under these circumstances, the float cannot *oil bind*. When near the correct adjustment a quarter turn left or right on the adjustment will make a great deal of difference in performance.

In domestic or apartment house chilling units, or submersion coils having the 7/32 in. fixed orifice the oil binding may be caused by too many chilling units on a given size machine. This lowers the velocity and consequently the oil pull out on these farthest away from the machine. The only remedy is to pump down the offending chilling unit, remove the head and substitute a 3/16 in. diameter orifice plug for the standard 7/32 in. plug.

With the new type automatic orifice in the domestic units, the condition cannot occur unless a large particle of scale or dirt should block the flapper disc in an open position and prevent it seating. Tapping will usually relieve such a condition in the remote possibility of its occurrence.

Clogged Oil Return Tube.—If tubing scale, filings or dirt collect in the oil return tube or strainer, so as to obstruct it, oil binding may result.

The only remedy is to remove the float head and clear the strainer or tube.

Plugged Line Filter.—In some cases it is remotely possible that the liquid line or the liquid filter may become plugged from an excess of dirt in the system. This will cause a dead chilling unit and the plug can be located by cracking connections successively until the joint is found where the liquid stops. Mashed or kinked tubing is the most frequent cause of this trouble.

Continuous Operation.—This may simply be a symptom of some of the troubles previously considered.

Severe frosting back due to any cause may force continuous operation. Correct as previously described. Overloaded machines may strike a balance point near cut off and may be unable to pull the chilling unit pressures down far enough to cut off. There are only two remedies. Either set the control to cut off at a higher temperature, or install a machine with enough capacity to pull the temperature down.

Compressor Not Pumping Full Capacity.—This may be caused by bad suction or discharge valves, worn rings, etc.

Chilling Unit Fails to Frost Fully During Run.—Sometimes on a chilling section installation, the first sections on the circuit will frost freely during the run while the latter sections near the return connections to the float valve will not frost.

Under these circumstances, the sections that do not film with frost are not doing their full share of work, and excessive machine operation will be necessary to keep the cabinet cold.

Under any circumstances, the section connected to the float outlet will be colder than the one at the opposite end of the circuit connected to the return inlet. This is true because the first section is fully flooded, and the last one carries a rather thin mixture of gas and liquid. It is not possible to have them at equal temperatures, but if properly regulated, all sections will operate to film with frost and be effectual in cooling the cabinet.

On float valve systems the flow of refrigerant through the section is governed by the frequency of lowering of the float ball.

This lowering is caused by drawing liquid out through the oil return tube.

The adjustable orifice permits drawing out enough liquid to take care of any normal set of sections.

The further the orifice is reduced by adjustment the greater the quantity of liquid drawn out, and consequently the more active the sections will be.

The best criterion for this adjustment is the condition of the line which returns gas and liquid from the sections to the float valve shell. If liquid be kept flowing in this line during the run the maximum effect will be obtained from the sections, and this line will frost freely.

The flow may be continuous with continuous frosting, or it may occur in even surges, as the float opens and closes, but for maximum results a frost film should be apparent on this line, clear to the end of the run.

If this line persist in defrosting near the end of the run, the sections are being starved, and the orifice must be run in further to increase the refrigerant flow. If, when this adjustment is secured, the frost line on the vaporizer has followed the suction line outside the cabinet or in extreme cases back to the machine, the only remedy is to add extra vaporizer surface. In any case, an excess of vaporizer coil will not have any unfavorable effect if extremes are avoided.

Cutting Off on High Pressure.—Any trouble that causes the head pressure to rise excessively may cause a machine to cut off and on at the high pressure mercoid.

The possibilities should be checked in the following order:

1. Insufficient water flowing.

   This may be due to misadjustment of water valve, line pressure, or mineral sediment plugging lines or valve.

2. Water supply warm.

   This can be caused by water backing up from hot water heaters or line running through boiler rooms.

Excess Charge.—This will cause cutting on and off by the high pressure control whenever the liquid floods the condenser tubing to such an extent that the surface in contact with warm gas is seriously decreased. Check by opening the test cock on the side of the condenser.

Ice Collecting on or Below Sections.—This trouble is caused by too low a cut on pressure.

The machine starts up before the last of the frost has melted off. It becomes harder to deal with when there is insufficient clearance between the bottom of the sections and the pan or deck. Keep the clearance wide and set on a high enough cut on to eliminate the last vestige of frost or ice before the machine starts up. Regulate the cabinet temperature by changing the cut off pressure.

Unbalanced Temperatures on Multiple Installation.—It will sometimes be found that the salesman or engineer on a job has underestimated the refrigeration demand on one cabinet, and overestimated the demand on another.

This results in equipment that gives temperatures below normal in one or above in another, with normal control settings. The best way to correct such a condition is to add one or more sections to the chilling unit whose cabinet is too warm. It can sometimes be remedied by removing one or more sections from the cabinet that is too cold, but this should not be done unless the machine has sufficient capacity to take care of the equipment at lowered suction pressures.

Chilling Units That Will Not Defrost During Idle Period.—This is caused by setting at too low a cut on pressure.

Occasionally temperatures are desired near or even below freezing. Under such circumstances, it is impossible to get a defrosting cycle.

If the cabinet temperature be below 32° it is a physical impossibility to melt the frost off the sections because frost only melts above 32°.

Float Valve Leaks (*Mayflower*).—If for some reason the float valve be prevented shutting off liquid supply at proper level, the refrigerant will be drawn through suction tube to crank case causing refrigeration and a formation of frost to take place at these points.

Sometimes there is insufficient liquid reserve in the receiver under compressor base to permit the liquid level in cooling unit to rise to a point where back frost will occur, and in this case only compressed vapor will be forced through float valve, causing a gurgling sound in cooling unit like air being blown under water. If this condition exist, compressor will be running at short intervals or continually, also a very low reading will be noticed if pressure gauge be attached to condenser shut off valve. To remedy this condition, first charge additional refrigerant into system.

If during this process frost should appear on suction tube, it is a sure sign that the float valve is not seating properly. This condition while rare, occurs shortly after a machine has been installed and is largely caused by careless handling of cooling unit in transportation. The trouble can usually be rectified by allowing system to remain idle for about 12 hours. (Refrigerator doors should be left open during this period.)

The rise in temperature in cooling unit causes the liquid to expand and its level to rise, thus forcing the float valve needle firmly into its seat.

If unsuccessful by this method, cooling unit hanger rod nuts may be loosened to permit unit to be rocked back and forth, which will agitate the liquid and thus cause the needle to move back and forth in its seat, having a tendency to properly seat float valve needle. If unable to correct trouble by above methods, it is possible that float valve is held open by a particle of foreign matter. Shut off liquid valve on compressor, block crank lever in switch housing, allowing compressor to run for about 30 minutes.

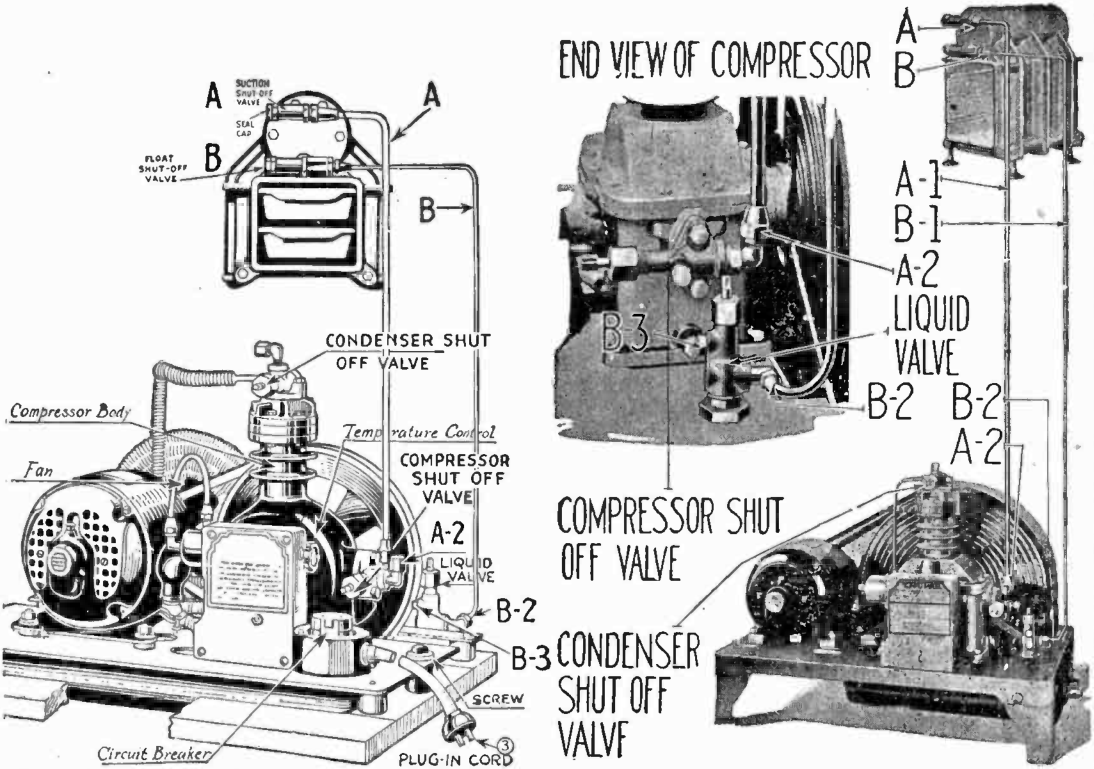
Stop compressor and apply blow torch to under side of receiver tank (move torch back and forth so as not to burn enamel) until gauge shows about 120 lbs. pressure.

Open liquid valve on compressor and allow liquid to rush under great velocity, through now wide open float valve. The general effect of this procedure is to wash out any foreign matter that may have become imbedded in float valve seat.

If, after all the methods just mentioned have been tried the system continue to back frost, it will be necessary to replace cooling unit.

Float Valve Stuck (*Mayflower*).—If float valve do not open, all the refrigerant in cooling unit will be pumped into receiver, causing little and eventually no refrigeration.

When this condition occurs, it is sometimes traceable to the needle point being wedged into its seat. To loosen, take a small piece of wood and place with end of grain against body of cooling unit directly above the float shut off valve and strike with short, sharp blows with small hammer. This procedure is usually successful in jarring needle out of its seat, permitting float ball to drop and liquid to flow into cooling unit until proper level is reached, at which point float valve will shut off.



FIGS. 8,695 to 8,697.—Mayflower domestic refrigeration unit.

If the proper results be not obtained by this method, it is possible that some foreign substance is lodged against outer orifice of float valve. To remove this obstruction, proceed as follows:

Remove plug from liquid valve and attach empty or partially empty service cylinder at B-3 (see fig. 8,695). Discharge liquid into service cylinder, thus relieving head pressure in compressor. Close valve on service cylinder.

Apply blow torch to tubing, leading from service cylinder to liquid valve, to drive liquid in tubing back to receiver.

Close charge valve and liquid valve and disconnect service cylinder. Turn compressor shut off valve to left as far as possible. Remove plug in shut off valve and insert half union coupling.

Complete a by-pass from this coupling to B-3, using short section of ¼ in. tubing with flare nuts on each end. Close compressor shut off valve by turning to right as far as possible. Start compressor by blocking switch with screw driver.

Now open charge valve. This will cause a vacuum to be drawn on liquid line and interior of float shut off valve on cooling unit, tending to withdraw obstruction.

During this procedure rap float shut off valve body above liquid valve with piece of wood and hammer.

Leaky Crank Shaft Seal.—This trouble is detected by methods depending on the kind of refrigerant employed. In an SO_2 machine a leak is detected by the smoke test.

Air in System.—A defective crank shaft seal, flare nut or tubing will cause air to enter through the suction or low pressure side.

Air, being a non-condensable gas, will cause a high head pressure in the condenser coils.

High head pressure indicates air in system or too much refrigerant.

If the compressor motor run in the wrong direction, the condenser will not get a sufficient blast of air. This results in overheating and high head pressure.

Purging System of Air. (*Mayflower*).—Shut off compressor and allow to remain idle for ten minutes.

Detach pressure gauge and turn stem on condenser shut off valve slightly to the right, allowing air to escape (air being lighter than SO_2 vapor rises to the top). If compressor be located in cabinet, or if a considerable amount of air is to be discharged, attach hose or piece of tubing and lead to out doors or in pail of lye water.

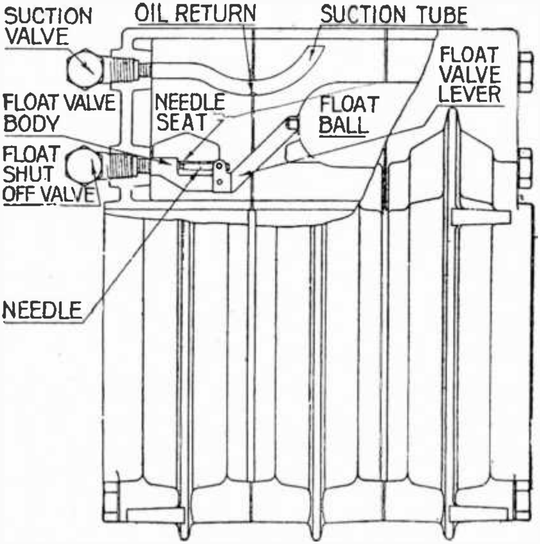


Fig. 8,698.—Mayflower float valve. The function of the float valve is to maintain a constant level of liquid sulphur dioxide in cooling unit, and if functioning properly, will shut off liquid supply before it reaches a point where it will be drawn back through small hole in suction tube marked oil return. This small hole is located at a point about a quarter inch above the normal liquid level in cooling unit and permits a certain amount of oil to float on top of liquid sulphur dioxide. (Oil being considerably lighter than sulphur dioxide.) If an excess of oil be pumped over by compressor, it will eventually reach this opening and be drawn back into the crank case, assuring lubrication of all moving parts.

Moisture in System.—If moisture come in contact with SO_2, sulphurous acid (H_2SO_3) will be formed.

This acid has a corrosive effect on the highly polished cylinder walls and causes the piston to stick. In mild cases it is sometimes possible to break compressor loose by a rocking motion of fan wheel and by drawing a small amount of oil, about ¼ pint in crank case.

If above method be not successful, it will be necessary to dismantle compressor, thoroughly clean, dry and evacuate same. This is best done at the factory.

This difficulty is rarely met with, but if it occur, it is invariably traceable to carelessness in installation, such as using tubing that has not been properly dried or sealed after it is dried, or by allowing air to enter system, especially in humid or rainy weather.

TEST QUESTIONS

1. *What is domestic refrigeration?*
2. *Name two types of compression system.*
3. *Name three methods of cooling the condensers.*
4. *Describe the motors, control mechanism, valves, stuffing box, etc.*
5. *Describe in detail a typical compression type machine.*
6. *What is the function of a stuffing box?*
7. *What are the five principal parts of a refrigerating unit?*
8. *Give the cycle of operation.*
9. *What is a multiple refrigeration system?*
10. *Name two general piping methods used in multiple systems.*
11. *Describe in detail a typical absorption system.*
12. *Give full instructions for operating and maintaining domestic refrigerators.*

CHAPTER 224

Domestic Oil Burners

Some knowledge of the fuel oils employed is essential to the intelligent operation of domestic oil burners. Fuels are derived from crude oils, obtained from different fields and vary considerably.

Oil fuels are now commercially known as domestic fuel oils Nos. 1 ,2, and 3; and industrial fuel oils, Nos. 4, 5, and 6. Sometimes the fuels are referred to as light, medium and heavy domestic oils; and light, medium and heavy industrial oils.

For most of the domestic burners, the manufacturers recommend fuel oil No. 3, while many burn either Nos. 1 or 2 fuel. The No. 4, a light industrial oil, is recommended for a small number of domestic burners now manufactured.

Effect of Grade of Oil on Economy.—The grade of fuel that can be used is usually fixed by the design of the burner with respect to the method of atomization, the type of ignition, etc.

The gravity feed burners invariably are designed to burn only the high grade distillates. The atomizing domestic burners use oil as heavy as No. 4. The grade of oil which can be burned determines to a considerable extent the cost of heating.

Oil Burners.--An oil burner is any device wherein *oil fuel is atomized or vaporized and mixed with air in proper proportion for combustion, previous to ignition.*

Oil burners may be classified:

1. With respect to operation, as

   a. Manually controlled;

   b. Automatic.

2. With respect to method of igniting, as

   a. Torch;

   b. Pilot light.

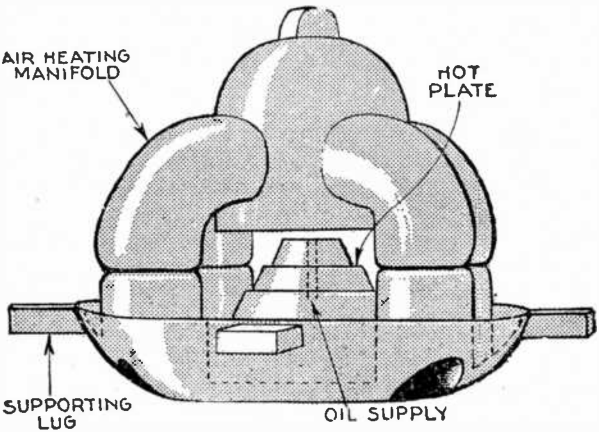


FIG. 8,699.—Casting which constitutes a simple gravity feed, vaporizing type burner

3. With respect to the gasifying process, as

   a. Vaporizers;

   b. Atomizers.

4. With respect to the method of oil feed, as

   a. Pressure;

   b. Gravity.

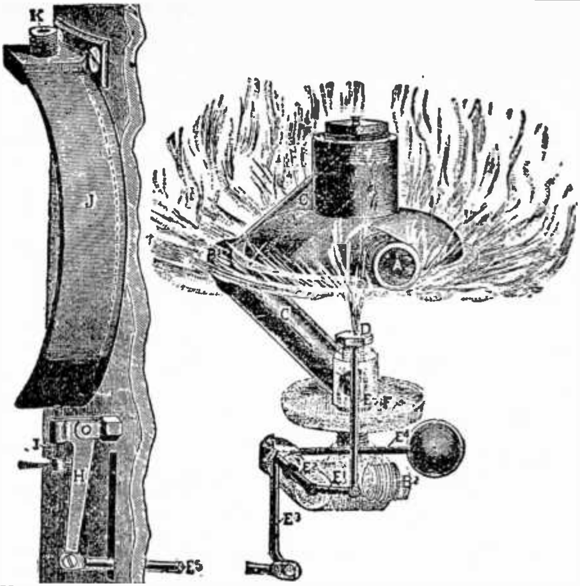


FIG. 8,700.—***Non-mixing*** gravity feed *vaporizing* or *gas* type burner and automatic control. It is designed for gasoline or other light hydrocarbons or ordinary headlight oil, of 150° test. ***In operation,*** the oil is supplied through a pipe to the vaporizer indicated by the letter **A**. In its passage through the fire box and the vaporizer, it is converted into a vapor or gas which burns without odor, soot or residuum. From the top of the vaporizer **A**, the gas is conveyed through an elbow pipe **C**, as shown by arrows, to the mouth of the burner, where it escapes through a small opening **D** (made adjustable), and is ignited. The flame striking centrally upon the bottom of the vaporizer **A**, is spread in every direction, thus serving the double purpose of generating the gas in the vaporizer and distributing the heat equally to every portion of the boiler. The flame striking centrally upon the bottom of the vaporizer is spread radially and by heating the vaporizer converts the liquid fuel into gas. Working in this small opening **D**, is a shut off plunger **E**, which, raised or lowered, controls the flow of the gas. This plunger is connected by means of a rod E^1, counter-balanced rock shaft E^2, bell crank lever E^3, connecting rod E^5, to bell crank lever **H**, and to a hollow spring on the outside of the furnace. The weight of these rods is counterbalanced by the rod and ball E^4. The hollow spring is supplied with steam at boiler pressure through a small pipe at opening **K**. The saucer **F**, is for oil or alcohol used in raising the proper heat under vaporizer at starting, and until sufficient gas is generated for its own reproduction; a matter of three or four minutes. The burner is furnished with removable plugs BB^1, to facilitate cleaning. Rock shaft E^2 is furnished with stuffing box **G**, to prevent leakage. ***In control,*** the straightening of the spring caused by an increase of pressure in the boiler, operates directly on the plunger by means of the adjusting screw **I**, bell crank lever **H**, and intermediate connections; thus establishing the relation between steam pressure and fire. Should the steam pressure rise, the plunger would close off the flow of gas correspondingly, and vice versa, thereby regulating the heat of the fire. The plunger cannot, however, shut off the flow of gas entirely; a small orifice is always left, enough to keep the burner and boiler hot; and in this way the trouble and annoyance of having to relight the fire after every stop is avoided.

Gravity Feed Vaporizing Burners.—This is the simplest type of burner, very often consisting merely of one or two rough castings which are set inside the furnace, and its initial cost is low.

There are two types of this burner, known as

1. Non-mixing;
2. Mixing.

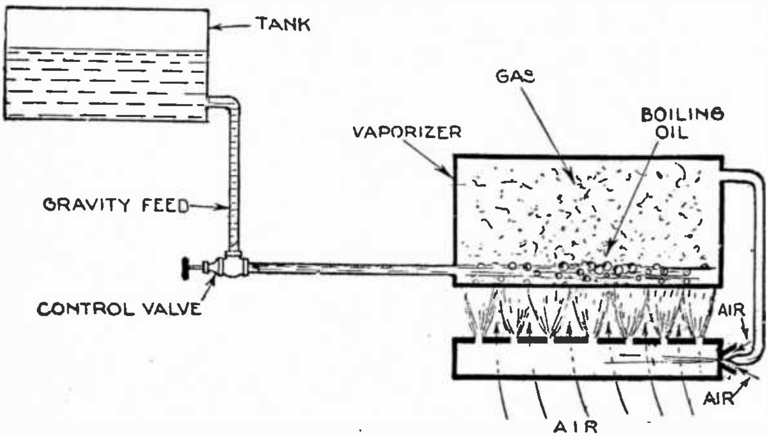


FIG. 8,701.—Elementary gravity feed *induction mixing vaporizing* burner. ***In operation,*** oil flows from tank to vaporizer, regulated by the control valve. The flame from the burner vaporizes the oil entering the vaporizer producing a gas which passes out to the mixer. The gas is injected through a nozzle into the *mixer* sucking in air, the mixture passing out and igniting at the top.

In the cheapest burners of this class the control is entirely manual; the burner is started by hand, and the control of temperature is effected in like manner. In some cases automatic control has been applied with apparent success.

The gravity feed non-mixing vaporizing burner is limited to the use of the relatively high priced fuels. Fig. 8,700 shows the construction of a burner of this type arranged for automatic control.

The principle upon which the non-mixing type operates is shown in fig. 8,700.

In this type the air to support combustion is brought into the furnace by the natural draft produced by the chimney. Some rather ingenious means are used to induce an intimate mingling of this air with the vaporized fuel, but in general, good combustion is not obtained by this method unless a highly volatile fuel be used.

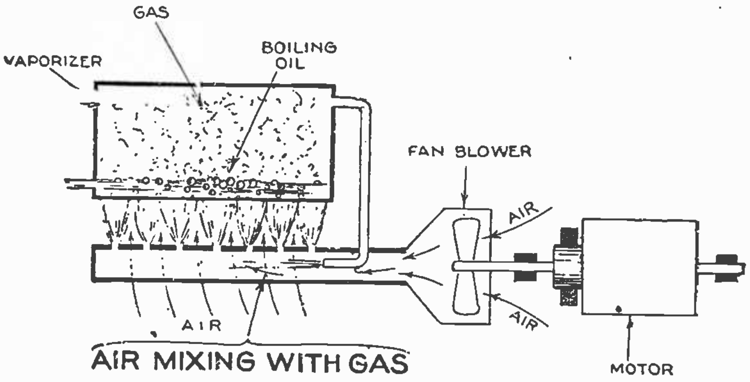


FIG. 8,702.—Elementary gravity feed *mixing*, vaporizing burner. Connected to the burner is a fan blower with outlet pipe surrounding the gas pipe as shown. ***In operation***, air from the fan blower mixes *inside* the burner with the gas coming from the vaporizer. Thus the air is mixed with the gas before ignition, resulting in a blue flame and efficient combustion.

The principle of the mixing type vaporizing burner is shown in fig. 8,702.

Fig. 8,703 shows the construction and working of a well known *mixing vaporizing* burner. This burner is, strictly speaking, a mixing, *combined atomizing and vaporizing burner*. That is, the oil is atomized by the air at the intake to the fan blower and the fine spray carried by the air current to the vaporizer where vaporization takes place before ignition.

Another type of mixing vaporizing burner is the hot plate variety shown in fig. 8,714.

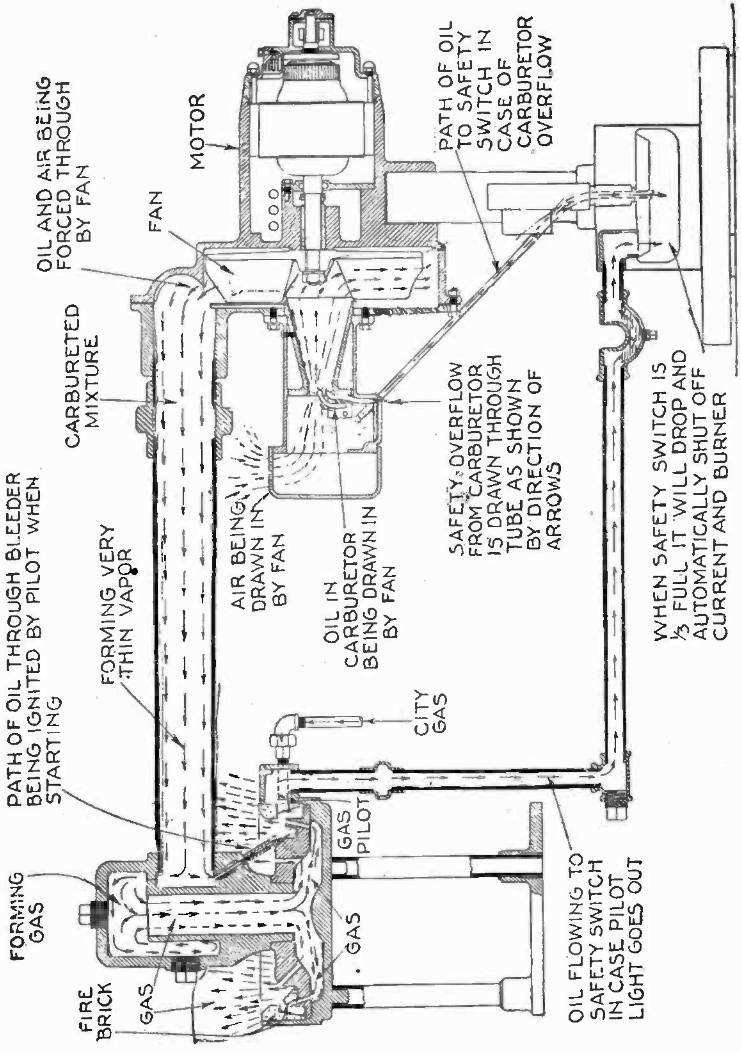


FIG. 8,702.—Crystal *mixing* vaporizing burner. Sectional view showing operation.

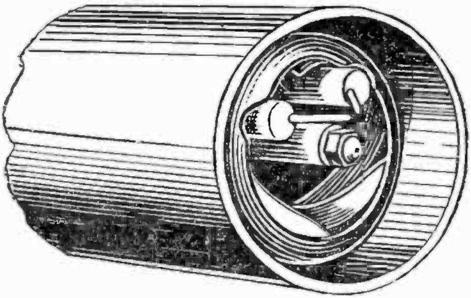


FIG. 8,704.—Oil-Electric draft tube, air diffuser and spray nozzle showing location of spark in relation to spray nozzle.

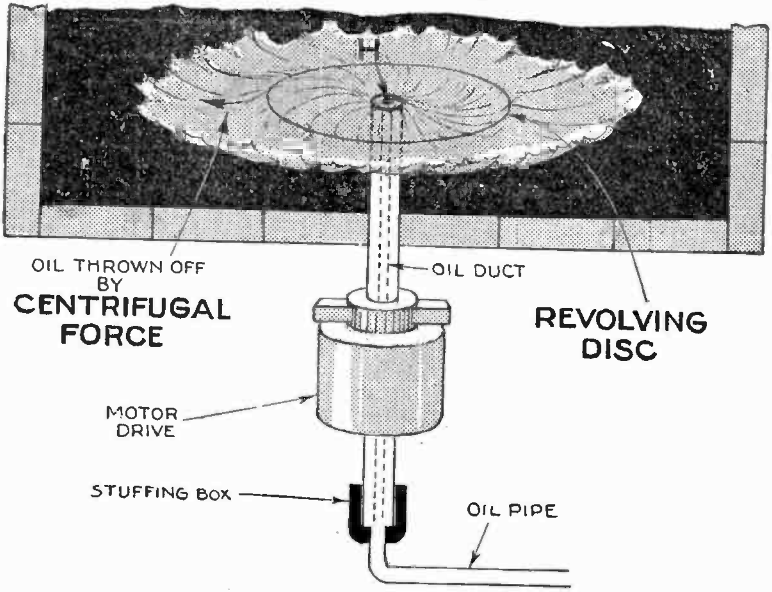


FIG. 8,705.—Elementary centrifugal force atomizing burner. The oil flows through the hollow spindle of a disc which is rotated at high speed by a motor. The oil overflowing at H, onto the disc at its center is hurled off the disc by *centrifugal force*, and ignited by a torch or pilot light, produces a ring of flame.

Here the vaporizer consists simply of a plate heated partly by a pilot flame as shown, ignition takes place at the plate, the plate being virtually a combined vaporizer and burner.

Atomizing Burners.—In this class of burner various methods are used for breaking up or atomizing the fuel. This is accomplished by:

1. Compressed air, or
2. Centrifugal force.

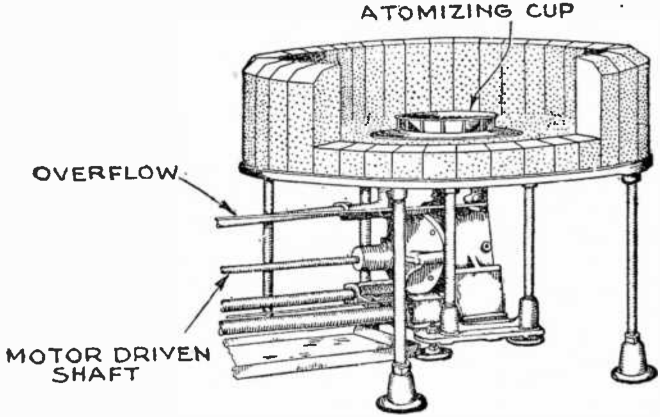


Fig. 8,706.—Motor driven centrifugal atomizing burner.

These two methods are shown in figs. 8,708 and 8,705 respectively. Fig. 8,706 shows a centrifugal force type burner as constructed.

Ignition.—Burners may be classified roughly with respect to the method of lighting, as

1. Wick;
2. Gas;

3. Electric;
4. Electric-gas;
5. Electric-oil.

With the manually controlled gravity burner, the hot plate is preheated by a wick which is saturated with oil and ignited by a torch.

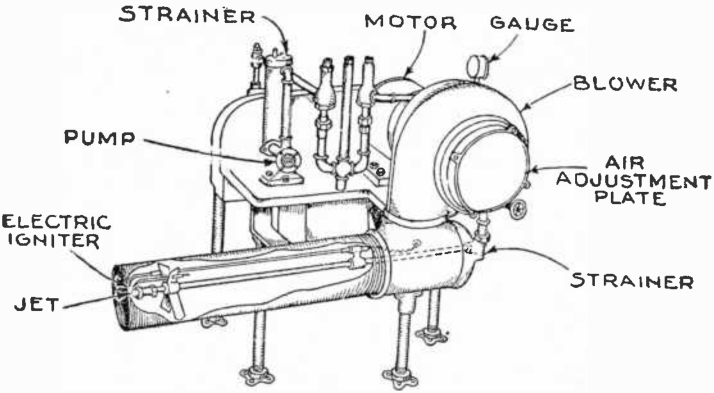


FIG. 8,707.—Motor driven atomizer burner of the electric ignition type.

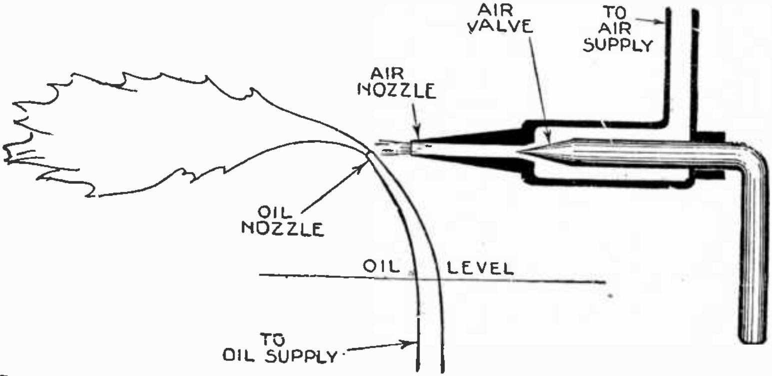


FIG. 8,708.—Atomizing oil by air jet or spray.

The plate must be heated to a temperature sufficient to vaporize the oil falling upon it. The heat of combustion is supposed to do this once the

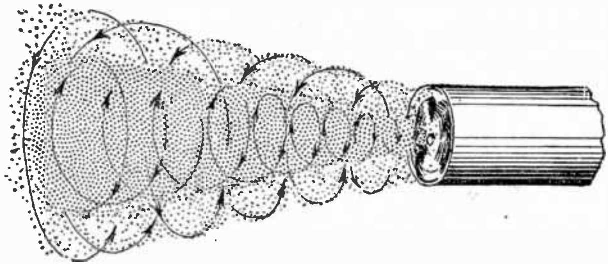


FIG. 8,709.—Method of commingling air and atomized oil by whirling each in contrary direction in conical streams. The oil stream comprises the inner cone, while the air stream comprises the outer.

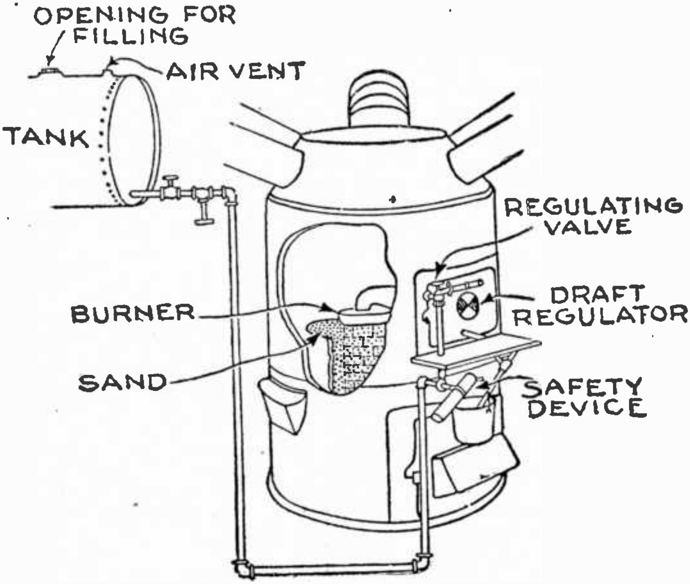


FIG. 8,710.—A simple manually controlled vaporizing burner installation in a warm air furnace.

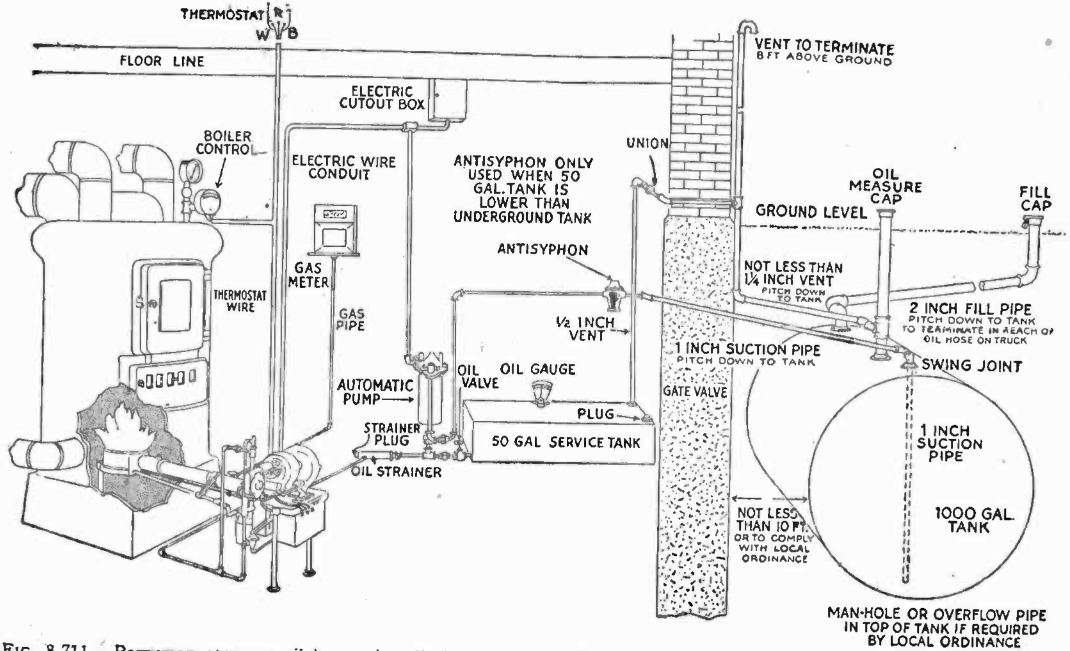


FIG. 8,711.—Berryman atomizer oil burner installation showing various connections, etc.

flame is started. The temperature of the house is maintained at a desired point by increasing or decreasing the intensity of the flame by means of a valve in the oil line, or the burner may be operated at a fixed intensity and then completely shut off as the condition may demand. Whenever the burner is off for a few minutes, the hot plate must be preheated again before the oil can again be vaporized and ignited.

In some automatically controlled vaporizing burners a gas flame is used for heating the hot plate and as a pilot light for igniting the fuel.

The gas flame burns continuously and keeps the hot plate at such a temperature as to cause the oil to vaporize when it is admitted to the apex of the place and trickles down over the corrugations, fig. 8,713. At the same time the pilot flame licks through holes drilled in the hot plate and ignites the mixture of vaporized oil and air. The automatic device in this case merely shuts off or opens a valve in the oil line to the burner.

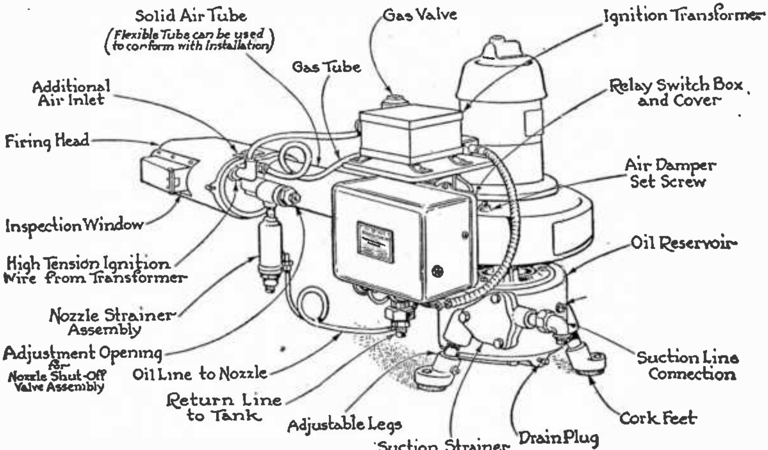


FIG. 8,712.—Wayne atomizer type burner. View showing parts.

The pilot flame is sometimes caused to expand at the time the burner comes on, and by this means the danger of extinguishing the pilot light is somewhat lessened and ignition is presumably hastened.

With the atomizing type of burner it is necessary to introduce a flame or electric arc within a region which is filled with an intimate mixture of oil and air in such proportions as to make it comparatively easy to ignite.

In the electric gas type, a gas pilot is turned on, the gas being ignited by a spark. The pilot light then ignites the charge. Still another device is the electric-oil ignition in which an independent atomized mixture is ignited by an electric arc and is utilized as a source of heat energy to ignite the charge of the burner proper.

In general, it should be noted that *the type of burner selected must conform to the particular igniting facilities present, whether gas or electricity, or both.*

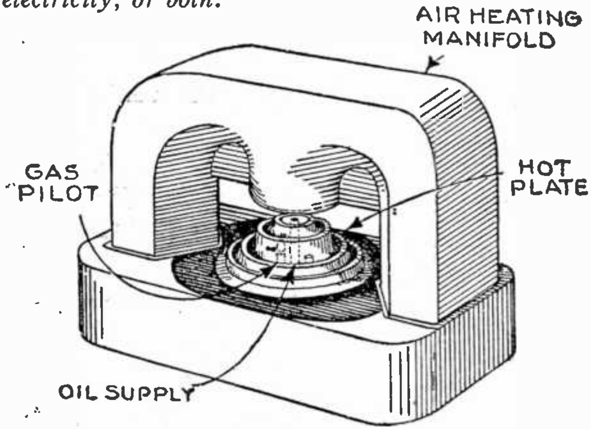


FIG. 8,713.—Casting of a vaporizing burner with which is incorporated the continuous burning gas pilot and plate heating flame.

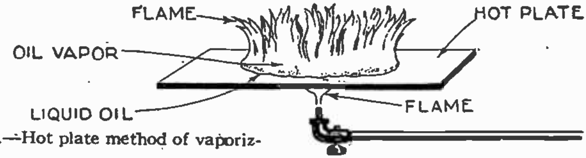


FIG. 8,714.—Hot plate method of vaporizing oil.

Combustion.—Oil fuel used by domestic oil burners contains principally hydrogen and carbon, with much smaller quantities of oxygen, nitrogen and sulphur. Of these elements, the carbon hydrogen and sulphur are the ones that burn or combine with oxygen.

Insufficient air supply is one cause of clouds of dense smoke and soot. This form of combustion is inefficient in that the fuel is not entirely consumed.

An excess of air is essential to insure that each subdivided bit of oil is provided with the amount of air necessary.

Furnace Design.—To obtain satisfactory results combustion must take place in a region of high temperature.

Note the following points on furnace design:

1. Practically all air must pass through the flame;

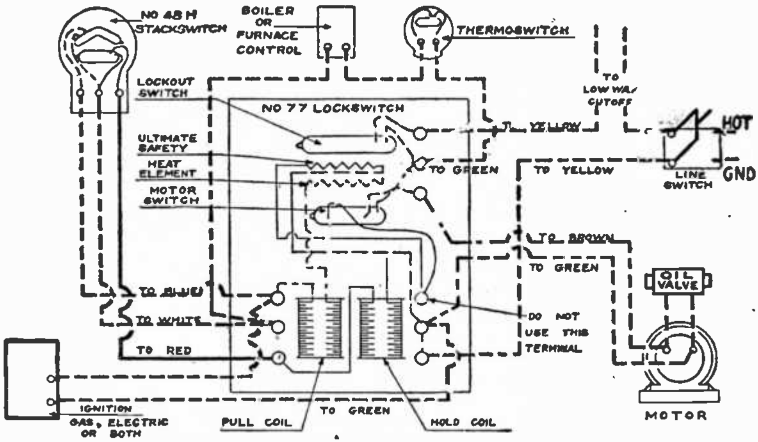


FIG. 8,715.—*Time-O-Stat control system, 1. Start or cold* position. In this position the mercury tubes are tipped downward toward the left. The current, therefore, cannot pass through the lower tube of the stack switch, but passes through the upper tube of the stack switch, returning over the blue wire to the blue terminal on the lower left hand board. At this point the current has two paths flowing outward to the ignition valve or spark transformer over one path and starting the ignition. The return line for the ignition circuit is connected to the green terminal on the lower right hand terminal board which is interconnected to the yellow terminal on the right hand terminal board and thus provides a return to the ground side of the line, completing the ignition circuit. The secondary path from the blue terminal on the lower left hand board leads the current to the pull coil and energizes this coil. This coil being energized rotates the motor switch to its on position and completes the circuit of the motor from the green terminal on the upper right hand board to the motor. The motor starts at this time. Its return line leads back to the ground connection through the green terminal on the lower right hand board. Connected in series with the pull coil is the heat element of the lockout mechanism through which, in the starting cycle, the current of the pull coil passes. The return line from the heat element leads back to the ground connection on the lower right hand terminal board at the green terminal. Upon completion of the current flow through the paths as outlined, the oil burner begins to run. Assuming entirely normal conditions, flame will result and the stack switch will be moved to its hot position, that is, both tubes tipped downward to the right.

2. The flame must not be allowed to impinge directly on either boiler sheets, tubes or brick work;

3. The flame produces better results when worked near hot brick;

4. The flame should be distributed over as large an area as possible to prevent localization of heat;

5. Every precaution must be taken to guard against excess air.

Automatic Control.—The oil flame is extremely rapid in heating and if not controlled in some manner will build up

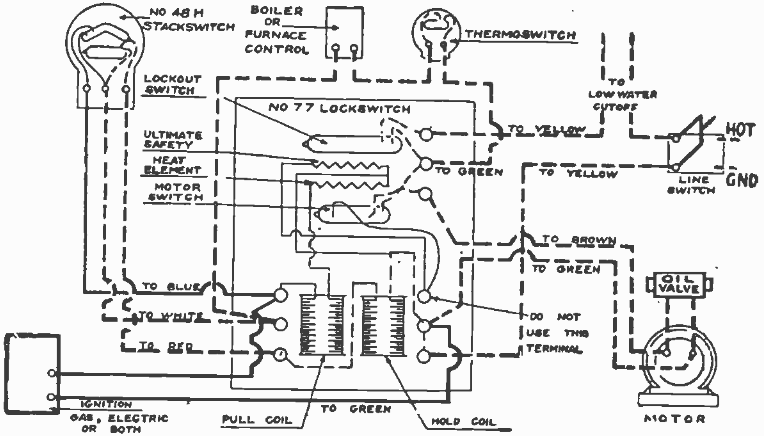


Fig. 8,716.—*Time-O-Stat control system, 2. Running position.* In this position the current enters as before through the line switch from the hot side of the line through the lockout switch to the green terminal on the upper right hand terminal board, then through the thermo-switch and limit control to the white terminal on the lower left hand terminal board. The current then passes out as before to the white terminal in the stack switch, but inasmuch as the stack switch is now in its hot position, the circuit through the blue terminal of the stack switch is open and thus the pull coil and the ignition have been de-energized and the ignition turned off. The current returns from the stack switch now on the hot side through the red terminal and to the red terminal on the lower left hand terminal board of the lock switch. From this terminal it is led through the hold coil, and from the hold coil it returns to the ground side of the line through the green terminal on the lower right hand terminal board. The hold coil being energized, the motor switch is maintained in the on position and the motor continues to run. Thus the flame and full operation of the oil burned is continued. The lockout switch heating element is of course taken out of the circuit as soon as the pull coil is de-energized and therefore the heat element cools off without opening the lockout switch. As soon as the thermo-switch limit control or low water cut off opens the circuit, current can no longer flow through either of the coils of the lock switch. therefore the motor switch returns to its off position and the burner is shut down.

temperatures and pressures in the heating system which may prove dangerous.

If the drafts of a coal furnace be inadvertently left open, the worst that can happen is to burn up the coal in the furnace. With the oil burner, however, overheating would go on as long as the oil supply lasted.

The power atomizing type of burner best lends itself to a variety of automatic controls, and it is in this type that such controls have been most successfully utilized.

The thermostat is the device on automatic burners *which renders the burner active or inactive in the process of maintaining desired room temperatures.*

In the thermostat there is a member, actuated by temperature changes, which operates to maintain a constant temperature by shutting off or starting the burner.

In automatic oil burner installations there are boiler controls in addition to the room thermostat.

The boiler controls are termed hydrostats, if it be a hot water system, and pressurestats if it be a steam system.

This boiler control is operated dually with the room thermostat and controls conditions at the boiler while the thermostat controls temperatures in the room. By the use of the hydrostat the temperature of the water in the boiler is kept within certain limits, and in the case of the pressurestat the steam pressure is kept within certain limits regardless of the temperature conditions in the rooms.

NOTE.—Time-O-Stat control system, 3. *Operation on ignition failure:* Should there be any failure of the ignition to start the fire properly when the thermo switch calls for heat, the stack switch will not go to the hot position during the starting cycle and the continued passage of heat through the heat element will warp the bimetal unit to which the lockout switch is attached and after a period of approximately a minute and a half the lock out switch will trip to the off position and shut down the oil burner by opening this switch. When this switch is open, current can no longer pass to any part of the lock switch system and in order to re-establish any operation in the lock switch system or the oil burner, it is necessary to reset the lockout switch by means of the manual reset in the lock switch. It has been demonstrated that a failure of ignition as the oil burner starts usually requires that some attention be provided for correction of the trouble, hence the opening of the lockout switch is made so that it will not reclose automatically.

In addition to the controls just mentioned, it is essential that precaution be taken *to cut off the burner in the event that ignition fails to take place.*

In such burners as permit, a drip bucket or sump is provided to catch the unburned fuel which flows to it when ignition fails. This device trips when a certain quantity has been delivered to it and either cuts off the oil supply or breaks the power circuit, in either case rendering the burner inoperative as to the generation of heat and flow of oil. The machine must then be reset by hand before operation can be resumed.

One of the chief objections to this control is the clogging of the line which delivers the unburned oil to the drip bucket or sump. owing to the accumulation of soot, scale, etc. Liberal passages offset this tendency to a great extent.

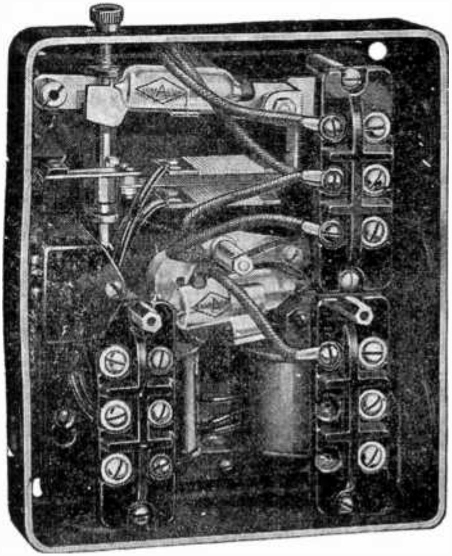
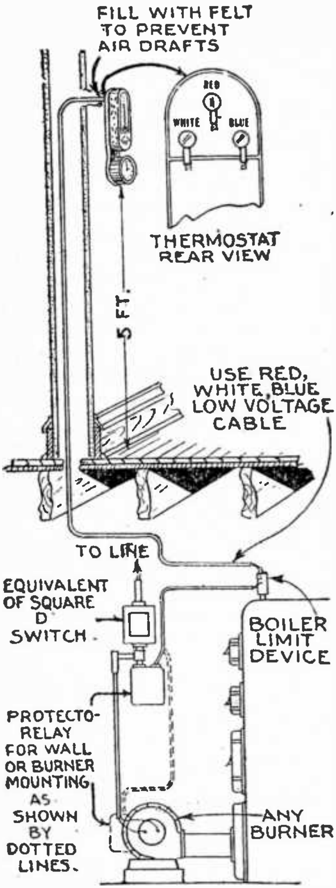


FIG. 8,717.—Time-O-Stat lock switch. This switch provides full automatic operation for oil burners of the power driven intermittent on and off type for either domestic or commercial use. The lock switch system is known as a high voltage system and all of the units of the system operate at the voltage of the electrical supply line.

Another emergency control is designed on the assumption that so long as the pilot light burns, the charge will be ignited and accordingly a thermostatic member which is exposed to the heat of the pilot light breaks the power circuit when the pilot light is extinguished.



FIGS. 8,718 and 8,719.—Installation diagram showing thermostat and connection. The thermostat or mechanical thermometer is the part of the device placed in one of the central rooms which is set for the degree of temperature desired.

When the general design of the burner is such as to make the catching of unburned oil and its subsequent delivery to a sump or drip bucket impracticable, the stack control is utilized.

A thermostatic member is placed in the stack and if, after a predetermined period, it do not become heated, indicating that the burner has failed to function, the thermostatic member breaks the power circuit and stops the motor and supply of oil.

Low water emergency controls are also applied in some installations and there are other devices, such as alarm bells, which are employed in conjunction with these emergency controls. Doubtless even more ingenuity will be manifested in this direction as design progresses.

Operation of Control System.—As an example of the methods employed in heating control a description of the operation of the Minneapolis-Honeywell system is here given.

This system consists of three separate units, so designed that they are integral parts and will not operate the burner except as a whole. These units are the recycling motor switch, combustion safety control, or protectostat with special relay, and room thermostat. A limiting device can be incorporated in the system and is highly desirable.

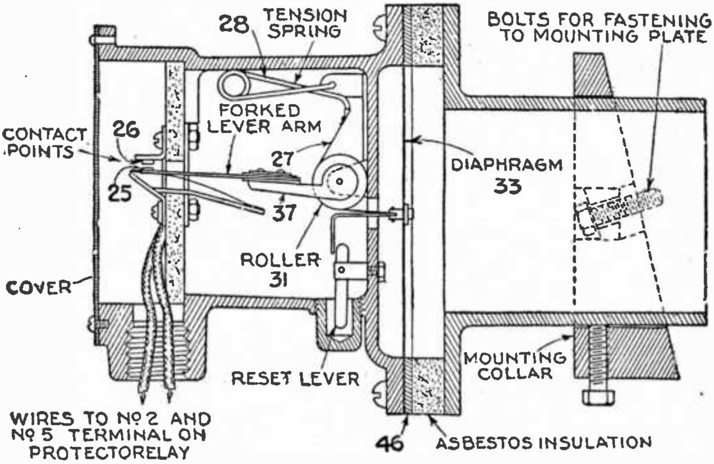
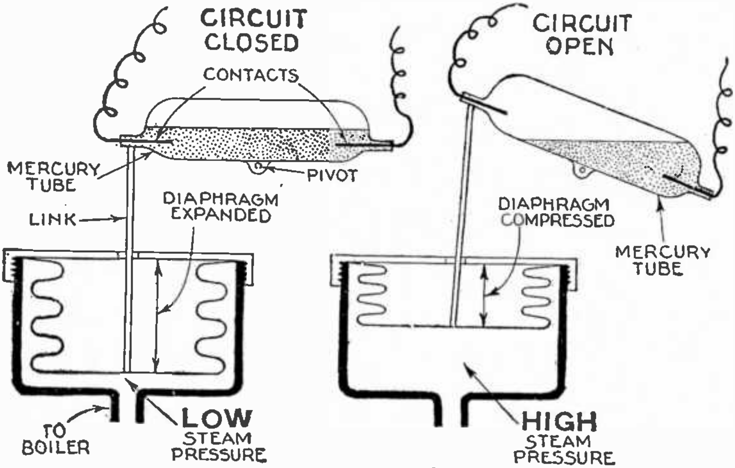


FIG. 8,720.—Minneapolis-Honeywell protectostat or combustion safety device. *It consists of* a main casting supporting an annular ring 46, to which a diaphragm 33, is attached. The diaphragm 33, and ring 46, expand and contract equally when subjected to the same temperature. This is the reason why the protectostat is not affected by changes in basement temperatures. If the diaphragm of the protectostat be subject to the radiant energy of an oil fire, the absorption of this energy will cause a temperature difference between diaphragm 33, and the ring 46. This causes the diaphragm 33, to expand rapidly and always buckle in the one direction as governed by strap 27, and spring 28, thus rotating roller 31, and raising arm 37, allowing contacts 25 and 26, to make. The closing of these contacts will close relay No. 2 of protectorelay. Evidently contacts 25 and 26, respond promptly to exposure to flame; also that the flame must be continued, for if it be not, the heat accumulated by the diaphragm is rapidly conducted to the ring 46 and housing, causing the diaphragm to cool and straighten out, separating the contacts 25 and 26.

The recycling motor switch provides low voltage current for the operation of the room thermostat and limiting device, and the low voltage side of the combustion safety control.

The maintaining switch and rotary line switch are of the rotary type and are always in definite relation to each other. They are integral parts of the motor switch, and in conjunction with the combustion safety control switch provide the safety features of the system.

The combustion safety control consists essentially of a thermostatic element of high temperature metal which is installed in the boiler or furnace smoke pipe and to which are connected suitable switches for both the line and low voltage circuits. These two switches are actuated by the expansion or contraction of the thermostatic element and prevent the continued operation of the oil burner under abnormal conditions. The combustion safety control closes the line circuit to the burner motor and opens the low voltage starting circuit as the burner goes into operation. When



FIGS. 8,721 and 8,722.—Elementary pressure switch illustrating principle. *In operation,* when the steam pressure is low the diaphragm or "bellows" will be expanded as in fig. 8,721, the link holding the mercury contact tube in horizontal position. In this position the mercury will cover both contacts closing the electric circuit which starts burner. As the steam pressure rises, the diaphragm is compressed which causes the mercury tube to tilt and open the circuit thus shutting off the burner as in fig. 8,722.

the burner is turned off by the motor switch these operations are reversed, and the controls are ready for a restart.

The system performs the following functions:

1. Starts and stops the oil burner at the command of the room thermostat, or when the temperature of the boiler or furnace has reached the predetermined maximum or minimum, if a limiting device be used.

2. Provides safety in the event of failure of ignition and premature extinguishment of the flame, thus preventing the abnormal discharge of oil in the fire box. It functions in from 15 to 45 seconds, depending upon local installation conditions.

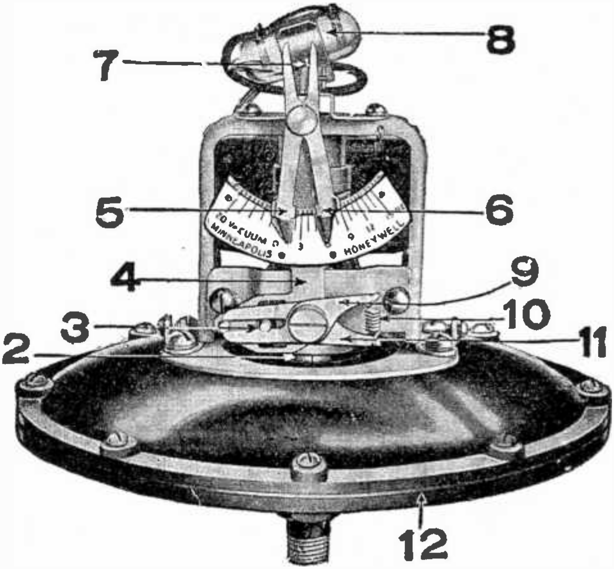


FIG. 8,723.—Minneapolis Honeywell vacuumstat or pressure switch for pressures lower than atmospheric as used on vacuum and so-called vapor systems. *It can be used* with systems employing a pump to maintain constant vacuum and both indicator hands may be set in the vacuum range. Within the base of the instrument is a flexible diaphragm that is forced upward as steam pressure is applied, carrying with it plunger 2, to which actuating pin 3 is attached. As the pressure increases pin 3, will cause arm 4, to which indicator hands 5 and 6, and the dial are attached, to move to the right. It will be noted that the upper half of the indicator hands extend and that pin 7, is attached to the mercury tube carrier and is located between the indicator hand extensions. As pressure is built up arm 4, assembly will move to the right until hand 6, extension meets pin 7, causing mercury tube 8, to tilt and stop the motor. As the pressure recedes, arm 4, assembly will move to the left until hand 5, extension meets pin 7, causing mercury tube to tilt and complete the circuit to the motor. Scissors 9, and 11, and spring 10, form the strain release.

3. In the event of a current failure, the motor switch will automatically recycle and start the burner again as current service is resumed.

In operation, when the room thermostat signals for heat, circuit is made to the maintaining switch, causing the motor switch to operate.

The rotary member of the line switch revolves, starts the burner motor, and carries the line circuit through the starting cycle. If ignition take place before the completion of the starting cycle, as it should, the heat of the stack will tilt the combustion safety control switch, and the line circuit to the burner motor will be carried through the line voltage tube thereof to continue the operation of the burner.

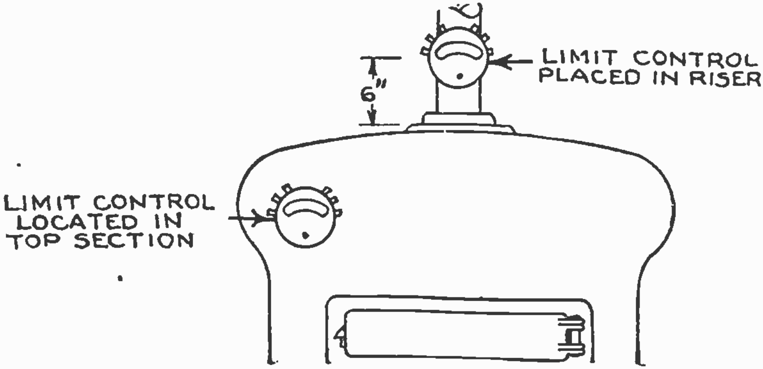
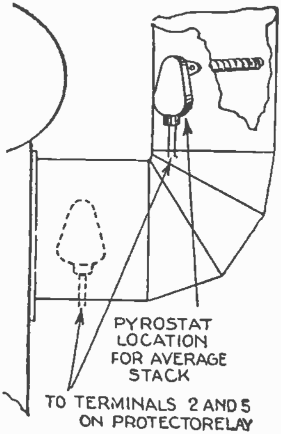
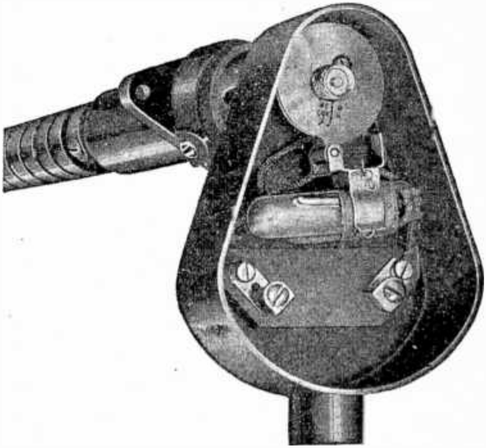


FIG. 8,724.—Minneapolis Honeywell aquastat or limit control showing placement. *It is used* to limit the water temperature in hot water heating plants. It may be used either independently to control the burner or in dual control with room thermostat. *For example,* with the room thermostat set at 70° and the aquastat at 160° the motor is shut off when the room temperature reaches 70° regardless of water temperature. However, if the water temperature reach 160° before the room temperature reaches 70° as might be the case when the boiler is being forced, the aquastat shuts down the burner. As soon as the boiler temperature has dropped a few degrees and should the room temperature still be below 70°, the aquastat will restart the motor. If the thermostat continue to call for heat, the aquastat will maintain the water temperature between 150° and 160° until the room temperature has reached 70°. This prevents overheating that at times may occur when only the room thermostat is used. Absolute control of the boiler at all times means more even and comfortable heating with a greater saving in fuel.

If ignition fail, no heat will be transmitted to the stack and at the completion of the starting cycle of the motor switch, the line circuit to the burner motor through the combustion safety control switch will be open, and the burner motor stopped. Both the burner motor and motor switch will be inoperative and in the dormant position until the release switch has been manually operated, which necessitates someone going to the basement to determine and remedy the cause of failure.

Should the fire be extinguished prematurely there will be an immediate drop in stack temperature which will tilt the combustion safety control switch and break the circuit to the burner motor. At the same time the circuit to the burner motor is broken through the line voltage mercury switch, contact is made in the low voltage mercury switch of the combustion safety control which closes the circuit to the motor switch and causes it to recycle.





FIGS. 8,725 and 8,726.—Minneapolis Honeywell stack switch or *pyrostat*. It is a combustion safety and operates on the change in stack temperatures. *Its operation* is caused by the tendency of the spirally wound bi-metallic strip to unwind with a rise in temperature. The spiral is so mounted as to project into the stack; one end is attached to the body of the pyrostat and the rotation of the free end as the temperature rises turns a shaft which passes back through the center of the spiral and into the body of the instrument. A ratchet toothed wheel is mounted on this shaft and turns with it. As the temperature rises, the ratchet wheel turns, carrying with it a phosphor bronze spring, which allows two contact points to come together completing the circuit to the protectorelay. As the ratchet wheel continues to turn with the continued rise in temperature, this spring passes from tooth to tooth without affecting the contact. If the stack temperature drop a predetermined amount the ratchet wheel will engage the spring and separate the contact point, breaking the circuit to the protectorelay.

The burner will be put through the starting cycle again, but if ignition fail the combustion safety control will remain in the cold position and the burner will stop. It will then be necessary for someone to determine and remedy the cause of failure and depress the release switch button before the burner can again be started. In the event of current failure when the burner is in the on position, the motor switch will automatically recycle and start the burner again as current service is resumed.

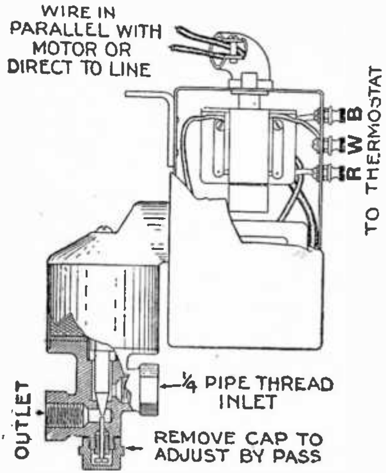


FIG. 8,727. — Minneapolis - Honeywell magnetic oil valve with relay. It is designed to control the high-low fire type oil burner directly from the room thermostat or limit control, or both. The valve is controlled by a small relay directly attached as shown. By this arrangement it is possible to operate a 110 volt valve by means of a low voltage thermostat. When the room thermostat calls for heat, a circuit is completed which energizes the valve, the plunger rises, allowing an increased amount of oil to flow and maintain the high fire. When the thermostat or limit control calls for less heat, the circuit to the valve is broken and the plunger falls to the low fire point.

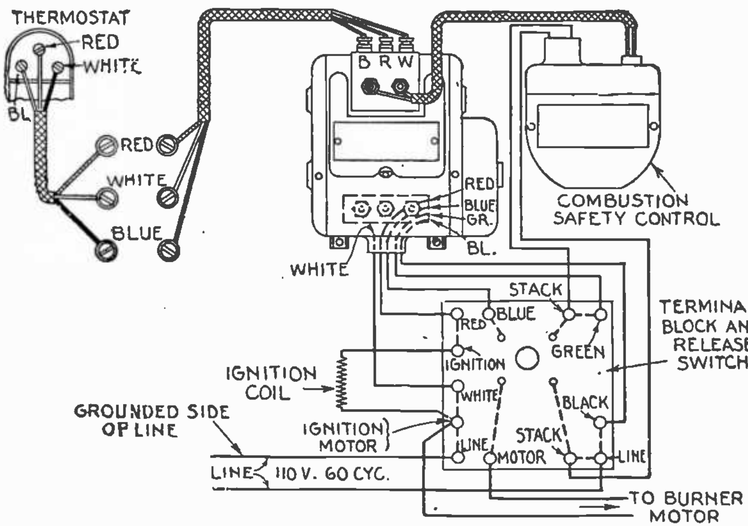
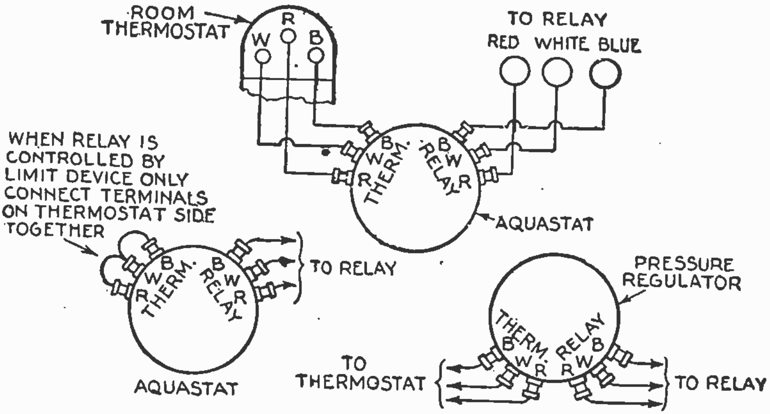


FIG. 8,728.—Minneapolis Honeywell connection diagram for motor switch; 110-220 volts, 60 cycle *a.c.*

Storage of Oil.—In contemplating the installation of an oil burner provision for storing fuel should be considered. For coal, the average home owner generally provides storage capacity ample to contain all the coal used during the heating season. With oil this is not usually the case. Aside from the added convenience of having a large supply of oil on hand, a more attractive price scale is offered to those consumers who buy oil in relatively large quantities.



FIGS. 8,729 to 8,731.—Diagram showing Minneapolis Honeywell thermostat and controls Minneapolis limiting devices were primarily designed for limiting the amount of heat generated by the furnace or boiler in excess of that which could be absorbed by the system. Ordinarily the limiting device is used in dual control with the thermostat, but it can be used as the controlling means without a thermostat if that be desirable. Such a hook up is easily made with the six terminal post instrument by bridging or linking the three posts marked *from thermostat*, together and omitting the thermostat, wiring the balance of the circuit in the usual way.

Large storage tanks are installed in various ways and usually must conform to the ordinances which regulate such matters in the particular locality. From this tank the oil must be fed to the burner by suitable means, since regulations restrict the quantity of oil which may be stored above the burner level.

Installation Notes.—The following information will be found helpful:

1. Not only the furnace, but the chimney and the smoke pipe should be cleaned prior to the installation.

2. The damper in the stack should be removed or wired wide open.

3. All air leaks around the furnace, the ash pit opening, the stack and the chimney should be caulked with furnace cement.

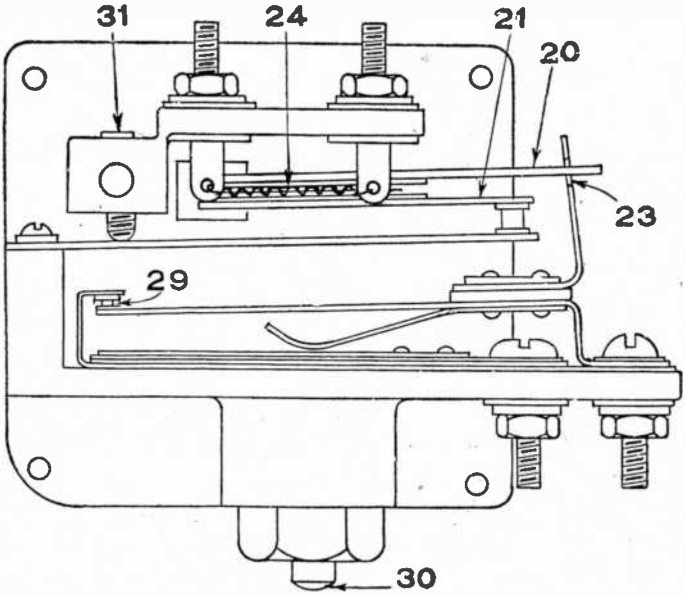


FIG. 8,732.—Minneapolis Honeywell thermal safety switch. *It acts* to provide a time element in the control system, allowing a sufficient ignition period, and affording a means of shutting down the burner as directed by the protectostat, preventing further operation until manually reset. *It consists of* the bimetallic strips 20 and 21, which when heated by the resistance wire grid 24, warp apart until the spring 23, is allowed to fall into the notched contacts 29, to snap open and latch, remaining so until blade 20 and 21, cool, when switch can be manually reset by push button 30. A bimetallic strip compensates for any movement of strips 20 and 21, due to rise and fall of the room temperature. The time required for the switch to operate can be varied by adjusting screw 31 to 30 seconds to 1½ minutes. Be very careful in making a change in adjustment, as a slight movement of screw will make a marked difference in time.

4. Local ordinances must be followed implicitly in regard to the installation of all electrical equipment.

5. All connections must be made tight. Oil leaks never take up. Clean all threads before putting on pipe joint cement and use a suitable cement. Red lead and similar dopes are not satisfactory, litharge and glycerine, *key paste*, or *pro tar* joint and gasket cement are best.

6. Pipe cement should be brushed on clean, dry male threads only.

7. Gasket unions must not be used. The brass seat ground joint type should be used.

8. Keep pipe line running absolutely parallel when running close together. All pipe must be straight without kinks and run in straight lines to give neat mechanical appearances.

9. Use all galvanized pipe and be sure it is clean inside. Rap and blow through it to remove all scale.

10. All electrical connections must be soldered.

11. See that the oil is of the proper grade to meet the needs of the burner and be careful to instruct the owner in regard to buying the right grade of oil to suit the requirements of the burner. This is an important detail.

12. See that the boiler is properly supplied with water.

13. See that the burner gets a fair start. Clean all flues of soot and dirt. Clean the boiler carefully. Remove all ashes and dirt.

14. Start burner and give it a thorough working test.

15. Leave the boiler or furnace room neat and clean.

TEST QUESTIONS

. *What is the effect of grade of oil on economy?*

2. *What is an oil burner?*

3. *Give full classification of oil burners.*

4. *Describe a gravity feed vaporizing burner.*

5. *What is the difference between a mixing and a non-mixing burner?*

6. *Explain how a non-mixing burner operates.*
7. *State the principle of the mixing type burner.*
8. *How does a hot plate burner work?*
9. *How is the oil broken up in an atomizing burner?*
10. *How are burners classified with respect to ignition?*
11. *In a hot plate burner how hot must the plate be heated?*
12. *What must be provided for safety if ignition fail?*
13. *What kind of a pilot flame is used in some automatically controlled vaporizing burners?*
14. *What are the conditions for proper ignition?*
15. *What determines the type of burner to be used?*
16. *What is combustion?*
17. *What happens with insufficient air supply?*
18. *Give some points on furnace design.*
19. *What is a thermostat?*
20. *Name the various devices necessary for automatic control.*
21. *Describe in detail the operation of the Minneapolis Honeywell control system.*
22. *What are the points relating to the storage of oil?*
23. *Give a few points on installation.*

CHAPTER 225

Air Conditioning

Air is a mechanical mixture, chiefly of the gases, oxygen and nitrogen, about in the proportion of one to four. Air nearly always contains certain impurities, such as ammonia, sulphurous acid and carbon dioxide.

The latter being a product of exhalation from the lungs and of complete combustion, is so universally present (about in the same proportion everywhere, except where concentrated by some local condition), that it may be regarded as a normal constituent of the air.

Air Conditioning.—The term *air conditioning*, sometimes called *manufactured weather*, means in general *the treatment to which atmospheric air is subjected in order to regulate its temperature and humidity, and to make it pure.*

The effects of air upon comfort and health are due to the reactions of the human being to variations in air temperature, humidity and purity. The sense or feeling of warmth is dependent upon the moisture content of the air, and for this reason comfortable and healthful heating requires coincident regulation of humidity.

The purity of the air breathed by the human being is, of course, primarily important to his physical well being and personal efficiency is materially depressed by air that is contaminated with foreign matter, particularly in congested centers, manufacturing districts, or in proximity to any source of pollution.

Air conditioning is a sure and sane means of eliminating the personal inefficiencies resulting from improper air qualities in spaces enclosing human beings.

Humidity.—By definition humidity of the air is *the amount of water vapor it contains.* Humidity is stated as:

1. Absolute, or

2. Relative.

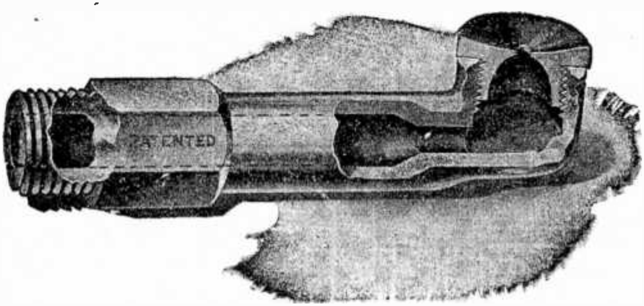


FIG. 8,733.—Carrier spray nozzle. The water entering through the small circular chamber tangentially, acquires a whirling motion and is discharged through a small orifice in the center of the cap. The approach to the orifice is conical in shape, so that the rotation, or whirling speed of the water is greatly increased at the instant of discharge

Absolute humidity is *the actual quantity of water in the air, usually expressed as so many grains of moisture in a cubic foot of air.*

A grain is 1/7,000 part of a pound. The amount of water the air is capable of holding is determined by the temperature. for *the warmer the air, the more moisture it can retain.* At 80° it can hold nearly twice as much moisture as at 60°.

Relative humidity denotes the relation between *the actual amount of water in the air and the maximum amount it is possible for the air to hold at the same temperature expressed in per cent.*

Air which is saturated has a relative humidity of 100%, while the air at the same temperature and holding but one-half of the saturation amount has a relative humidity of 50%.

It is the *relative humidity* and not the *absolute humidity*, that

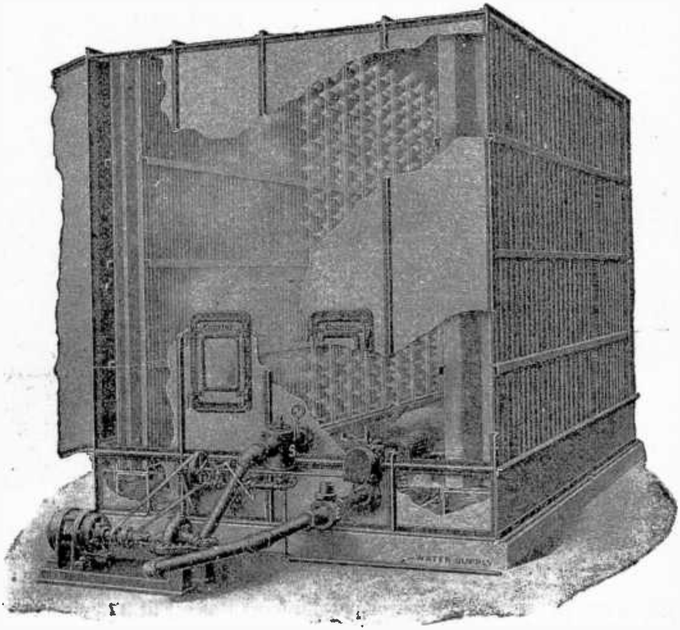


FIG. 8,734.—Carrier humidifier equipped with rotary strainer. ***In operation,*** air enters at right, through the baffle plates, passes through the spray chamber and leaves at the left through the washer eliminator plates. ***The parts are,*** R, rotary strainer; E, ejector heater P, pump; M, pump motor, S, pot strainer is important, for there exists a definite relation between the relative humidity and the moisture content of fibrous materials.

The higher the temperature of the air, the greater is its capacity to hold water. For example, air with a relative humidity of 70% at 90° contains

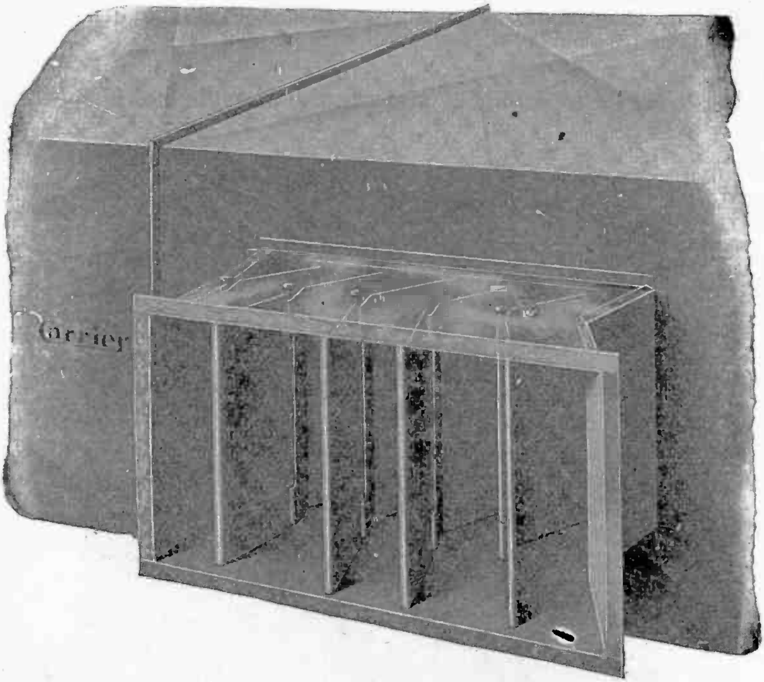


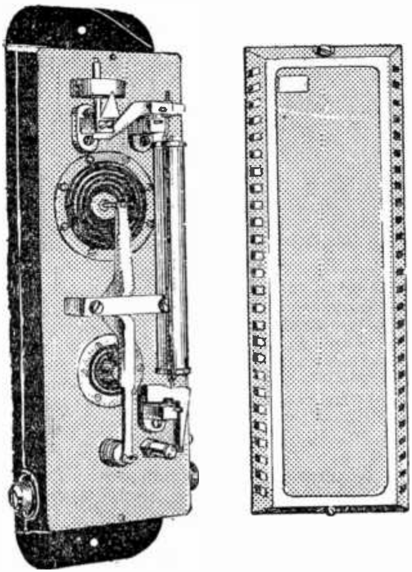
FIG. 8,735.—Carrier diffuser outlet (phantom view showing construction of the vanes).

about seven times as much water per cubic foot as air at 32° with the same relative humidity.

To put it another way, if air be heated without adding water vapor, the relative humidity decreases, and if it be cooled without taking out water vapor the relative humidity is increased.

The feeling as to whether the air is moist or dry *depends on relative and not absolute humidity.*

Since all substances which are affected by the presence of water vapor in the air absorb or give off water substantially in proportion to the relative humidity, this form of notation is the one most commonly used, and humidity is generally understood to mean relative humidity, or percentage of saturation.



FIGS. 8,736 and 8,737.—Carrier adjustable hygrostat with cover removed to show the hygroscopic mechanism. This instrument varies the humidity in accordance with variations in temperature, maintaining any desired relation between the two.

Dew Point.—By definition, this is *the temperature at which air becomes saturated with water vapor.*

NOTE.—***Relative humidity*** is little understood by the average person, as indicated by the widespread (though now decreasing) use of radiator pans, and mechanical or electrically heated devices for the evaporation of moisture in homes or offices.

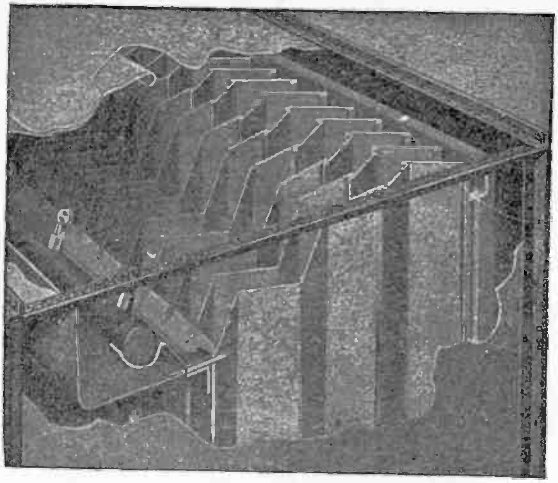


FIG. 8,738.—Buffalo air washer; part of casing removed showing *eliminator* in position. The eliminator which is integral with the scrubbing surface, is made up of a series of corrugated plates spaced and set in a vertical position across the discharge end of the spray chamber. The eliminator is made of a single sheet, the last three corrugations having projecting lips or gutters which remove the entrained water from the air. The plates are assembled in an angle iron frame demountably carried on clips on the sides of the casing. These angles are provided with slots into which the edges of the plates are slipped and held rigidly.

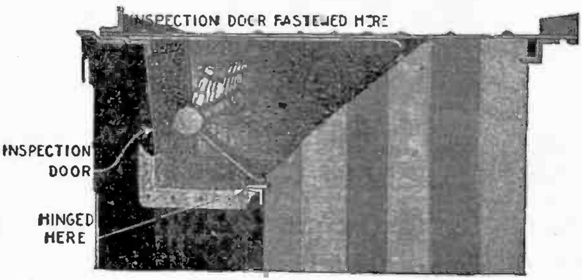
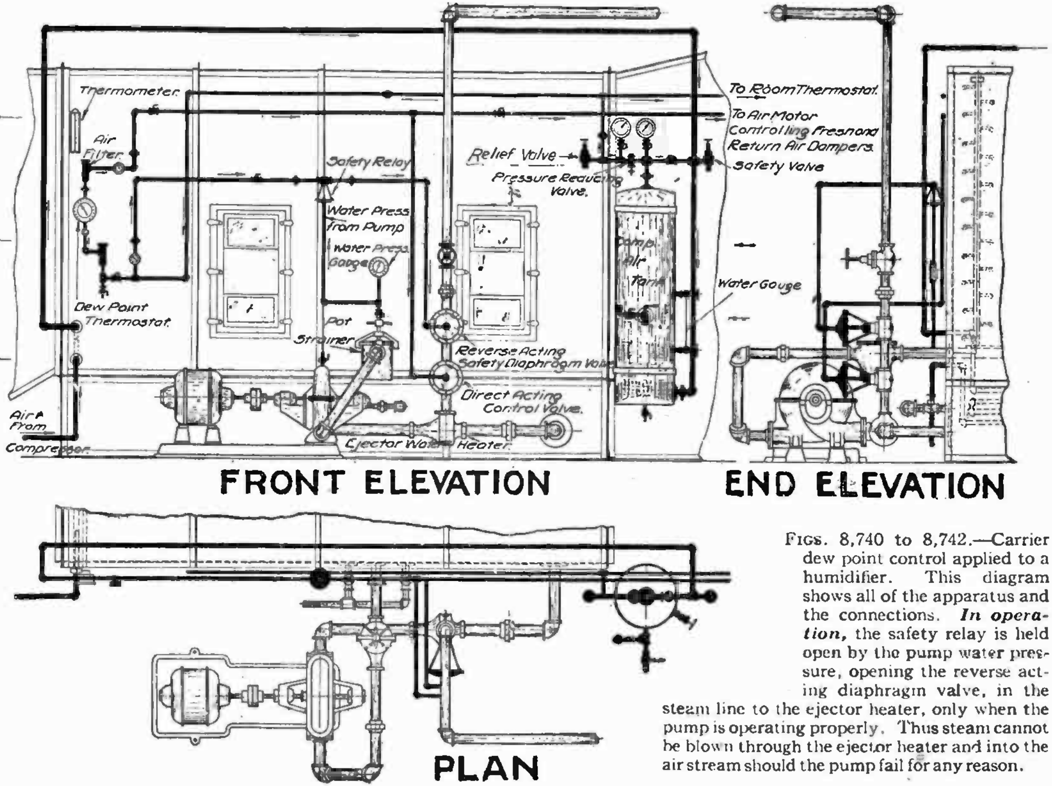


FIG. 8,739.—Buffalo flooding nozzles. The flooding of the eliminator, type A and B, washers, is done by an independent set of nozzles across the top. These nozzles distribute the water over the washing surface uniformly. The flooding is used continuously but provision is made for shutting off atomizing sprays in summer on very humid days. When the atomizing sprays are shut off, the increase in the humidity is so small that it practically amounts to nil.



FIGS. 8,740 to 8,742.—Carrier dew point control applied to a humidifier. This diagram shows all of the apparatus and the connections. ***In operation,*** the safety relay is held open by the pump water pressure, opening the reverse acting diaphragm valve, in the steam line to the ejector heater, only when the pump is operating properly. Thus steam cannot be blown through the ejector heater and into the air stream should the pump fail for any reason.

Since the capacity of air to hold water vapor decreases with lowering temperature, it is always possible by cooling the air to reduce its capacity to the point where the water vapor present just equals this capacity. The air is then said to be *saturated*.

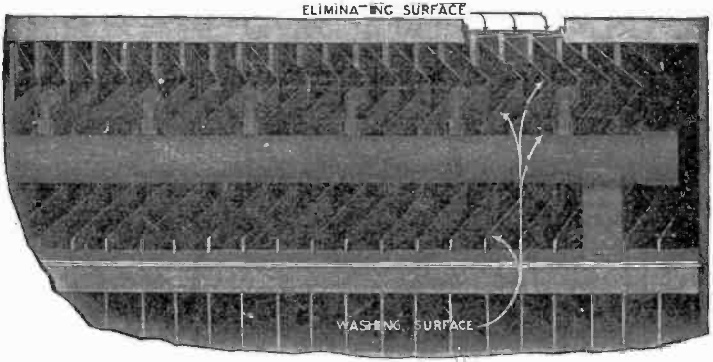


FIG. 8,743.—Buffalo eliminators; front view showing washing surface and narrow passages through which the air passes. The eliminators are so arranged that the first four corrugations are kept constantly flooded with a sheet of water which catches any solid matter, not already precipitated by the first set of sprays, and washes it to the settling tank. The wet surface exposed to the air thus obtained amounts to 19.5 sq. ft. of washing surface per 1,000 cu. ft. of air per minute, counting only the side of the corrugation against which the air impinges.

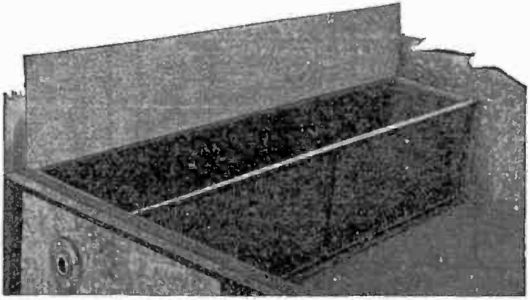


FIG. 8,744.—Buffalo suction compartment with screen cover. The settling tank is divided into two compartments by a brass wire cloth strainer, through which the water passes before entering the suction of the pump. This strainer offers a surface of more than one sq. ft. for each foot in width of the tank. The area of the strainer being many times the area of the suction pipe, provides a thorough filtering of the water at very low velocity.

If cooled below this saturation point, the capacity is still further decreased, the air cannot hold as vapor all of the water present, and the excess condenses into visible form as fog or dew. Accordingly, this condensation begins at the *dew point*.* When the relative humidity is 100%, the air is fully saturated, and no more *invisible* vapor can be added without precipitation as dew, fog, or rain.

Wet and Dry Bulb Hygrometer.—This is a device *for measuring the relative humidity* or hygrometric state.

It consists of two thermometers mounted side by side, the bulb of one being kept moist by means of a loose cotton wick

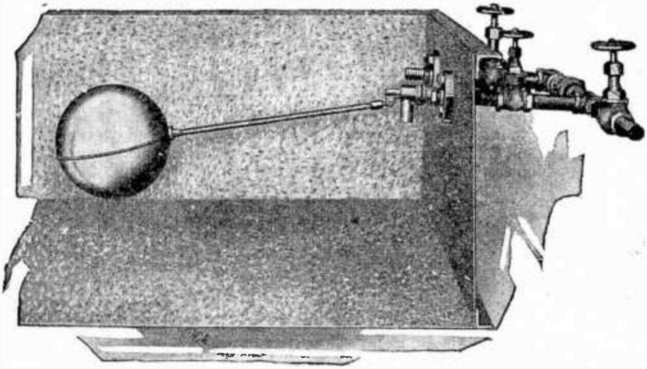


FIG. 8,745.—Buffalo automatic make up and quick filler. The required water level in the tank is automatically maintained by the float valve here shown. This allows constant operation of the pump at uniform suction head. It is also essential that provision be made for rapid filling of the tank after cleaning, and this is provided for by the extra flanged pipe inlet, which also serves as a hose connection.

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*NOTE.—*Example of dew point.*—A good illustration is the sweating of a vessel of ice water on a hot day. What really happens is that a thin film of air surrounding the vessel is cooled below the dew point, and the excess water is deposited as sweat. To put it in figures, if the air be at 72° with 60% relative humidity, it contains about 5 grains of water to the cubic foot. If the layer of air around the vessel be cooled to 42°, the air at this temperature can hold only 3 grains per cubic foot *when saturated*, and the extra two grains per cubic foot is precipitated or deposited on the vessel as sweat. The same thing happens in the formation of dew out of doors when the lowering of temperature at night brings the air near the ground below the dew point. Frost is formed whenever the dew point is below 32° or freezing temperature.

tied around it, the lower end of which dips into a vessel of water.

On account of evaporation from the bulb, this instrument is cooled, and indicates a lower temperature than the other, the difference depending upon

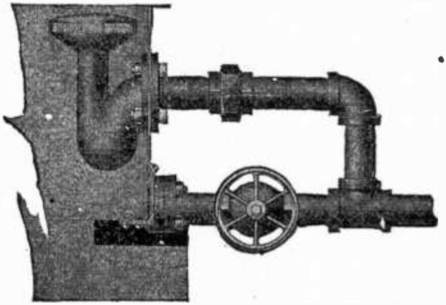


FIG. 8,746.—Buffalo water sealed overflow and drain. The water sealed overflow pipe is bolted to the side of the tank. Hooded construction prevents waste of the spray water. A drain box connection which can be easily cleaned is provided under the tank.

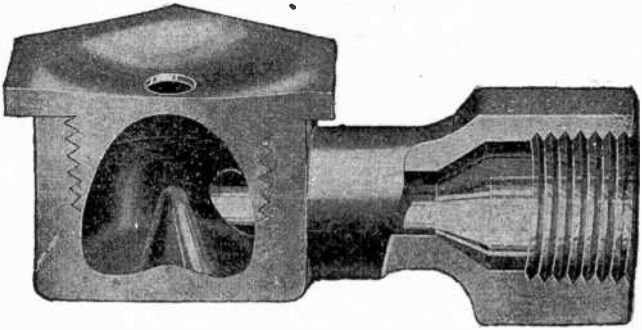


FIG. 8,747.—Sectional view of Buffalo spray nozzle. *In operation*, water enters a small circular chamber tangentially, which gives it a whirling or centrifugal action. The approach to the discharge opening is conical in shape, so the rotation, or whirling speed of the water, is greatly increased as it approaches the discharge. The effect of this arrangement is to give a most minutely divided or atomized spray, which offers an enormous amount of surface for washing and evaporation. The construction of the nozzle is such as to make it free from clogging with foreign material. The area of orifice of the nozzle is ample. In order to provide against clogging of the strainer, at least 12 sq. ins. of strainer screen is provided for each and every spray nozzle, giving a strainer surface 280 times the area of the nozzle orifice.

the rate of evaporation and hence upon the amount of aqueous vapor present in the air.

There is no simple relation between the readings and the hygrometric state; the latter is deduced therefore by reference to tables, although various empirical formulæ have been proposed.

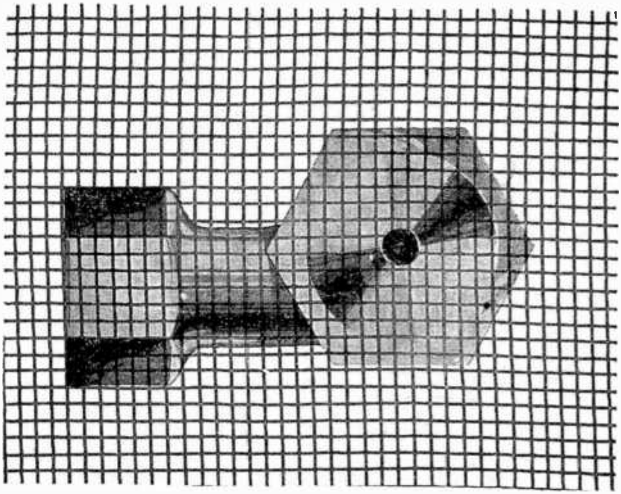


FIG. 8,748.—Buffalo spray nozzle under strainer screen, exact size.

The accompanying relative humidity tables are for use with wet and dry bulb thermometers. Directions are given under the tables.

Accurate readings can be obtained only when the air is caused to pass very rapidly over the moistened wick, either by means of a fan, aspiration, or by whirling the thermometer. The latter is the usual method, the instrument, comprising a dry bulb and a wet bulb thermometer mounted on a handle or chain for whirling, being known as a *sling psychrometer*.

No stationary wet and dry bulb hygrometer mounted on a wall (unless in a strong air current) can indicate the true wet bulb temperature and such instruments are to be avoided.

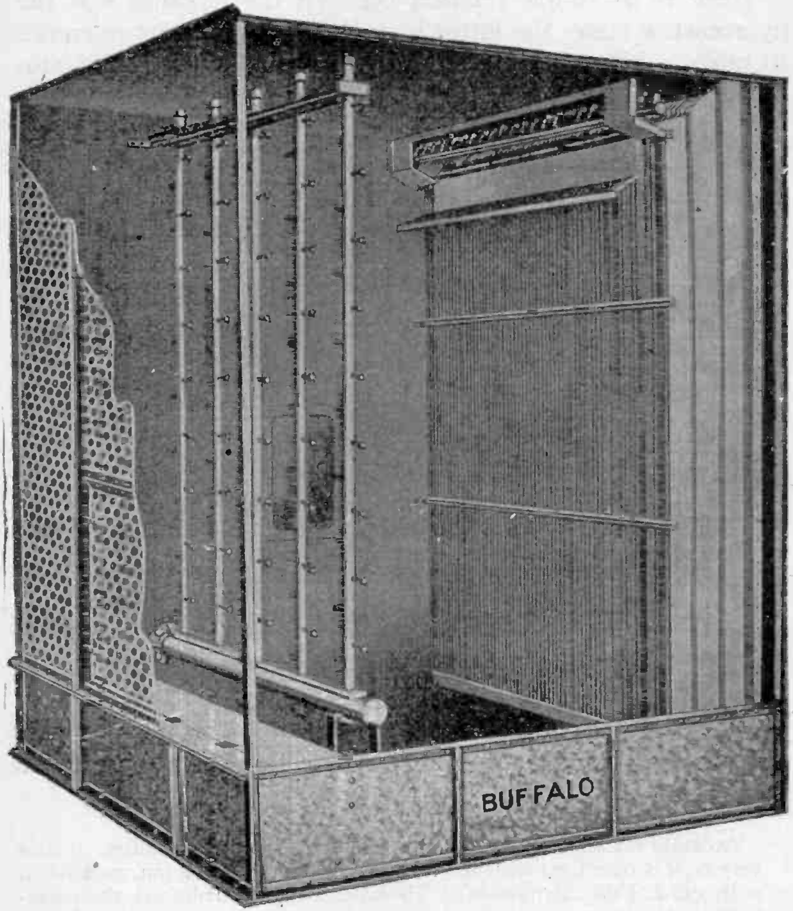


FIG. 8,749.—Buffalo type A, air washer with side and distributing plate removed to show interior construction.

RELATIVE HUMIDITY TABLES

FAHRENHEIT DEGREES. BAROMETER 29 INCHES.

Reading of Dry-Bulb Thermometer	Difference in Degrees Between Wet- and Dry-Bulb Thermometers											
	1	2	3	4	5	6	7	8	9	10	11	12
32	90	79	69	60	50	41	31	22	13	4		
33	90	80	71	61	52	42	33	24	16	7		
34	90	81	72	62	53	44	35	27	18	9	1	
35	91	82	73	64	55	46	37	29	20	12	4	
36	91	82	73	65	56	48	39	31	23	14	6	
37	91	83	74	66	58	49	41	33	25	17	9	1
38	91	83	75	67	59	51	43	35	27	19	12	4
39	92	84	76	68	60	52	44	37	29	21	14	7
40	92	84	76	68	61	53	46	38	31	23	16	9
41	92	84	77	69	62	54	47	40	33	26	18	11
42	92	85	77	70	62	55	48	41	34	28	21	14
43	92	85	78	70	63	56	49	43	36	29	23	16
44	93	85	78	71	64	57	51	44	37	31	24	18
45	93	86	79	71	65	58	52	45	39	33	26	20
46	93	86	79	72	65	59	53	46	40	34	28	22
47	93	86	79	73	66	60	54	47	41	35	29	23
48	93	87	80	73	67	60	54	48	42	36	31	25
49	93	87	30	74	67	61	55	49	43	37	32	26

Reading of Dry-Bulb Thermometer	Difference in Degrees Between Wet- and Dry-Bulb Thermometers																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
50	93	87	81	74	68	62	56	50	44	39	33	28	22	17	12	7	2
51	94	87	81	75	69	63	57	51	45	40	35	29	24	19	14	9	4
52	94	88	81	75	69	63	58	52	46	41	36	30	25	20	15	10	6
53	94	88	82	75	70	64	58	53	47	42	37	32	27	22	17	12	7
54	94	88	82	76	70	65	59	54	48	43	38	33	28	23	18	14	9
55	94	88	82	76	71	65	60	55	49	44	39	34	29	25	20	15	11
56	94	88	82	77	71	66	61	55	50	45	40	35	31	26	21	17	12
57	94	88	83	77	72	66	61	56	51	46	41	36	32	27	23	18	14
58	94	89	83	77	72	67	62	57	52	47	42	38	33	28	24	20	15
59	94	89	83	78	73	68	63	58	53	48	43	39	34	30	25	21	17
60	94	89	84	78	73	68	63	58	53	49	44	40	35	31	27	22	18
61	94	89	84	79	74	68	64	59	54	50	45	40	36	32	28	24	20
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29	25	21
63	95	90	84	79	74	70	65	60	56	51	47	42	38	34	30	26	22
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31	27	23
65	35	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26
67	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28
69	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29

Reading of Dry-Bulb Thermometer	Difference in Degrees Between Wet- and Dry-Bulb Thermometers																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32
73	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34
75	96	91	87	82	78	74	70	66	63	59	55	51	48	44	41	38	34
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	36
77	96	91	87	83	79	75	71	67	63	60	56	52	49	46	42	39	36
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37
79	96	91	87	83	79	75	71	68	64	60	57	54	50	47	44	41	37
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38
82	96	92	88	84	80	76	73	69	65	62	58	55	52	49	46	43	40
84	96	92	88	84	80	77	73	70	66	63	59	56	53	50	47	44	41
86	96	92	88	85	81	77	74	70	67	63	60	57	54	51	48	45	42
88	96	92	88	85	81	78	74	71	67	64	61	58	55	52	49	46	43
90	96	92	89	85	81	78	75	71	68	65	62	59	56	53	50	47	44
92	96	92	89	85	82	78	75	72	69	65	62	59	57	54	51	48	45
94	96	93	89	86	82	79	75	72	69	66	63	60	57	54	52	49	46
96	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53	50	47
98	96	93	89	86	83	79	76	73	70	67	64	61	59	56	53	51	48
100	96	93	90	86	83	80	77	74	71	68	65	62	59	57	54	52	49

To use tables, find difference in reading between dry- and wet-bulb thermometers. Under that figure, opposite dry-bulb reading, find per cent of Relative Humidity. *Example:* Dry bulb 75°, wet bulb 63°, difference 12. Under 12 and opposite 75 find 51% Relative Humidity.

Moistening Effect of Air.—*Air at high relative humidities (regardless of the absolute humidity) exerts a greater moistening effect than air at lower relative humidities.*

The moistening effect of the air varies approximately with its relative humidity, without regard to the actual weight of water vapor present.

In a textile mill, for instance, where one of the chief functions of air conditioning is to control the moisture in the yarns in course of manufacture, it should now be obvious that temperature control is equally as important as moisture control, since it is upon the relative humidity (water vapor

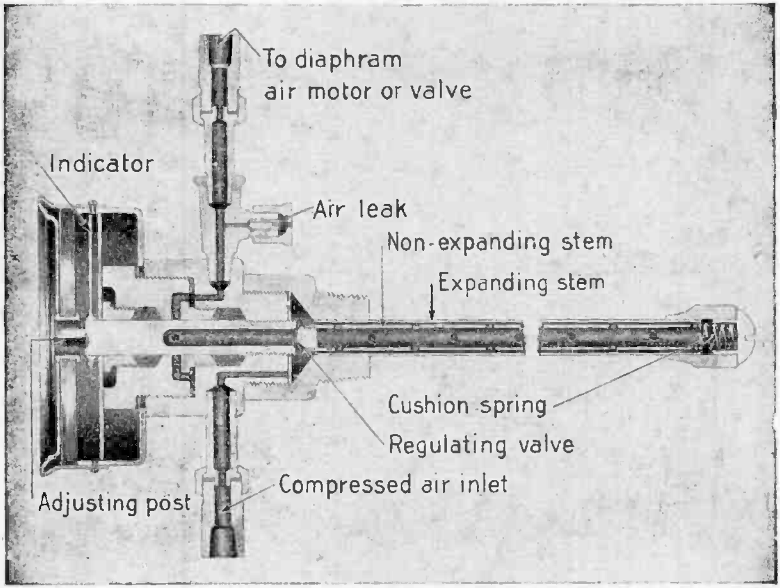


FIG. 3,750.—Carrier graduated thermostat; sectional view showing operating principle. ***It consists essentially of*** an outer expanding stem, usually of brass, and an inner non-expanding stem of nickel steel. These two members are rigidly connected at one end. The other end of the inner, non-expanding member, is provided with a bronze valve, ground to fit an adjustable valve seat. Between the inner and outer tubes there is an annular chamber. Compressed air, from a small auxiliary compressor, usually driven from the fan or pump shaft, is admitted to this annular space, and its passage through the instrument is regulated by the small valve attached to the non-expanding stem. As the temperature of the air surrounding the stem of the instrument rises, the outer member expands, the regulating valve recedes from its seat, and the compressed air passes through into the outlet chamber, from whence it goes to the diaphragm valve in the steam line to the spray water heater. Upon reaching this diaphragm valve, the compressed air moves it so as to decrease the amount of steam admitted to the ejector heater and thereby reduce the temperature of the spray water as required. When the temperature of the air leaving the conditioning machine falls below the point desired, the outer shell contracts and closes the compressed air supply to the diaphragm valve, whereupon the pressure upon the diaphragm of the valve is relieved through the air leak, as shown in the figure, and the valve opens, admitting steam to the spray water heater.

content as related to temperature) that the moistening effect of the air depends.

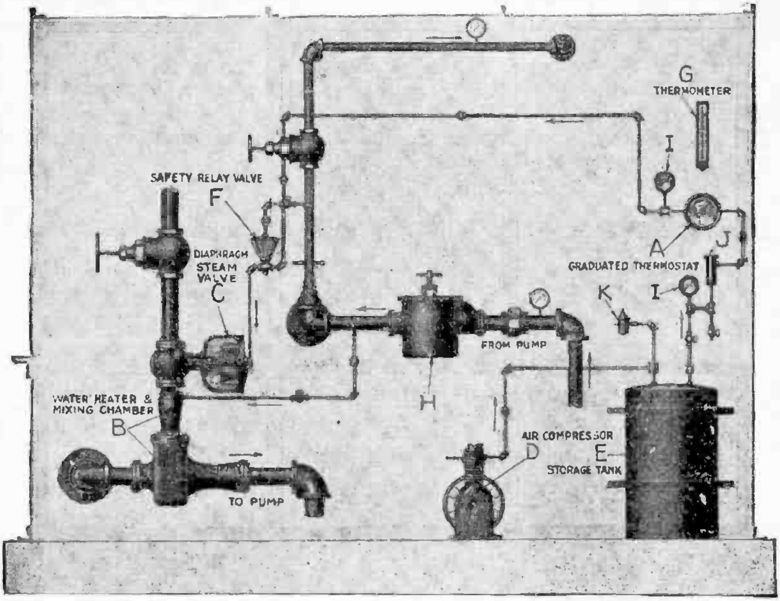


FIG. 8,751.—Buffalo ejector type dew point humidity control. ***In operation,*** saturation is produced by heating the spray water. This water supplies the latent heat of evaporation, and, in addition, raises the temperature of the incoming air to the desired dew point; that is, to the temperature necessary to hold the required amount of moisture. The water temperature is varied as may be necessary to maintain a constant dew point under variable conditions of entering air. The stem of a graduated thermostat **A**, is placed in the passage just beyond the eliminators, so that it is exposed to the temperature of the air leaving the washer. Any change in temperature causes a contraction or expansion of this thermostat and the temperature regulation is accomplished by contraction and expansion. A water heater and mixing chamber **B**, of the ejector type, is placed in the suction line to the pump. The diaphragm steam valve **C**, is placed in the steam line which supplies the water heater. This valve is operated by compressed air pressure from graduated thermostat **A**. The air compressor **D**, furnishes air at about 15 lbs. pressure to the storage tank **E**. The compressor is driven by the same motor that drives the spray water circulating pump. The diaphragm steam valve **C**, is normally closed. It only admits steam to the circulating water when air pressure is admitted to the diaphragm through the reverse acting thermostat **A**. This arrangement provides a safety feature in addition to a sensitive and accurate control, for if the air pressure should fail the steam would immediately be shut off. To provide for further safety from over humidification a safety relay valve **F**, is placed on the air line to the steam valve. This relay allows air to pass to the diaphragm steam valve **C**, only when the washer sprays are in operation.

Drying Effect of Air.—Briefly, *the drying effect of air varies approximately inversely with its relative humidity, the greater the relative humidity, the lesser the drying effect.*

It should be noted that it is the relative humidity which determines the effect and that, therefore, the effect depends upon both the temperature and the water vapor content of the air—since relative humidity depends upon both these factors.

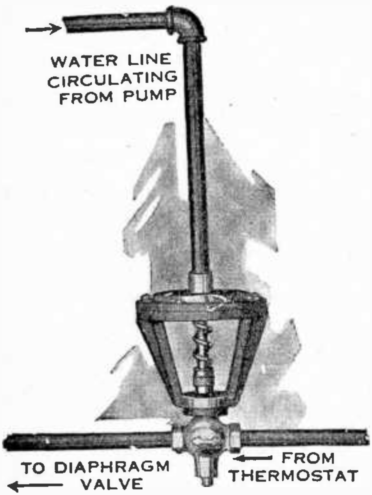
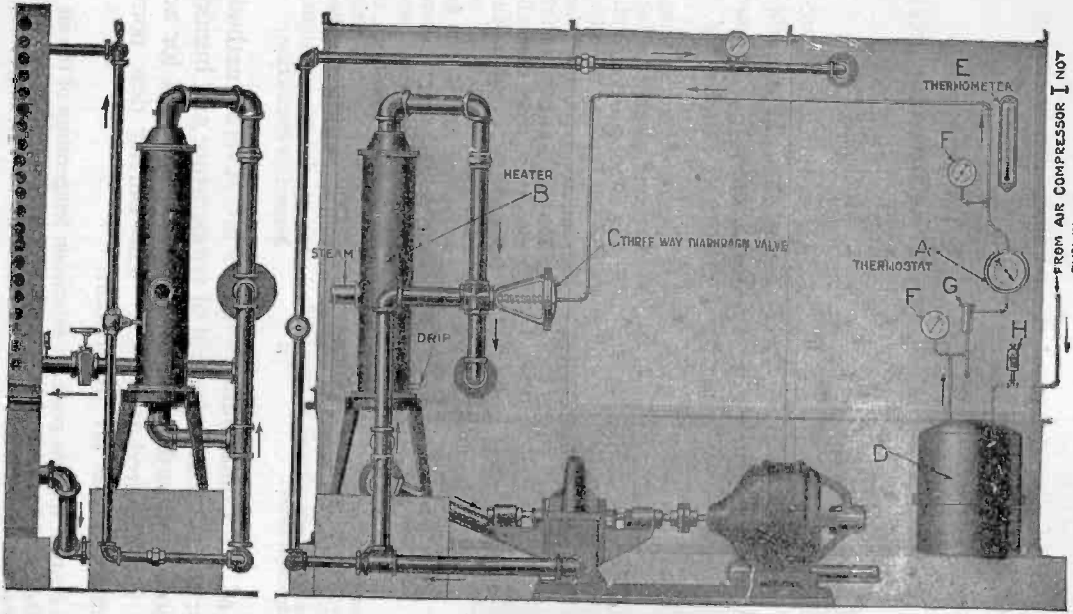


FIG. 8,752.—Buffalo safety relay valve.

Heating Effect of Air.—The quantity of heat which dry air contains is very small, because its specific heat is low, .2415 (for ordinary purposes) which means that one lb. of air falling one degree in temperature (Fahr.) will yield but .2415 of the heat which would be available from one lb. of water, reduced 1° in temperature. The presence of water vapor in the air materially increases the total heating capacity of the air because of the latent heat of the vapor itself.

Moist hygroscopic materials in the presence of dry air, even at high dry bulb temperatures, may actually be cooled, rather than heated. This occurs because the dry air immediately begins to evaporate moisture from the material and in so doing removes from the material, as well as from the air, the latent heat of evaporation.

Air Conditioning.—This operation (sometimes called "manufactured weather") involves four distinct air conditions upon



FIGS. 8,753 and 8,754.—Buffalo closed heater type dew point humidity control. Where steam is not available at a pressure of 3 lbs. or over, that is, where a vacuum steam heating system or hot water heating system is installed, an ejector heater cannot be depended upon for continuous and satisfactory service. In such plants a closed water heater is substituted for the ejector heater and safety device with the reverse acting diaphragm valve. The mixing valve *C*, is used with the closed water heater and is operated by the graduated action dew point thermostat. The seat of this valve takes intermediate positions to give the proper mixture of heated and by-passed water required.

the *relation of all* of which depend the comfort and health effects of indoor air.

These are:

1. Temperature;
2. Relative humidity;
3. Purity;
4. Motion.

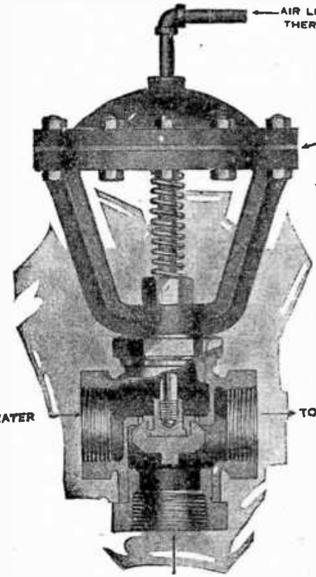


FIG. 8,755.—Carrier diaphragm valve. *It is located* in the steam line to the water heater, and is of the direct acting type, which means that it is held open by means of a spring, and closed when air pressure is admitted to its diaphragm motor.

Air conditioning accomplishes *the simultaneous control of the four conditions enumerated.*

Any system which neglects any *one* of these factors is not an air conditioning system. Hence a ventilating system or a fan heating system which merely moves unconditioned air, heated air, cooled air, filtered air or moistened air, is not an air conditioning system. Such systems have their legitimate applications, of course, but are too often confused with or miscalled air conditioning systems. hence this distinction.

Methods of Air Conditioning.—There are several methods employed for the automatic control of temperature and humidity and various standard forms of apparatus are used for accomplishing the required purposes. The Carrier dew point control is here given as an illustration.

With this control, the dew point, or saturation temperature of the air is automatically controlled by means of a simple expansion thermostat, exposed to the air at the instant of saturation in the air conditioning machine

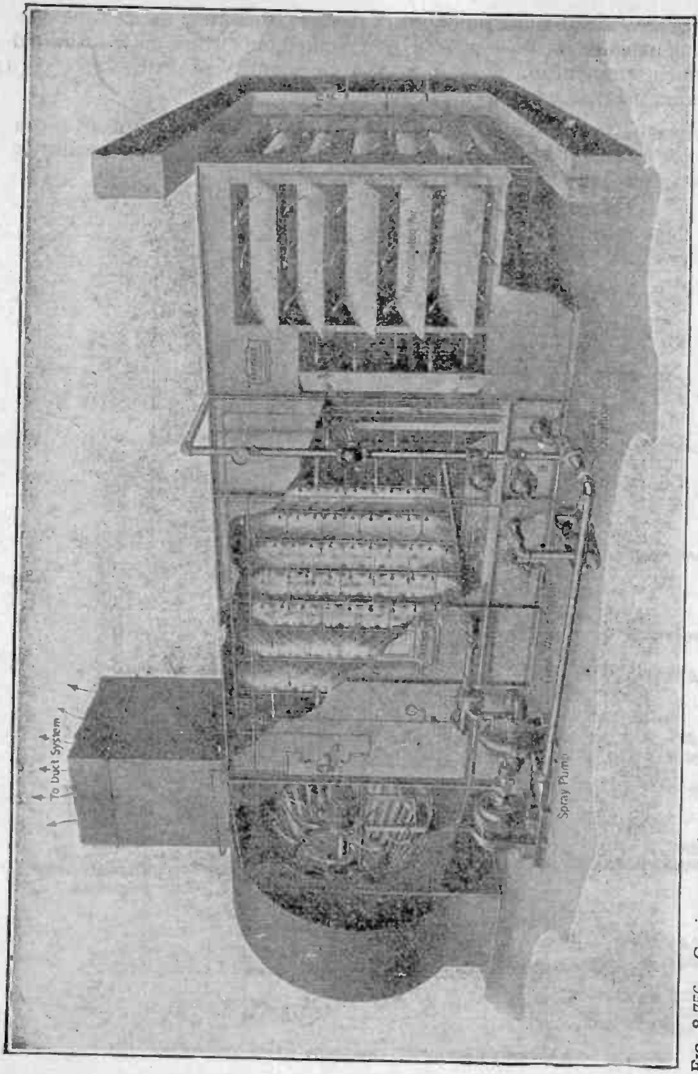


FIG. 8,756.—Carrier central station air conditioning unit showing the automatically controlled dampers, the spray chambers, the fan and the water circulation system. Within this chamber the air is completely cleansed, its moisture content adjusted, either increased or reduced. From the fan the air is delivered through the duct system to the rooms to be conditioned.

itself. Thus, the absolute humidity of the air is definitely fixed in the conditioning machine, because, as has been pointed out, where air is saturated at a given temperature, it contains a given quantity of water vapor corresponding to that temperature.

Obviously, any absolute humidity (*i. e.*, the number of grains of water vapor per cu. ft. of air) can be established by adjusting the thermostat to the corresponding temperature.

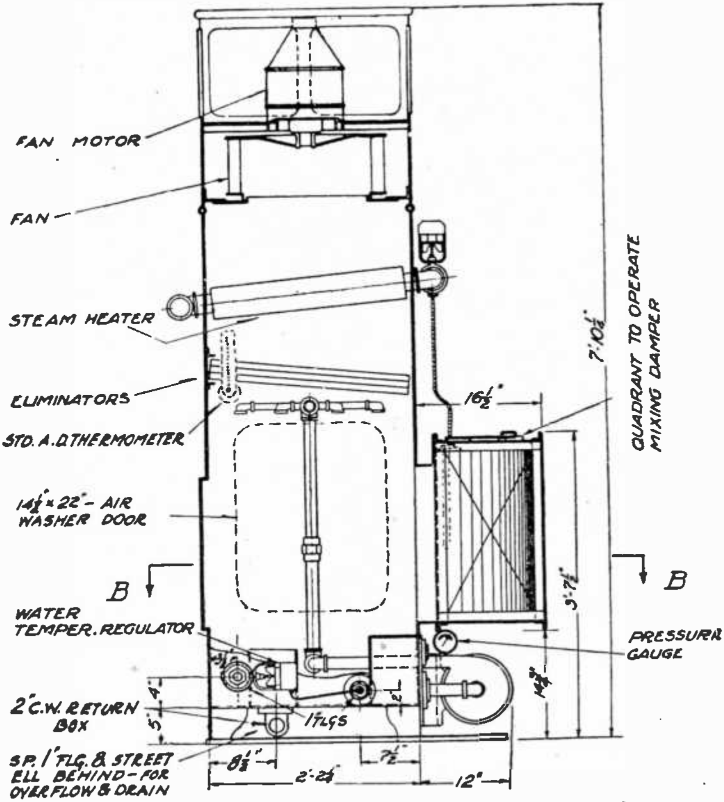


FIG. 8,757 —Carrier unit air conditioner, showing in detail its construction and operation

The saturated air leaving the machine is heated by passage through suitable heaters, and its dry bulb temperature is increased sufficiently to establish the required dry bulb temperature in the space being conditioned.

The temperature of the air leaving the heaters is controlled by means of a second thermostat located in the room itself, and regulating the steam admitted to the heaters.

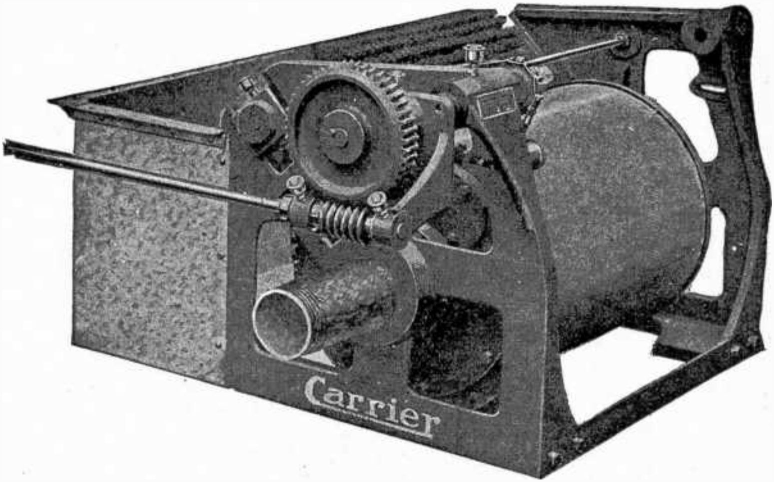


FIG. 5,758.—Carrier rotary strainer for removal of dirt or other foreign matter. The strainer is placed in the settling tank of the conditioning machine. The suction line to the pump is connected to a hollow trunnion, open to the interior of the revolving screen cylinder. A stiff cylindrical brush revolves against the surface of the revolving screen, sweeping it clear of accumulated dirt or fibrous matter. The dirt so collected by the brush is deposited in a small auxiliary tank, so that it does not again mingle with the water. The strainer tank requires cleaning about once a week, ordinarily, the operation takes not more than 15 minutes.

In certain instances it is permissible, during the summer season, for the dry bulb temperature to exceed that maintained in the winter, so long as the relative humidity is controlled at an approximately constant value. In such instances there is no provision for dehumidification, and the humidifier is used to effect as great a degree of cooling as possible by evaporation only. The dew point temperature of the air leaving the humidifier then becomes the same as the wet bulb temperature of the outdoor air, the dew point thermostat being inoperative.

The dry bulb temperature in the enclosure is regulated in accordance with the prevailing wet bulb temperature of the entering air and this regulation is accomplished by means of a hygrostat located within the enclosure, usually adjacent to the thermostat which is used for winter control. The shift from the room thermostat to the room hygrostat can be made either manual or automatic as required. In most cases it is automatic.

The hygrostat, which is sensitive to relative humidity, controls the dry bulb temperature of the enclosure by regulating the volume of air admitted. This avoids the use of heaters, and takes advantage of the available sun

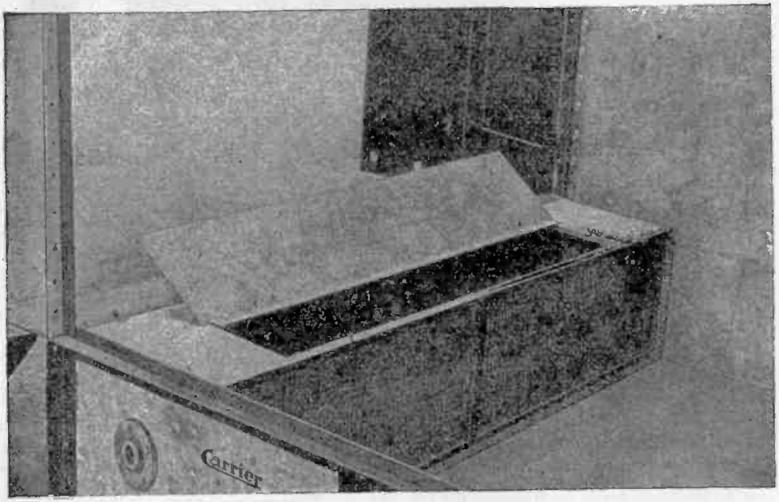


FIG. 8,759.—Carrier fixed suction strainer, the cover open. The pump connection shows in the lower left corner.

heat, or heat from sources within the room. If the dry bulb temperature of the enclosure be high, the hygrostat opens the volume dampers and admits a greater volume of cooler air from the humidifier.

If the dry bulb temperature be low, the hygrostat reduces the volume of cooler air and permits the sun's heat, or the heat from sources within the enclosure, to restore the desired condition.

If in summer, a dry bulb temperature lower than that of the atmosphere must be maintained, a dehumidifier is provided. In this case the dehumidifier acts, during the winter, as a humidifier, under dew point control, and, during the summer, functions as a dehumidifier under the same dew point control, except that the dew point thermostat at the dehumidifier, instead of regulating the steam to the water heater, regulates the three way mixing valve in the pump suction line, controlling the temperature of the spray water by admixture of the warmer water from the spray chamber settling tank and cold water from the refrigerating coils, or other source; and the room thermostat, instead of regulating the steam to the heaters, regulates

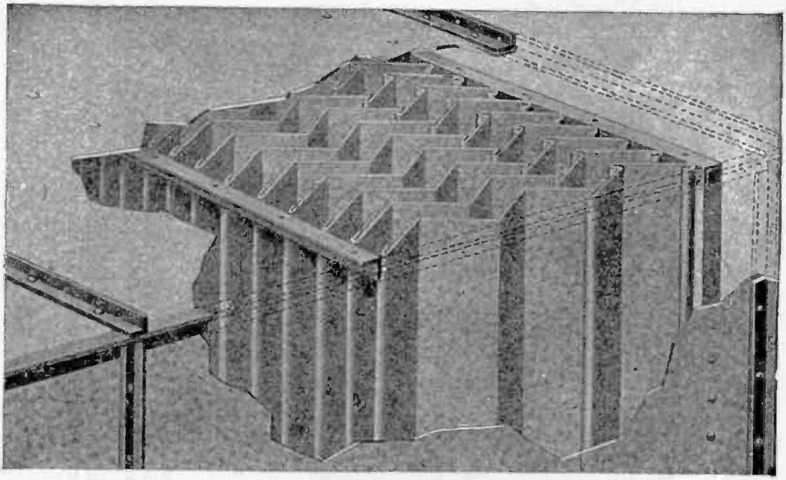


FIG. 8,760.—Carrier washer eliminator plates. ***In operation,*** as the air leaves the spray chamber it passes through a set of staggered washer eliminator plates which baffle the air from right to left, so that it is scrubbed against the wet surfaces of the plates. The cleansing action resulting is extremely effective, removing practically all of the solid foreign matter carried in the air, including those air borne organisms of disease, mold or decay with which the air may be contaminated. The latter three corrugations of the plates are provided with lips or gutters which trap the entrained free water carried in the air stream, remove it and return it to the settling tank.

the volume dampers in the supply ducts, controlling the temperature of the room by means of the volume of cold, dehumidified air permitted to enter.

The two control instruments, then, regulate the actual water vapor content of the air and its dry bulb temperature, thereby fixing its relative humidity.

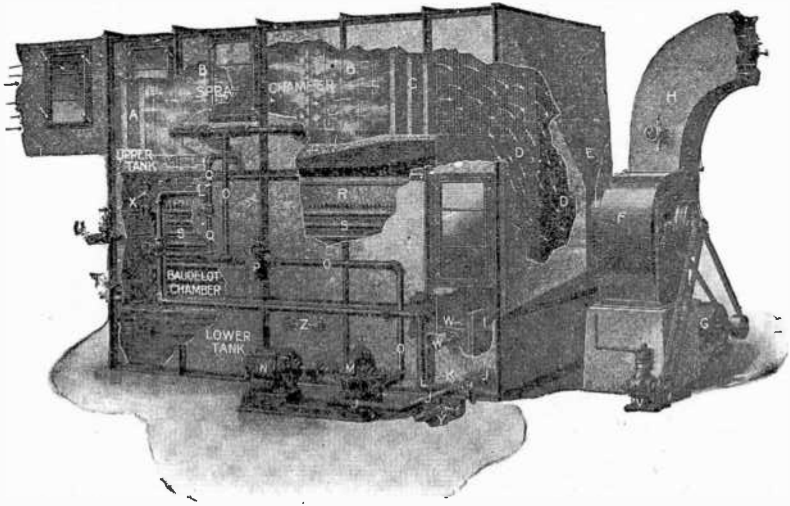


Fig. 8,761.—Carrier aenumidifier. A, distributor plates; B, sprays; C, eliminator plates; D, outlet; E, fan connection; F, fan, G, fan motor; H, fan outlet connection to duct system; I, pump suction screen; J, pump suction line; K, three-way mixing valve; L, line from upper tank to three-way valve; M, pump; N, pump motor; O, pump discharge line; P, pot strainer; Q, by-pass to upper tank for quick cooling at start; R, drip troughs over baudelot coils; S, baudelot cooling coils; T refrigerant connections; V, air compressor for automatic control; W, overflow from lower tank; X, upper tank drain; Y, lower tank drain to sewer; Z, fresh water connections for make up and cleaning.

There are many variations of this control, but to a general understanding of air conditioning practice, a knowledge of this control is sufficient.

In the complete conditioning of air, its purity must be maintained. Air conditioning machines, humidifiers and dehumidifiers, thoroughly wash and cleanse the air, removing practically all of the solid or soluble gas impurities, and most of the aerobic organisms of disease and decay.

The cleansing effect of the Carrier air conditioning machine is produced by the finely divided and uniformly dense water spray and the staggered washer eliminator plates against which the air is baffled as it leaves the

FIGS. 8,762 to 8,764.—Webster spiral mist nozzle disassembled to show construction.

chamber. These plates are flooded with water, so that their wet surfaces accomplish an extremely effective cleansing action.

Addition of Moisture to Air.—The addition of moisture to the air is termed *humidification*, and the conditioning machine, when functioning to add moisture to the air, is termed a *humidifier*. A humidifier is, in reality, *a low pressure, low temperature boiler in which the water is evaporated into vapor and then caused to mix with the air.*

In a humidifier, the water acts as the medium which conveys heat to the air, and as the source of the water vapor required to saturate the heated air. When the temperature of the spray water is above that at which the moisture in the air will condense, the conditioning machine is functioning as a humidifier.

Removal of Moisture from Air.—When the conditioning machine is functioning to remove moisture from the air, it is called a *dehumidifier*, and the process of removing moisture from the air is termed *dehumidification*.

The removal of moisture from the air is accomplished by condensation, the temperature of the air being lowered below its dew point, thereby causing the excess water to condense and fall into the tank of the conditioning machine.

In this case the water acts solely as a conveyor of heat from the air (besides its cleansing action) and, as such, the finely divided mist is extraordinarily effective (practically 100%).

In the Carrier system the dehumidifier functions either as a humidifier or as a dehumidifier, without alteration or rearrangement, except that the valves in the control line from the dew point thermostat are adjusted to connect the steam control to the water heater for winter operation, and to connect the three way mixing valve for summer operation.

Whether the requirement is humidification or dehumidification, the apparatus always operates under accurate automatic control, maintaining the required indoor conditions winter and summer, regardless of the outdoor weather.

Air Movement.—The effectiveness of any air conditioning apparatus depends as much upon the proper distribution of the air as upon the efficiency of the conditioning machine itself.

It may be said that an air conditioning installation is no better than its duct system. To be effective, the conditioned air must be uniformly distributed over the entire area of the enclosure, and, especially in closed or dry rooms, processing rooms, the circulation must not only be uniform, but vigorous.

Evaporative Cooling.—Since outdoor summer air is rarely fully saturated, there is usually a considerable difference between its dry bulb and its wet bulb temperature.

This difference is called the wet bulb depression. Due to the higher dry bulb temperature of summer, the wet bulb depression is greatest during the summer season.

As has been explained, the wet bulb temperature is that temperature to which air would be cooled, by evaporation, if the air were brought into contact with water and allowed to absorb sufficient water vapor to become saturated.

Thus, if outdoor summer air be drawn through a humidifier, wherein it will be completely saturated, its dry bulb temperature will be reduced to its wet bulb temperature, and the air will leave the humidifier at the outdoor wet bulb temperature. This cooling is accomplished entirely by evaporation, and is due to the latent heat required to convert the liquid water into water vapor, such conversion occurring the instant the air is brought into contact with the mist in the spray chamber of the humidifier, the heat being taken from the air.

The spray water in the humidifier is used over and over, only that quantity being added which is actually absorbed by the air. Thus, without any additional operating expense, a humidifier will, in summer, perform the function of cooling the air through the wet bulb depression.

The wet bulb depression is often, in some localities as much as 25° or even 30°, and quite commonly from 10° to 15°, even in localities adjacent to great bodies of water, where the humidity is high and the wet bulb depression, therefore, correspondingly low. In the vicinity of New York, for instance, the maximum outdoor wet bulb temperature is about 78°.

On such a day the dry bulb temperature would probably be about 90°, the wet bulb depression being 90° − 78° = 12°. In Denver, where the maximum wet bulb is usually less than 78°, the coincident dry bulb is usually much higher than 90°, resulting in a greater wet bulb depression, which means that more cooling can be accomplished by evaporation.

Precautions in Using the Sling Psychrometer.—This instrument, shown in fig. 8,772, consists of *two accurately graduated mercury thermometers mounted on a metal strip and equipped with a swivel handle or a chain to permit whirling.* The thermometers are known as the wet and dry bulb.

The wet bulb is provided with a closely fitting fabric cover, usually silk, which serves to retain liquid and keep the bulb wet during observations. The dry bulb is set somewhat higher on the metal strip than the wet bulb, to avoid the influence of evaporative cooling.

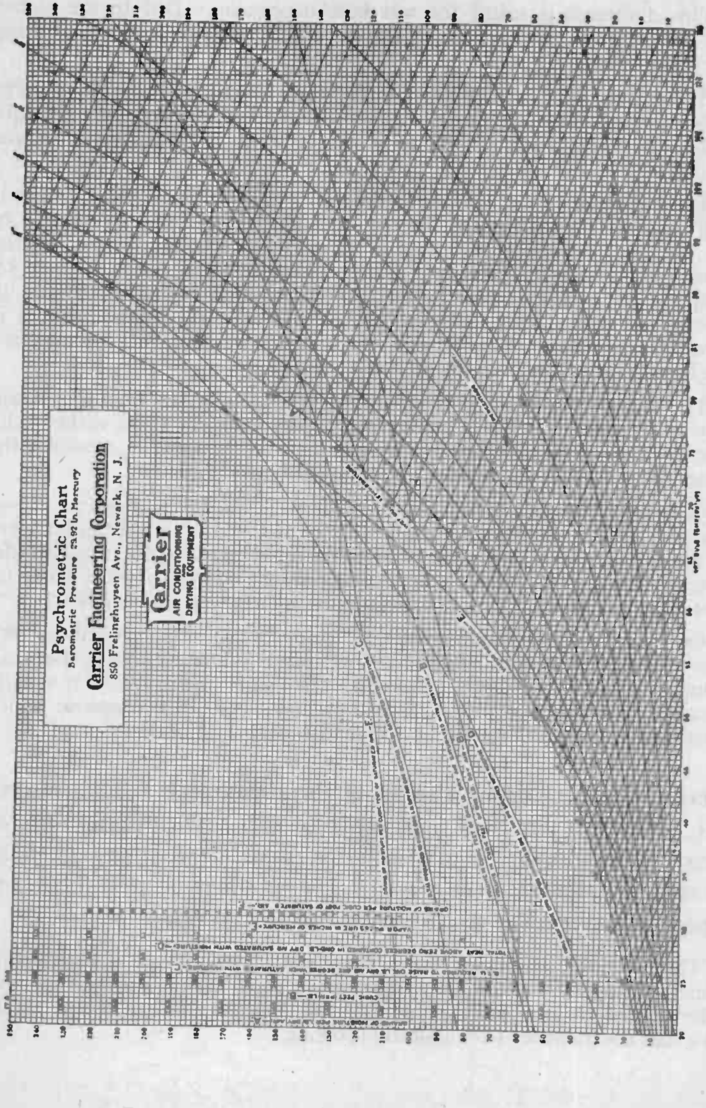


FIG. 3,765.—Psychrometric chart.

To observe the wet and dry bulb temperatures of the air, the wet bulb is thoroughly saturated with clean water, preferably distilled. The instrument is then whirled at a rate of 100 or more *r.p.m.*

The whirling should be continued for a half or three-quarters of a minute, then stopped and read quickly, the wet bulb first. Record the wet and dry bulb readings and make, immediately, one or more subsequent observations to check.

The following precautions should be observed:

1. The wet bulb covering should be of clean, closely fitting fabric free from sizing or other foreign matter.

2. Do not touch wet bulb covering with oily fingers.

3. Use clean water, preferably distilled.

4. If air be in motion, face the breeze while making the observation.

5. Step from side to side, while whirling, to prevent body influence.

6. If observations be made out of doors, it is well to seek shade from direct sunlight.

7. Be sure the wet bulb has been cooled to the minimum.

8. The stationary wet and dry bulb hygrometer is frequently subject to an error greater than 20% of the wet bulb depression, and is not a reliable instrument.

How to Use Psychrometric Chart.—On the chart, fig. 8,765, the *dry bulb temperatures* are shown by vertical lines, with the values indicated on the base line of the chart.

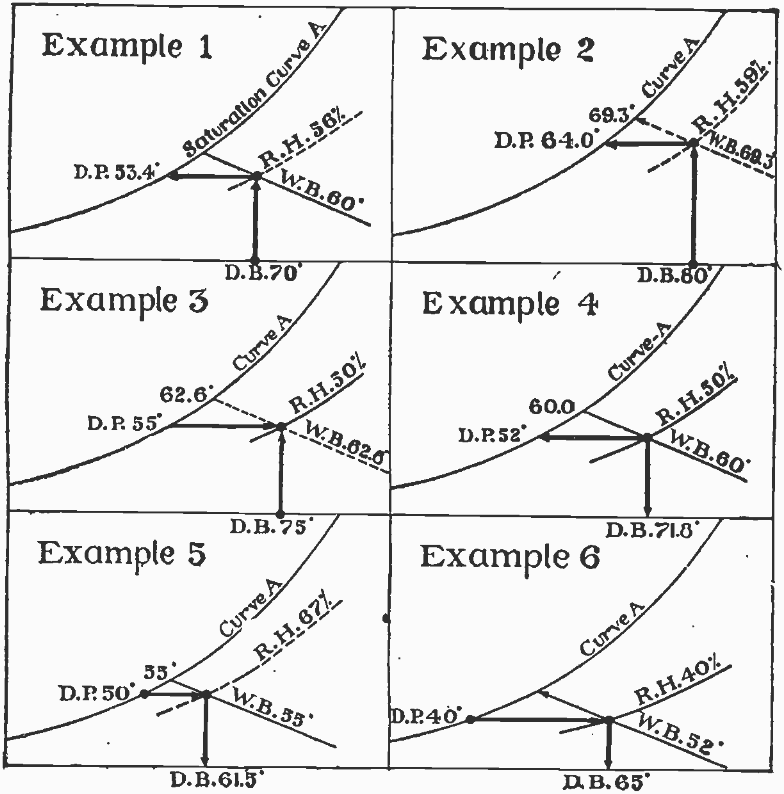
The *wet bulb temperatures* are represented by the oblique lines with values indicated at their intersection with the curved line A, marked "Dew point or saturation temperatures."

Dew point temperatures are represented by horizontal lines with values indicated at their intersections with the curved line A, marked "Dew point or saturation temperatures."

NOTE.—*The Draper recording hygrometer* gives a permanent and continuous record of relative humidity over a period of one week.

The percentages of relative humidity are represented by converging curved lines with values indicated thereon.

Any two of the above properties may be found, if the other two are known. The following examples and diagrams indicate the methods of using the chart.



FIGS. 8,766 to 8,771.—Diagrams to accompany the examples illustrating methods of using the psychrometric chart.

Example 1.—Given: Dry bulb temperature, 70°; wet bulb temperature, 60°. Find the percentage relative humidity and the dew point.

Locate point of intersection of vertical line representing 70° dry bulb temperature with the oblique line representing 60° wet bulb temperature.

By interpolation this point indicates the percentage of relative humidity as 56% and by following the intersecting horizontal line to the left to its intersection with curve A, the dew point is indicated as 53.4°.

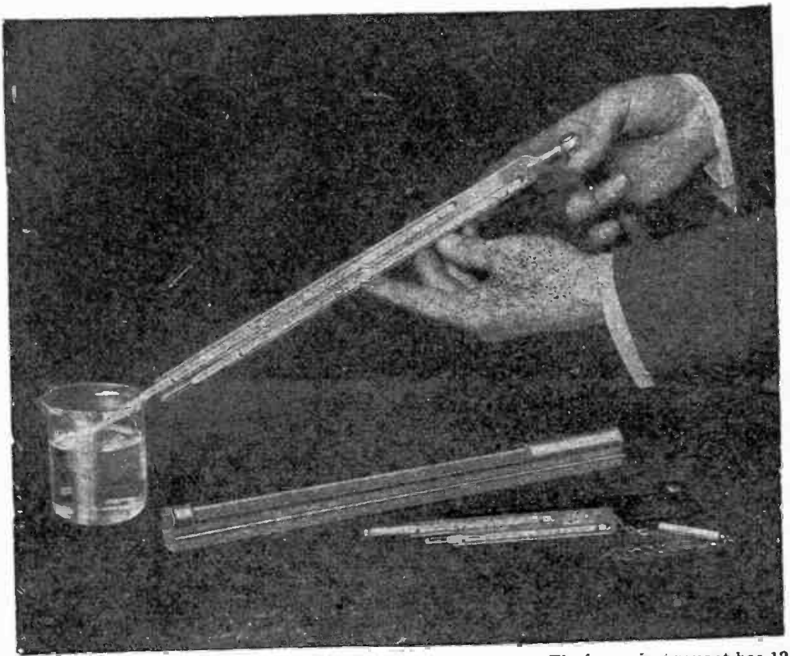


FIG. 8,772.—Two convenient forms of the sling psychrometer. The larger instrument has 12 in. thermometers graduated in one degree divisions. The smaller instrument, lying on the table, has a smaller temperature range and less open graduations, but is a convenient pocket type.

Example 2.—Given: Dry bulb temperature. 80°; relative humidity, 59%. Find the dew point and wet bulb temperature.

Locate the point of intersection of the vertical line representing 80° dry bulb temperature with the interpolated position of the curved line which would represent 59% relative humidity.

Reading horizontally to the left from this point, to curve A, the dew point is indicated as 64° and reading obliquely upward to the left, be-

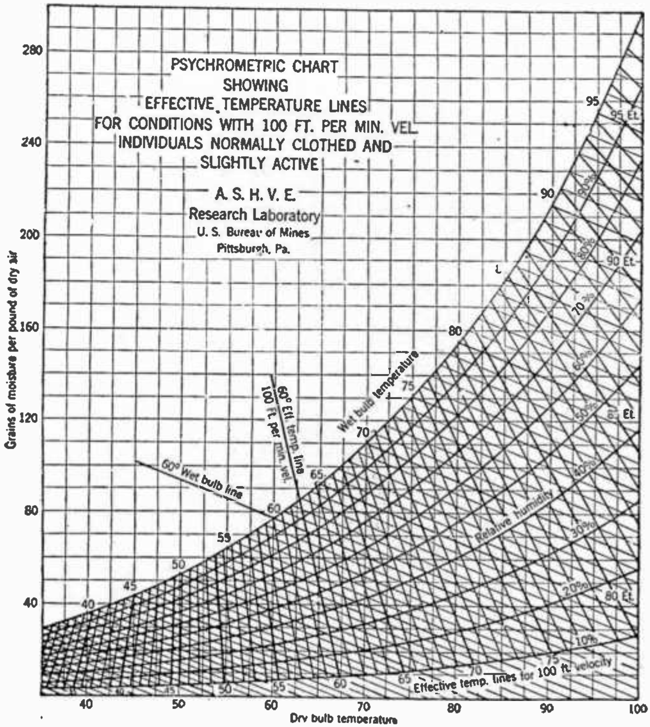


FIG. 8,773.—"Comfort Chart" for air velocity of 100 ft. per min.

tween the wet bulb lines, to curve A, the wet bulb temperature is indicated as 69.3°.

Example 3.—Given: Dry bulb temperature, 75°; dew point temperature, 55°. Find percentage relative humidity and wet bulb temperature.

Locate the point of intersection of the vertical line representing 75° dry bulb temperature with the horizontal dew point line intersecting curve A, at 55°. This point indicates the relative humidity as 50%, and by interpolation the wet bulb temperature as 62.6°.

Example 4.—Given: Relative humidity 50%; wet bulb temperature, 60°. Find dry bulb temperature and dew point.

Locate the point of intersection of the curved line representing 50% relative humidity with the oblique line representing 60° wet bulb temperature.

Reading vertically downward from this point to the dry bulb temperature scale, the dry bulb temperature is indicated as 71.8° and, reading horizontally to the left to curve A, the dew point is indicated as 52°.

Example 5.—Given: Wet bulb temperature, 55°; dew point, 50°. Find dry bulb temperature and relative humidity.

Locate the point of intersection of the oblique line representing 55° wet bulb temperature with the horizontal line representing the dew point of 50°.

Reading vertically downward from this point to the dry bulb temperature scale, the dry bulb temperature is indicated as 61.5°, and by interpolation, the relative humidity is indicated as 67%.

Example 6.—Given: Relative humidity, 40%; dew point, 40°. Find dry bulb temperature and wet bulb temperature.

Locate the point of intersection of the curved line representing 40% relative humidity with the horizontal line intersecting curve A at 40° dew point temperature.

Reading vertically downward from this point to the dry bulb temperature scale, the dry bulb temperature is indicated as 65°, and reading obliquely upward to the left, along the wet bulb lines, to curve A, the wet bulb temperature is indicated as 52°.

TEST QUESTIONS

1. *What is air conditioning?*
2. *Define humidity.*
3. *What is the difference between absolute and relative humidity?*

4. *Which kind of humidity is important?*
5. *Define the term dew point?*
6. *What happens if air be cooled below the saturation point?*
7. *Describe the wet and dry bulb hygrometer..*
8. *Describe the dew point.*
9. *What is the moistening effect of air?*
10. *How does the drying effect of air vary?*
11. *Describe the heating effect of air.*
12. *Name the four items of air conditioning.*
13. *Describe several methods of air conditioning.*
14. *What is a unit air conditioner?*
15. *What is a hygrostat?*
16. *Describe the construction of washer eliminator plates.*
17. *What is a de-humidifier?*
18. *What name is given to the addition of moisture to air?*
19. *Name an important item in air conditioning.*
20. *What is a sling psychrometer?*
21. *State precautions in using the sling psychrometer.*
22. *How is a psychrometric chart used?*
23. *Give examples showing methods of using the psychrometric chart.*

CHAPTER 226

Farm Lighting

The development of small electric light plants designed especially for house lighting in districts remote from city light service is rapidly displacing the objectionable kerosene lamp. Moreover, with the electric plant, energy is available for use with various household devices such as irons, washing machines, percolators, toasters, etc.

The Lighting Plant.—The essential elements comprising a farm lighting plant are:

1. Prime mover;

   (usually a gas engine)

2. Dynamo;
3. Storage battery;
4. Control devices.

The engine may be either *direct connected* to the dynamo, or may have *belt transmission*.

The direct connected type requires less room and avoids maintenance of a belt. Fig. 8,774 shows how compact is the direct connected unit. Gas engines, storage batteries, etc., have been fully treated in other volumes of this Series.*

NOTE.—For ***gas engines and ignition***, see Vol. VIII; for ***storage batteries***, see Vol. III.

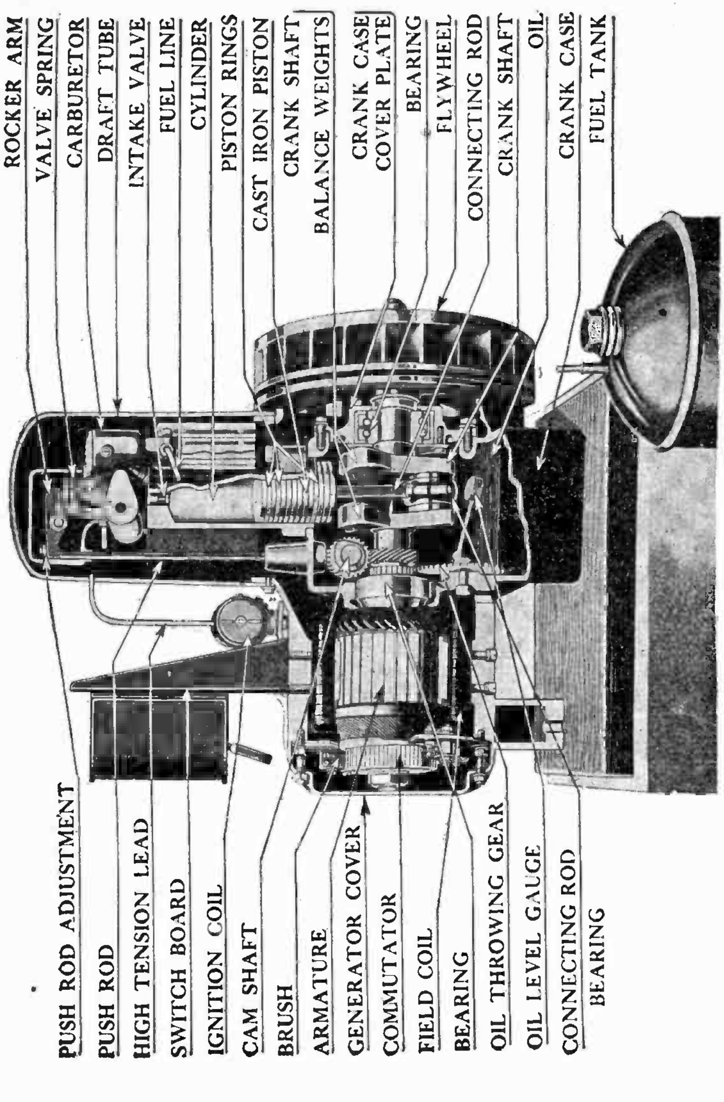


FIG. 8,774.—Delco single cylinder air cooled engine and direct connected dynamo. Sectional view showing parts. The fly wheel with its air vanes serves also as a blower to air cool the engine.

To simplify the plant and prevent trouble in cold weather, air cooled engines are used.

The method of cooling is shown in fig. 8,775. When this system is used it is necessary to have proper ventilation, in the room where the plant is

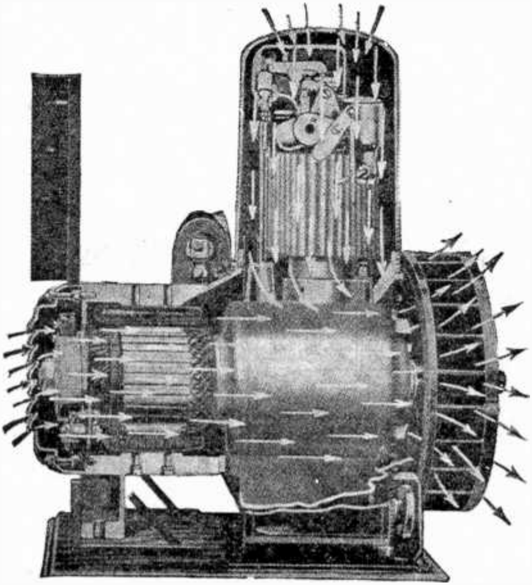


FIG. 8,775.—Delco air cooled engine showing ventilation. ***In construction,*** the fly wheel of the engine is built with a number of blades in it. When the engine is running, the blades pull the cool air down through the top of the draft tube over the cylinder through the air pockets in the crank case and exhaust it through the fan blades. At the same time air is drawn through the louvres on the dynamo cover, through the dynamo into air pockets in the crank case and exhausted through the fan blades on the fly wheel. A continued circulation of air is kept going between the fins on the engine and through the dynamo.

installed. When making an installation, careful check should be taken that the draft tube and cap are in their proper positions and that the generator cover has the louvres or slots pointing downward.

When the plant is installed in the basement or in an out building near the residence, provision should be made to muffle the exhaust. One method of doing this is shown in fig. 8,776.

If the exhaust gases be not properly disposed of after they leave the engine and are forced to go through a pipe that consists of sharp turns or a clogged muffler, back pressure will exist. This will cause the plant to overheat, gradually burn the valves, causing them to stick, retarding the speed of the plant, which will reduce the output.

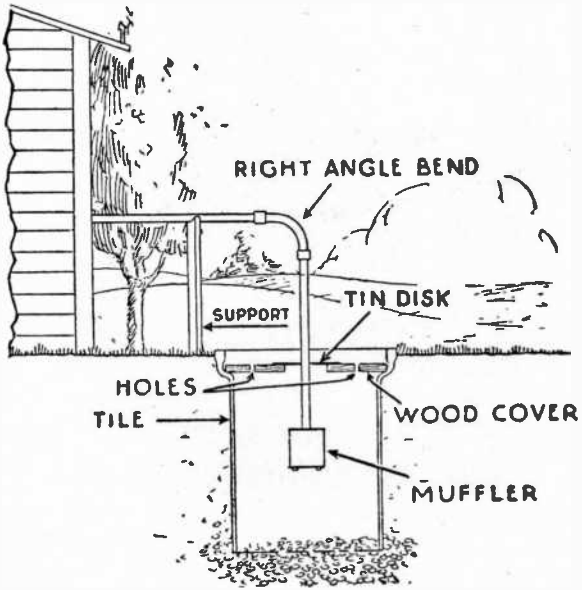


FIG. 8,776.—Muffled exhaust. Bury a two ft. sewer tile in the ground so that the top will project slightly above the surface. The bottom of the tile should be open to allow water to drain out. Two pieces of 1 in. pipe and a right angle bend should be used to run from the exhaust flange on the plant to the center of the tile approximately half way down. The muffler should then be fastened to the pipe in the tile. A wooden cover should be made to fit in the top part of the tile and a hole 7 ins. in diameter cut in the center of it. A tin disc should be nailed over this hole to prevent the wood becoming burnt. It will be necessary to drill several small holes in the top to allow the exhaust gases to escape from the tile. A concrete cover can also be used in place of wood. This should be made so that it can be easily removed should it be necessary to clean the muffler. A 1 in. pipe should be cast in the concrete to allow the exhaust gases to escape from the tile.

Every serviceman should carefully plan his installations so that the exhaust pipe runs straight and the use of bends should be avoided where possible.

Control.—A storage battery lighting plant requires various control devices to insure satisfactory operation. The battery

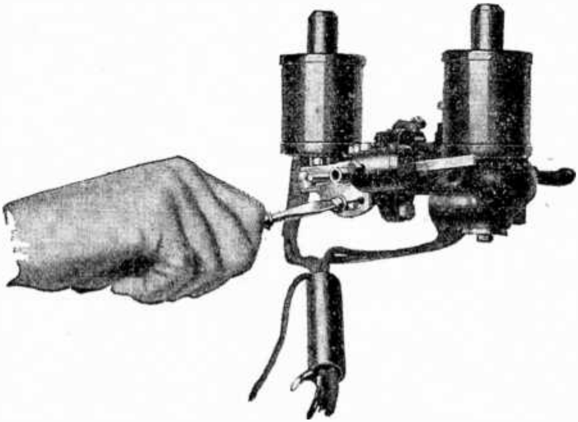


FIG. 8,777.—Delco electro-magnetic throttle control with cover removed showing method of adjusting.

must be charged at the proper rate and be protected against delivering a reverse current through the charging circuit, and too great overload on the lighting circuit. Accordingly provision must be made:

NOTE.—*The most satisfactory way* to install the exhaust is to run the pipe straight out without any bends or elbows. This will allow a free escape of the exhaust gases and prevent back pressure. However, if it be absolutely impossible to do this, and it is necessary to have bends, use only one inch sweeps or right angle bends. These bends are used by electricians for conduit work and can be obtained at an electrical supply store.

NOTE.—*Never* install a muffler inside a building, as the exhaust gases will effect the ventilation of the plant, and the carbon monoxide gas exhausted by the plant is very injurious to any person who breathes it.

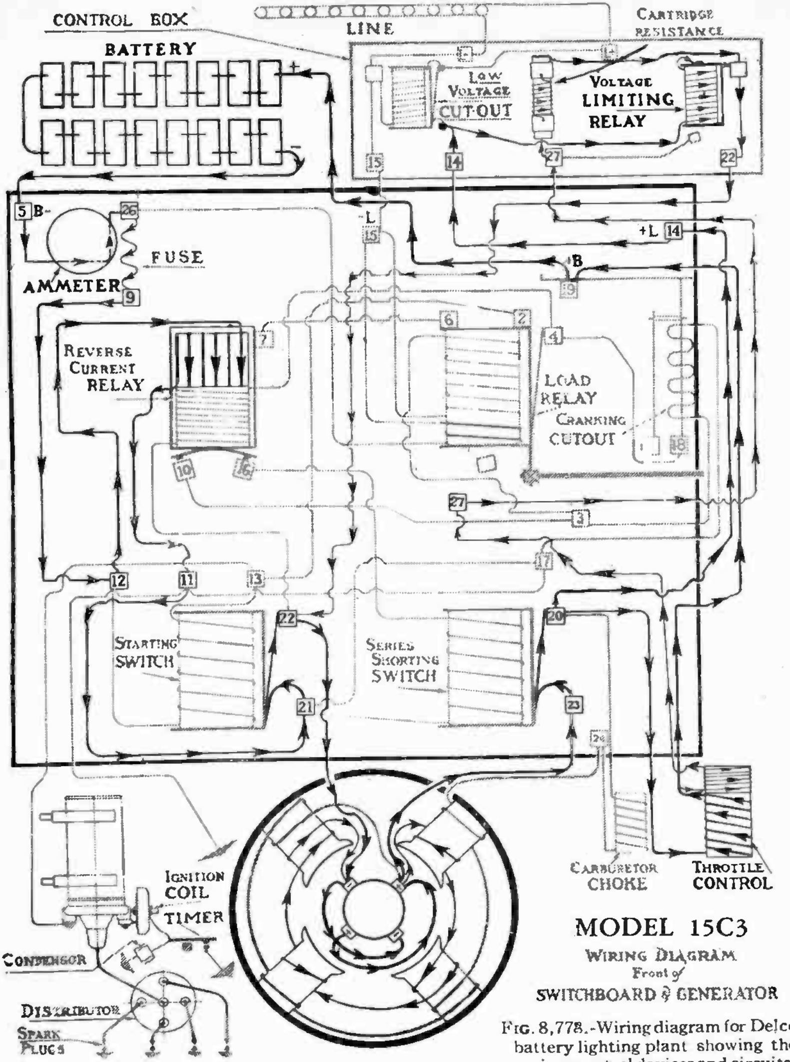


FIG. 8,778.—Wiring diagram for Delco battery lighting plant showing the various control devices and circuits.

1. For speed control of the engine;
2. For battery cut out under abnormal conditions.

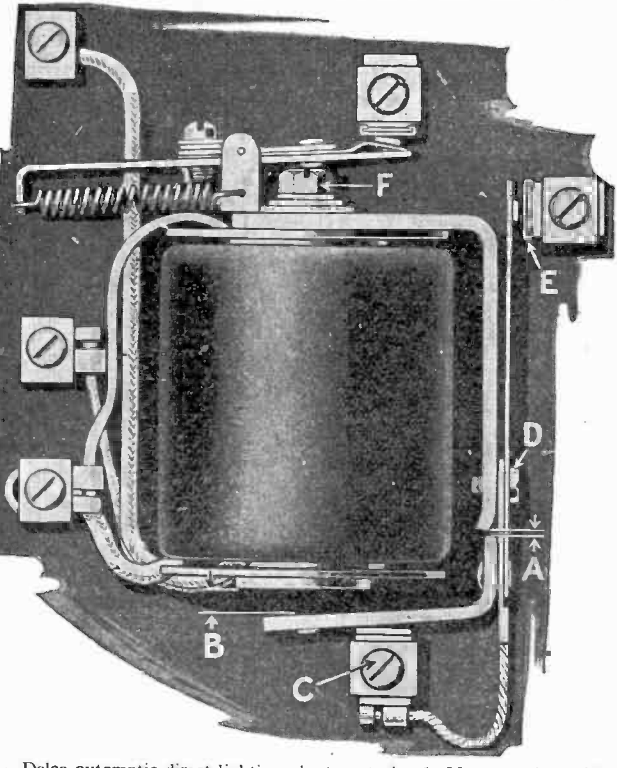


FIG. 8,779.—Delco automatic direct lighting plant control. ***1. Master relay.*** Whenever a light or load is turned on the line, current from the 6 volt battery passes through the shunt or inside winding of the master relay and magnetizes the iron core. The magnetized iron core attracts the armature to it and closes the ignition switch. After the engine has started and the dynamo voltage is from 22 to 28 volts, the shunt winding is shorted by another relay and current passing through the series or outside winding magnetizes the iron core which holds the armature in the closed position. When the last light or load has been turned off, the current passing through the series winding ceases, which allows the armature to drop, thereby opening the ignition contacts. Since the master relay is the first relay to go into action and controls the rest of the relays and the plant, it is very important that all adjustments be accurate and correctly made. ***The parts are:*** A, air gap; B, distance between armature and center of core; C, adjustment screw and stop; D, adjustment screw; E, stationary contact; F, bolt.

The devices ordinarily used will now be explained.

Throttle Control.—The load on an engine charging a storage battery varies within wide limits and accordingly some form of governor is necessary to maintain the speed within prede-

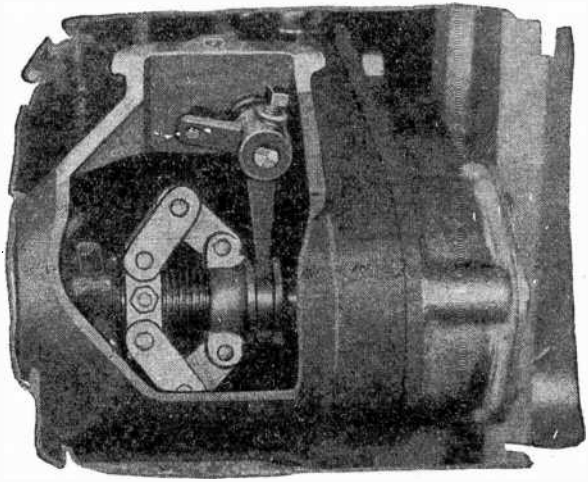


Fig. 8,780.—Delco mechanical throttle control. ***In construction,*** the carburetor throttle lever is connected to the governor by a finger, which is engaged in a grooved collar on governor. When the governor weights, under spring tension, are not compressed, the collar forces the finger forward, opening the throttle. As the speed increases, the governor weights are gradually forced away from the shaft by centrifugal force, pulling the collar and finger back toward the dynamo end of the plant, closing off the carburetor throttle, which decreases the engine speed. The pre-determined speed limits are 1,100 and 1,200 *r.p.m.*

termined limits. The governor varies the throttle opening to correspond with the load; that is, when the load on the dynamo increases, the speed of the engine decreases slightly and the governor causes the carburetor throttle to open, thus feeding more fuel to the engine and holding the speed to the required limit.

Governors are of two kinds:

1. Mechanical; 2. Electro-magnetic.

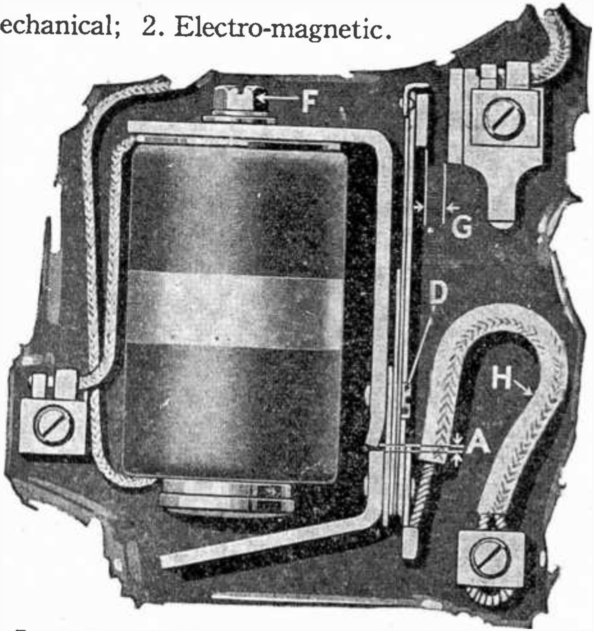


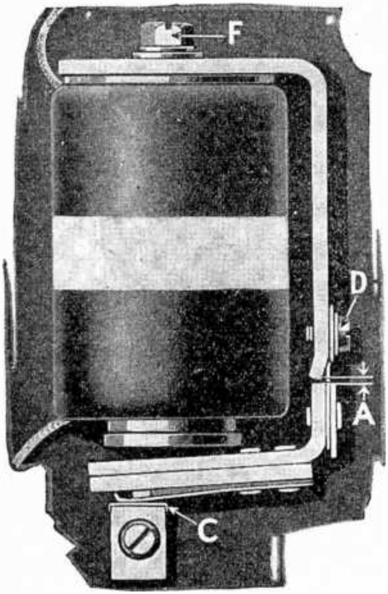
FIG. 8,781.—Delco automatic direct lighting plant control. *2. Starting switch.* When the ignition switch is closed on the master relay, current from the six volt battery passes through the windings of the starting switch and magnetizes the iron core. The magnetized iron core attracts the armature to it and closes the starting switch contacts. The starting motor, heater and cranking cut out are furnished with current from the 6 volt battery when the starting switch contacts are closed. *The parts are:* A, air gap; D, screws; F, bolt; G, stationary contact; H, flexible lead.

The construction and operation of one form of mechanical governor is shown in fig. 8,780.

One form of electro-magnetic throttle control consists of a solenoid (or magnetic coil with a core) connected in series with the line load. An iron plunger rod connected to the throttle at one end extends up into the solenoid.

Whenever the plant is called upon to deliver current to the line, this current passes through the solenoid. This creates a magnetic field within the core which in turn acts against a weight and spring tension placed upon the plunger in such a way as to move it up or down in the solenoid. The iron plunger upon being moved up or down causes the throttle to be opened or closed accordingly.

As the load on the line is increased the additional current flowing through the solenoid or throttle control coil increases the strength of the magnetic field causing the throttle to be opened wider. A decrease in current similarly causes a closing of the throttle or butterfly valve.



Relays and Switches.—In addition to throttle control just described various other devices are necessary for the proper operation of the plant. These are shown in the wiring diagram, fig. 8,778, for a storage battery plant. Suitable control is also made for plants in which the dynamo furnishes current direct to the line.

Diesel Engine.—This type of oil engine differs from others, principally in that *the fuel is introduced directly into the cylinder in the form of a spray*

FIG. 8,782.—Delco automatic direct lighting plant control. *3. Release relay.* After the engine has started and dynamo voltage is approximately 3 volts, current from the dynamo passing through the windings of the release relay magnetizes the iron core and attracts the armature to it. The release relay frame, armature and contact C, directly beneath the armature, are in series with the starting switch winding. Therefore, when the armature of the release relay is drawn upward to the iron core, the starting switch winding is opened, the iron core loses its magnetic strength, and the armature drops down, opening the starting switch contacts. After the last light or load has been turned off and the dynamo voltage has dropped down to nothing the armature of the release relay drops back to its former position on the contact C, directly beneath it. Since the release relay controls the vaporization and mixture of the fuel when the plant is starting, it is very important that the adjustments be accurate and correctly made. *The parts are:* A, required (.002) distance between armature and frame when armature is held against pole face; C, contact; D, adjustable screws; F, bolt.

by an atomizer and due to the very high degree of compression is ignited by the heat of compression.

The Diesel cycle may be completed in either two or four

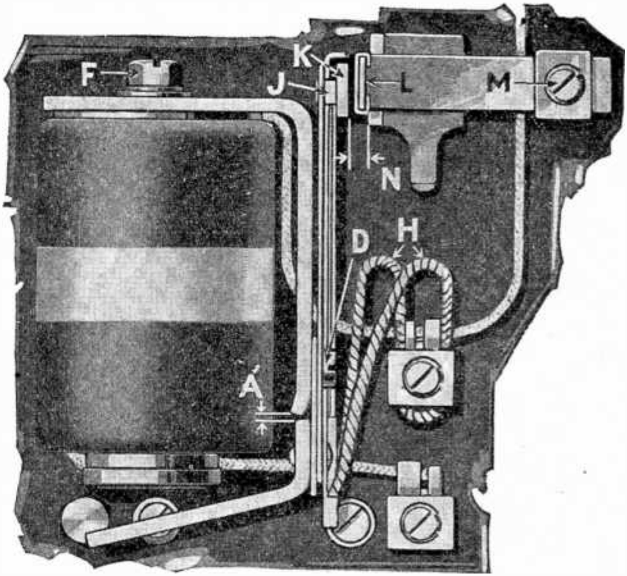


FIG. 8,783.—Delco automatic direct lighting plant control. *4. Load switch.* When the dynamo voltage has increased to approximately 22 to 28 volts, current from the dynamo passing through the load switch winding magnetizes the iron core. The armature is attracted to the core and closes, first, the small or battery charging switch and then the large or load switch. While the battery charging switch is closed, it performs two duties, it allows current from the dynamo to charge the battery and it short circuits the shunt winding of the master relay. The load switch, when closed, permits current from the dynamo to pass through the series winding of the master relay and out to the lights or power appliances on the line. After the last light or load has been turned off and the dynamo voltage drops, the load switch armature drops down and opens the battery charging and load switches. *The parts are:* A, air gap; D, adjustment screws; F, bolt; H, flexible leads; J, battery charging switch blade; K, load switch blade; L, stationary contact; M, adjustment screw; N, 5/8 in. clearance.

strokes, the latter being the prevailing practice. Briefly, the four stroke Diesel cycle is as follows:

Suction Stroke.—Admission of air into the cylinder.

Compression Stroke.—Compression of the charge of air to about 500 lbs. pressure which causes its temperature to rise to about 1,000° Fahr.

As this pressure is reached gradually it does not cause a shock to the engine, such as an explosion to the same pressure would give.

Power Stroke.—At the beginning of the stroke, oil previously delivered to the injection valve is blown into the cylinder in the form of fine spray by a small quantity of air compressed by a special compressor to 700 or more lbs. pressure. The oil spray meeting the highly heated air in the cylinder ignites and burns, combustion continuing so long as the fuel is being injected, usually for about one tenth of the power stroke.

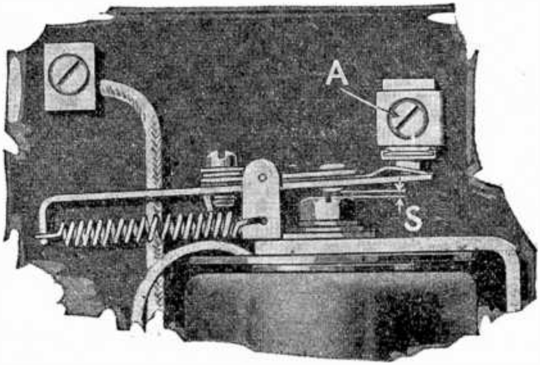


FIG. 8,784.—Delco automatic direct lighting plant control.5. *Stop charge switch.* To allow the entire output of the dynamo to go out into the line when a heavy load is required, a switch is used to stop the dynamo from charging the battery. Current from the dynamo passing through the series winding of the master relay magnetizes the iron core and attracts the armature of the stop charge switch to it. When the armature is drawn down, the contact points are opened and the battery receives no charge. The stop charge switch should open between 16 and 19 amperes. A, screw to adjust the air gap S.

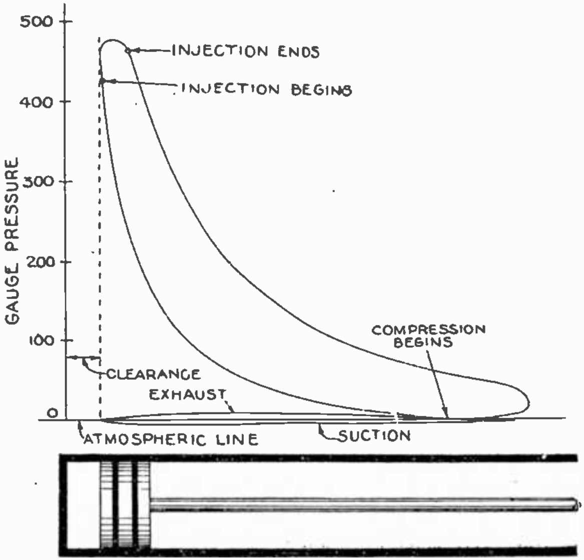
Usually the heat generated by the combustion is not sufficient to prevent the pressure in the cylinder falling while admission is taking place, so that the admission line on the indicator card falls below the constant pressure line as seen in the indicator card, fig. 8,785.

Exhaust Stroke.—Expulsion of the products of combustion from the cylinder, this completing the cycle.

Notwithstanding the very high fuel economy of the Diesel engine which is its principal feature, offsetting this more or less are such items as:

1. High first cost;

2. High compression pressure required to ignite the charge, hence any leakage of the valves, piston rings will cause faulty ignition. This applies



FIGS. 8,785 and 8,786.—Typical indicator card of Diesel four cycle engine. It will be noted from the diagram that the pressure range and mean effective pressure is much greater than in other engines which accounts for the massive construction.

NOTE.—*Diesel Engine Troubles.*—The following are most frequently met with: *Failure to start*. Usually due to: 1, faulty working of starting valves; 2, ignition failure. *Ignition fails*. 1, loss of compression; 2, inadequate charge of fuel; 3, incorrect timing of valve. *Pump fails*. 1, foreign matter in check valve; 2, air bound pump; 3, leaky stuffing box. *Loss of compression*. Leakage past worn piston or past valves. *Overloading*. This injures the exhaust valves by too high exhaust temperature. *Underloading*. Too small fuel charge may cause ignition failure. *Irregular running*. Usually due to: 1, defective governor; 2, incorrect fuel timing; 3, incorrect charges

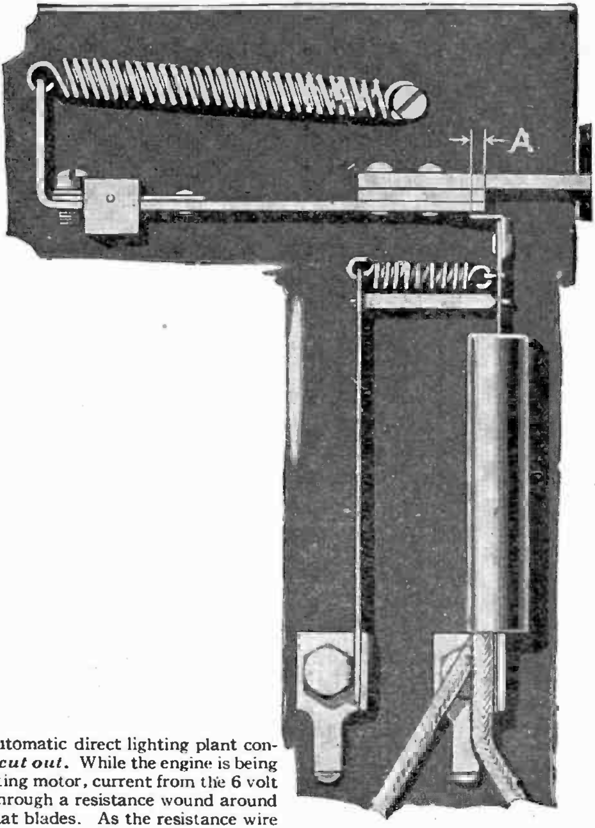


FIG. 8.787.—Delco automatic direct lighting plant control. ***6. Cranking cut out.*** While the engine is being cranked by the starting motor, current from the 6 volt battery is passing through a resistance wound around one of the thermostat blades. As the resistance wire gets hot, the thermostatic metal being subjected to change in temperature becomes distorted from its original shape and opens the cranking circuit. The cranking cut out should not open the cranking circuit every time the plant is started, but only when the plant will not start after being cranked for 45 to 60 seconds. After the cranking cut out has opened the cranking circuit and the trouble has been remedied, it is necessary to raise the lever momentarily to allow the thermostat to make contact again. If only one thermostat blade were used, variations of atmospheric temperatures would have effect on it and while the engine was being cranked the thermostat would open the cranking circuit before the engine could start, or it would crank too long. Therefore, another thermostat is used and mounted to repel the other under all atmospheric conditions, but when the resistance wire on the other is heated, enough energy is produced to open the circuit. A, is the distance required for the thermostat to travel before cranking circuit is opened.

to the compressor which furnishes the spraying air as well as to the power cylinder;

3. Trouble likely with overload operation because the effect of overloading is to increase the fuel charge so that the amount is greater than

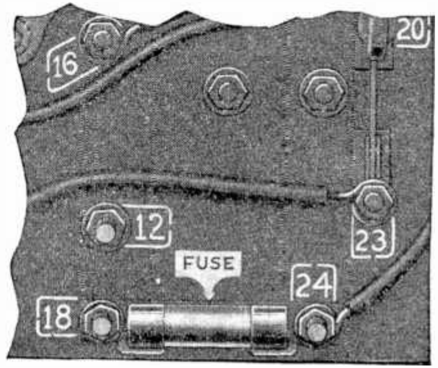


FIG. 8,788.—Delco automatic direct lighting plant control. *7. Fuse.* If at any time the plant fail to start, examine the fuse which is mounted on the back of the switchboard. Do not use a larger ampere fuse than the one that comes with the plant or is recommended by the factory.

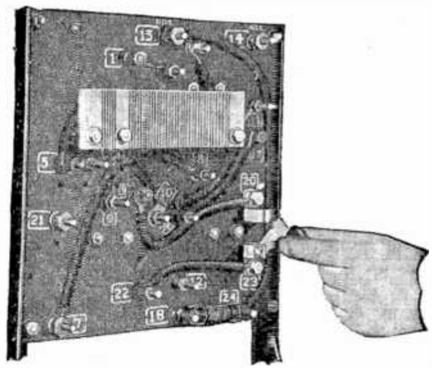


FIG. 8,789.—Delco automatic direct lighting plant control. *8. Service switch.* The small knife switch that is located on the back of the switchboard should be opened only when cranking the plant by hand. When the plant is running, the switch must be closed. The plant will not start automatically while the switch is open.

can be burned with the air available. The result is that combustion continues after expansion has begun, and if the overload be great it may even be that the charge will still be burning when the exhaust valve is opened, which condition will quickly destroy the exhaust valve;

4. Operation with leaky valve will result in both valve and seat being cut out by the hot gases blowing through at high velocities;

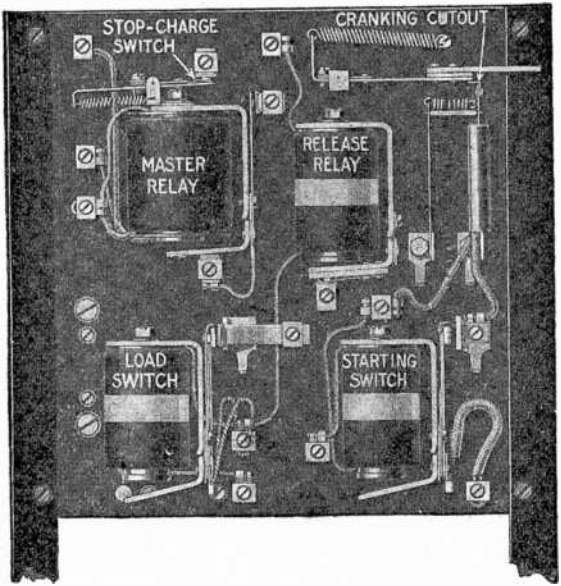


FIG. 8,790.—Delco automatic direct lighting plant control. *9. Switchboard.* This is the front view of the switchboard with cover removed, showing the location of the various relays and switches.

5. Close and high grade attention required;

6. Repairs more costly than with engines working on a less exacting cycle;

7. Great weight and bulk per unit of power developed;

8. Uncertainty as to future cost of fuel;

9. Lubrication troubles.

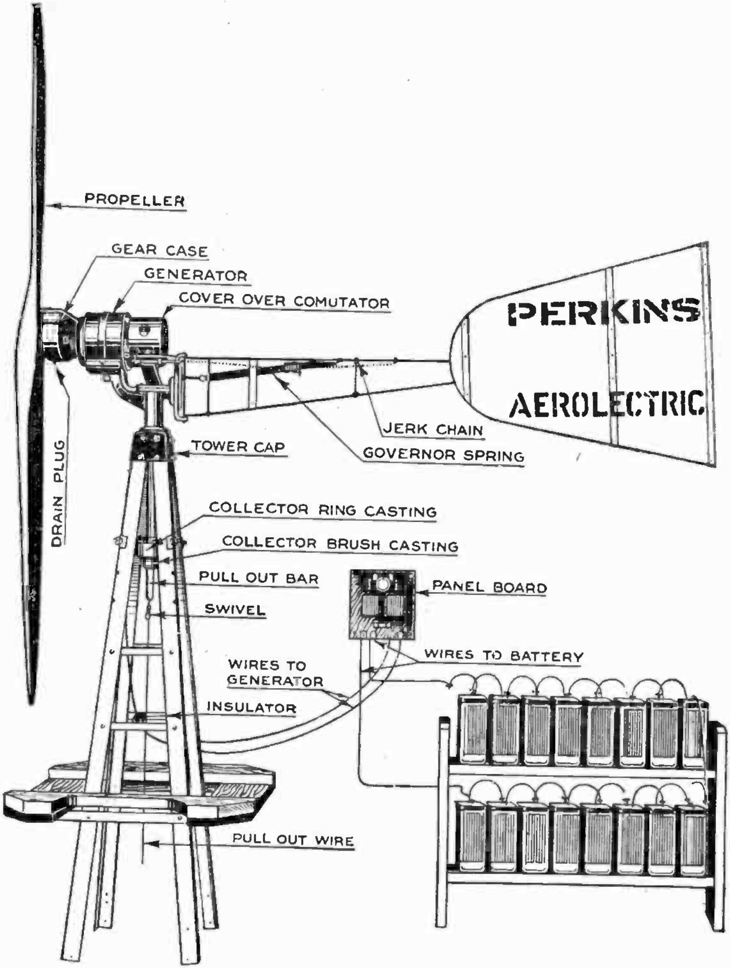
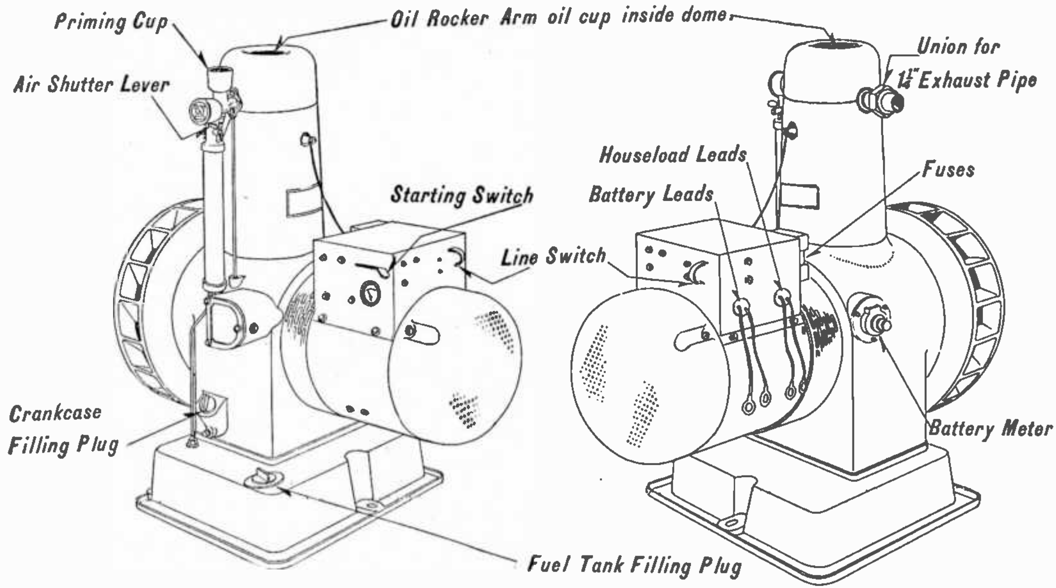


FIG. 8,791.—Aerolectric generating mechanism with gear case cover removed, showing transmission between wheel and dynamo. This is a wind mill suitably geared to a dynamo forming a unit for charging a storage battery, the latter being used as current source for house lighting.



FIGS. 8,792 and 8,793.—Westinghouse 110 volt light and power plant for use with storage battery. Views showing important parts.

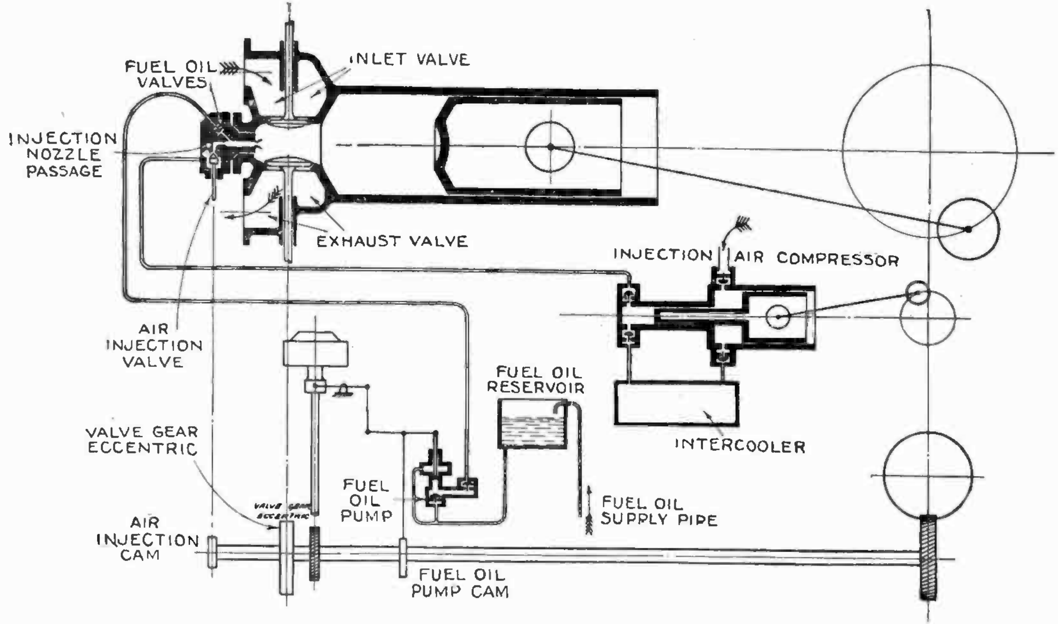


FIG. 8,794.—Diagram of a Diesel engine. ***In operation***, during the *suction stroke* pure air is drawn into the cylinder through the main inlet valve and a proper charge of fuel oil (determined by the position of the governor) is pumped without pressure into the injection nozzle passage. On the *compression stroke*, the air in the cylinder is compressed to about 500 lbs. pressure, which gives it a temperature in excess of 1,000° Fahr. At the *beginning* of the *power stroke*, air from the compressor at 700 to 900 pounds per square inch is admitted through the injection nozzle for a period of about ten per cent of the stroke. The oil previously deposited in the injection nozzle during the suction stroke is picked up by the injection air and gradually sprayed into the combustion chamber, where combustion occurs at constant pressure during the period of injection. During the *exhaust stroke* the products of combustion are expelled from the cylinder, thus completing the cycle.

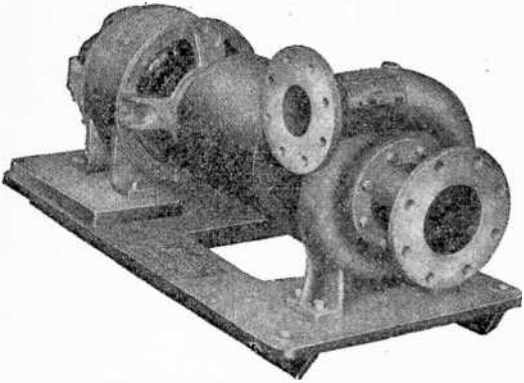


FIG. 8,795.—Fitz Rualite turbo-generator set comprising a completely self-contained hydro-electric power unit, including Fitz high speed water turbine direct connected to electric generator and provided with built in automatic governor. Standard units available in capacities ranging from ½ *kw.*, capacity to 100 *kw.* capacity.

TEST QUESTIONS

1. *Of what does a farm lighting plant consist?*
2. *What kind of a cooling system is used on the engine?*
3. *What provision should be made when plant is installed in the basement?*
4. *Make installation sketch showing muffled exhaust.*
5. *Name two general classes of lighting plants.*
6. *What kind of control devices does a battery lighting plant require?*
7. *Describe the method of throttle control.*
8. *Name two kinds of governors.*
9. *Describe the electro-magnetic governor control.*
10. *What relays and switches are used?*
11. *Describe the Delco automatic direct lighting plant control.*
12. *Describe a lighting plant with wind mill drive.*

CHAPTER 227

Hydraulics

The term hydraulics is defined as *the science which treats of liquids, at rest or in motion*. This involves two divisions of the subject known technically as

1. Hydro-statics;
2. Hydro-dynamics.

Hydro-statics refers to liquids ***at rest***, and hydro-dynamics to liquids ***in motion***.

The treatment of these subjects here relates to water and the entire chapter may be considered as an introduction to the chapters following on Pumps.

Water.—Those who have had experience in the design or operation of pumps, including the author, have found that water is an unyielding substance when confined in pipes and pump passages, thus necessitating very substantial construction to withstand the pressure, and periodic shocks or ***water hammer***.

The following table gives the relative volume of water at different temperatures compared with its volume at its temperature of maximum density or 39.1° Fahr.

Relative Volumes of Water at Different Temperatures

Degrees Fahr	Volume	Degrees Fahr.	Volume	Degrees Fahr.	Volume
39.1	1.00000	95	1.00586	158	1.02241
41.0	1.00001	104	1.00767	167	1.02548
50.0	1.00025	113	1.00967	176	1.02872
59.0	1.00083	122	1.01186	185	1.03213
68.0	1.00171	131	1.01423	194	1.03570
77.0	1.00286	140	1.01678	203	1.03943
86.0	1.00425	149	1.01951	212	1.04332

Weight of Water per Cubic Foot at Different Temperatures

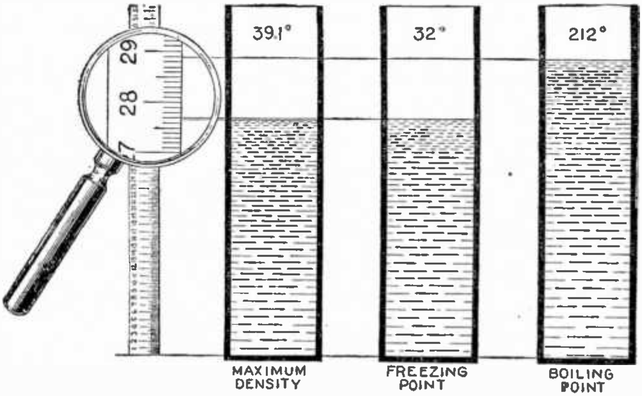
Temp. deg. F.	Weight lbs. per cu. ft.	Temp. deg. F.	Weight lbs. per cu. ft.	Temp. deg. F.	Weight lbs. per cu. ft.	Temp. deg. F.	Weight lbs. per cu. ft.
32	62.42	80	62.23	130	61.56	180	60.55
35	62.42	85	62.18	135	61.47	185	60.44
40	62.42	90	62.13	140	61.37	190	60.32
45	62.42	95	62.08	145	61.28	195	60.20
50	62.41	100	62.02	150	61.18	200	60.07
55	62.39	105	61.96	155	61.08	205	59.95
60	62.37	110	61.89	160	60.98	209	59.84
65	62.34	115	61.82	165	60.87	210	59.82
70	62.31	120	61.74	170	60.77	211	59.79
75	62.28	125	61.65	175	60.66	212	59.76

Some Properties of Water.—This remarkable liquid composed of two parts hydrogen and one part oxygen (H_2O) at its maximum density (39.1° Fahr.) will expand as heat is added, and it will also expand slightly as the temperature falls from this point, as shown in figs. 8,796 to 8,799.

The weight of one cu. ft. of water at its maximum density is generally taken at the figure given by Rankine, 62.425 lbs. per cu. ft.*

The weight of one U. S. gallon or 231 cu. ins. is generally taken at 8⅓ lbs.

The weight of one British gallon (Imperial gallon) or 277.27 cu. ins. of water at 62° Fahr. is 10 lbs.



FIGS. 8,796 to 8,799.—The most remarkable characteristic of water: *expansion below and above its temperature or "point of maximum density"* 39.1° *Fahr*. Imagine one pound of water at 39.1° F. placed in a cylinder having a cross sectional area of 1 sq. in. as in fig. 8,797. The water having a volume of 27.68 cu. ins., will fill the cylinder to a height of 27.68 ins. If the liquid be cooled it will expand, and at say the *freezing point* 32° F., will rise in the tube to a height of 27.7 ins., as in fig 8,798 before freezing. Again, if the liquid in fig. 8,798 be heated, it will also expand and rise in the tube, and at say the *boiling point* (for atmospheric pressure 212° F.), will occupy the tube to a height of 28.88 cu. ins. as in fig. 8,799.

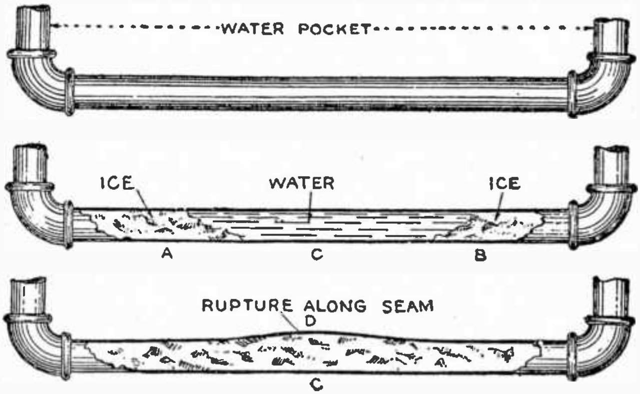
Head and Pressure.—These are the two primary considerations in hydraulics. The word head signifies *the difference in*

*NOTE.—*Some authorities* give as low as 62.379. The figure 62.5 commonly given is approximate. The highest authoritative figure is 62.428. At 62° Fahr., the figures range from 62,291 to 62.36. *The figure* 62.355 *is generally accepted as the most accurate*, though for ordinary calculations the figure 62.4 is generally taken, this corresponding to the weight at 53° Fahr.

level of water between two points, and it is usually expressed in feet.

There are four kinds of head:

1. Static head; 3. Total static head;
2. Dynamic head; 4. Total dynamic head.



FIGS. 8,800 to 8,802.—Familiar occurrence illustrating the rupture of water pipes due to the expansion of water in freezing.

Static head *is the height from a given point of a column, or body of water* ***at rest,*** considered as causing or measuring pressure.

Dynamic head *is an equivalent or virtual head of water in motion which represents the resultant pressure due to the height of the water from a given point, and the resistance to flow due to friction.*

The total static head *is the static lift plus the static head.*

The total dynamic head *is the dynamic lift plus the dynamic head.*

Thus, when water is made to flow through pipes or nozzles, there is a loss of head. These terms are illustrated in fig. 8,805.

The following table gives the loss of head due to friction of water in pipes of various sizes and for various rates of flow.

Friction of Water in Pipes

Loss of head in feet due to Friction, per 100 feet of smooth, straight cast iron pipe

Gallons Per Minute	½-Inch Pipe		¾-Inch Pipe		1-Inch Pipe		1¼-Inch Pipe		1½-Inch Pipe		2-Inch Pipe		2½-Inch Pipe		3-Inch Pipe		4-Inch Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
2	2.10	5.30	1.20	1.40														
3	3.16	11.30	1.80	2.90	1.12	0.90												
4	4.21	19.20	2.41	5.00	1.49	1.52	0.86	0.40	0.63	0.187								
5	5.26	29.00	3.01	7.50	1.86	2.32	1.07	0.60	0.79	0.283	.51	.09	0.33	0.05				
10	10.52	105.00	6.02	27.10	3.72	8.40	2.14	2.18	1.57	1.02	1.02	.36	0.65	0.12	0.45	0.05		
15			9.02	57.00	6.13	18.90	3.92	4.65	2.72	2.25	1.53	0.81	0.98	0.25	0.68	0.11		
20			12.03	97.00	7.44	30.10	4.29	7.90	3.15	3.70	2.04	1.29	1.31	0.43	0.91	0.18		
25					9.30	45.50	5.36	11.90	4.56	5.60	2.55	1.96	1.63	0.66	1.13	0.27		
30					11.15	64.00	6.43	16.90	4.72	7.80	3.06	2.73	1.96	0.92	1.36	0.38		
35					13.02	85.00	7.51	22.30	5.51	10.30	3.57	3.66	2.29	1.23	1.59	0.51		
40					14.88	109.00	8.58	28.50	6.30	13.30	4.08	4.68	2.62	1.57	1.82	0.65	1.02	0.16
45							9.68	35.20	7.08	16.60	4.60	5.80	2.95	1.97	2.02	0.80	1.17	0.20
50							10.72	43.20	7.87	20.20	5.11	7.10	3.30	2.38	.227	0.98	1.28	0.24
70							15.01	81.00	11.02	37.60	7.15	13.20	4.60	4.42	3.18	1.83	1.79	0.45
75									11.80	42.70	7.66	14.90	4.93	5.07	3.41	2.11	1.92	0.52
100									15.74	73.00	10.21	25.60	6.54	8.60	4.54	3.52	2.55	0.88
120											12.25	36.00	7.84	12.00	5.45	4.97	3.06	1.22
125											12.75	38.90	8.16	13.01	5.68	5.40	3.19	1.33
150											15.30	54.00	9.80	18.72	6.80	7.72	3.84	1.82
175													11.43	23.70	7.92	9.75	4.45	2.40
200													13.07	30.90	9.08	12.80	5.11	3.12
225															10.42	16.00	6.32	4.72
250															11.28	19.70	6.40	4.80
270															12.45	22.70	6.90	5.50
275															12.70	23.60	7.03	5.71
300															13.62	27.10	7.66	6.70
350																	8.90	8.80
400																	10.20	11.30
450																	11.50	14.10
470																	12.16	16.00
475																	12.30	16.40
500																	12.77	17.20

Gallons Per Minute	5-Inch Pipe		6-Inch Pipe		8-Inch Pipe		10-Inch Pipe		12-Inch Pipe		16-Inch Pipe		20-Inch Pipe		24-Inch Pipe		30-Inch Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
70	1.14	0.15																
100	1.63	0.29	1.14	0.10														
120	1.96	0.41	1.42	0.18														
125	2.04	0.46	1.48	0.20														
150	2.45	0.63	1.71	0.23														
175	2.86	0.84	2.00	0.34														
200	3.27	1.06	2.28	0.44														
225	3.67	1.33	2.57	0.53														
250	4.08	1.60	2.80	0.66	1.60	0.16												
270	4.42	1.86	3.03	0.81	1.70	0.18												
275	4.50	1.94	3.06	0.82	1.73	0.19												
300	4.90	2.25	3.40	0.92	1.90	0.26												
350	5.72	2.99	3.98	1.21	2.20	0.29												
400	6.54	3.81	4.54	1.58	2.60	0.40												
450	7.35	4.75	5.12	1.96	2.92	0.46	1.80	0.150										
470	7.78	5.30	5.49	2.23	3.07	0.55	1.92	0.170										
500	8.17	5.80	5.60	2.33	3.20	0.58	2.04	0.200	1.42	0.08								
550	8.99	6.90	6.16	2.81	3.52	0.70	2.26	0.236	1.57	0.098								
600	9.80	8.10	6.72	3.36	3.84	0.83	2.46	0.282	1.71	0.106								
650	10.62	9.40	7.28	3.93	4.16	0.96	2.66	0.327	1.85	0.134								
700	11.44	10.80	7.84	4.56	4.46	1.10	2.86	0.368	2.00	0.154								
750	12.26	12.30	8.50	5.00	4.80	1.24	3.06	0.422	2.13	0.170								
800			9.08	5.64	5.12	1.41	3.28	0.476	2.27	0.196								
850			9.58	6.25	5.48	1.63	3.48	0.534	2.41	0.22								
900			10.30	7.22	5.75	1.76	3.68	0.592	2.56	0.24								
950			10.72	7.65	6.06	2.05	3.88	0.653	2.70	0.25								
1000			11.32	8.60	6.40	2.16	4.08	0.718	2.84	0.295								
1100			12.50	10.22	7.03	2.51	4.50	0.860	3.13	0.35								
1200			13.52	11.92	7.67	3.04	4.91	1.040	3.41	0.41								
1500					9.60	4.48	6.10	1.490	4.20	0.61	2.39	0.171						
2000					12.70	7.65	8.10	2.500	5.60	1.02	3.19	0.280						
2500							10.10	3.810	7.00	1.56	3.99	0.397						
3000							12.10	5.300	8.40	2.42	4.79	0.568	3.08	0.191				
3500							14.10	7.200	9.80	2.80	5.59	0.745	3.59	0.251				
4000									11.35	3.80	6.38	0.956	4.10	0.323				
5000									14.20	5.82	7.96	0.144	5.13	0.488	3.55	0.199	2.27	0.067

When pipe is slightly rough, add 15 per cent. When very rough, add 30 per cent.
Vel.—Velocity feet per second. Fric.—Friction head in feet.

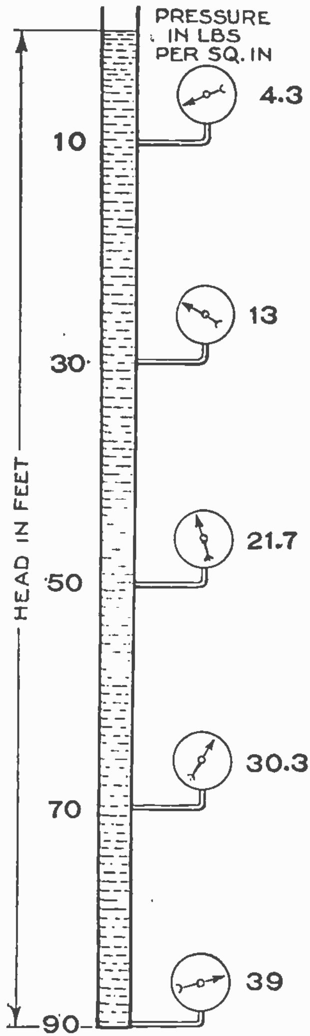


Fig. 8.803.—The pressure of water due to head increases with the depth.

Friction of Water in Elbows

Loss of head in feet, due to friction in various sizes of smooth 90° elbows when discharging the given quantities of water

Gals. per Minute	1-Inch Vel.	1-Inch Fric.	1¼-Inch Vel.	1¼-Inch Fric.	1½-Inch Vel.	1½-Inch Fric.	2-Inch Vel.	2-Inch Fric.	2½-Inch Vel.	2½-Inch Fric.	3-Inch Vel.	3-Inch Fric.	4-Inch Vel.	4-Inch Fric.	5-Inch Vel.	5-Inch Fric.	6-Inch Vel.	6-Inch Fric.	8-Inch Vel.	8-Inch Fric.	10-Inch Vel.	10-Inch Fric.	12-Inch Vel.	12-Inch Fric.
5	2.04	0.06	1.30	0.14																				
10	4.08	0.22	2.60	0.21																				
15	6.12	0.49	3.90	0.29	2.73	0.09																		
20	8.16	0.87	5.20	0.52	3.64	0.16																		
25	10.20	1.35	6.50	0.80	4.55	0.25	2.60	0.09																
30	12.24	1.95	7.80	1.15	5.46	0.36	3.06	0.13																
35	14.28	2.65	9.10	1.60	6.37	0.50	3.57	0.18	2.29	0.09														
40	16.32	3.46	10.40	2.05	7.28	0.64	4.05	0.23	2.62	0.11														
45			11.70	2.70	8.19	0.81	4.60	0.29	2.95	0.14	2.02	0.06												
50					9.10	0.99	5.11	0.35	3.30	0.18	2.27	0.08												
70					12.74	1.98	7.15	0.70	4.60	0.34	3.18	0.19	1.79	0.05										
100							10.20	1.41	6.54	0.74	4.54	0.29	2.55	0.10										
120							12.25	2.24	7.84	1.17	5.45	0.46	3.06	0.15	1.96	0.06								
150							15.30	3.20	9.80	1.58	6.80	0.66	3.84	0.22	2.45	0.09								
175									11.43	2.16	7.92	0.90	4.45	0.30	2.86	0.12	2.00	0.06						
200									13.07	2.96	9.08	1.18	5.11	0.40	3.27	0.16	2.28	0.07						
250											11.28	1.84	6.40	0.62	4.08	0.25	2.80	0.12	1.60	0.04				
270											12.45	2.35	6.90	0.70	4.42	0.25	3.03	0.14	1.70	0.05				
300											13.62	2.63	7.66	0.89	4.90	0.36	3.40	0.18	1.90	0.06				
350													8.90	1.24	5.72	0.50	3.98	0.24	2.20	0.09				
400													10.20	1.59	6.54	0.63	4.54	0.29	2.60	0.10				
450													11.50	2.01	7.35	0.81	5.12	0.39	2.92	0.13	1.80	0.05		
470													12.16	2.26	7.78	0.90	5.40	0.46	3.07	0.14	1.92	0.06		
500													12.77	2.47	8.17	1.01	5.60	0.48	3.20	0.16	2.00	0.07	1.40	0.04
750															12.26	2.24	8.40	1.09	4.80	0.36	3.00	0.15	2.10	0.07
1050																	12.57	2.41	7.04	0.76	4.40	0.29	3.08	0.14
1250																	14.10	3.02	8.00	1.00	5.00	0.40	3.50	0.20
1500																			9.60	1.44	6.10	0.58	4.20	[illegible]

When pipe is slightly rough, add 15 per cent. When very rough, add 30 per cent.
Vel.—Velocity in feet per second. Fric.—Friction head in feet.
Table shows loss for one elbow, and is based on Weisbach's Formula for short radius bends.

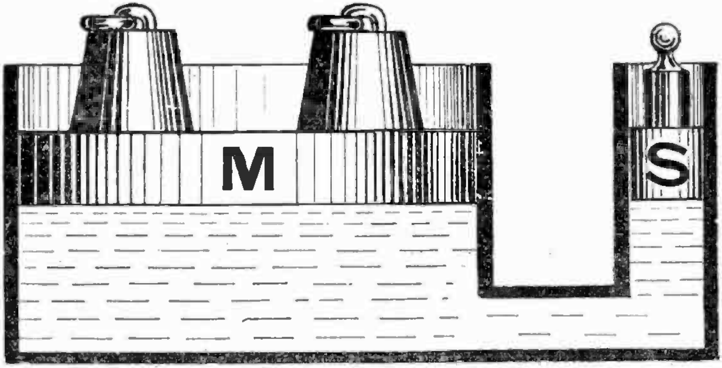


FIG. 8,804.—Pressure exerted by a liquid. *The pressure exerted by a liquid on a surface is proportional to the area of the surface.* Two cylinders of different diameter are joined by a tube and filled with water. On the surface are two pistons **M** and **S**, which hermetically close the cylinders, but move without friction. Let the area of the large piston **M** be, say thirty times that of the smaller one **S**, and let a weight, say of two pounds, be placed upon the small piston. The pressure will be transmitted to the water and to the large piston, and as this pressure amounts to two pounds in each portion of its surface equal to that of the small piston, the large piston must be exposed to an upward pressure thirty times as much, or 60 lbs. If now a 60 lb. weight be placed upon the large piston, both pistons will remain in equilibrium, but if the weight be greater or less, the equilibrium will be destroyed.

In any installation it is important to consider the friction of water in elbows as the table on page 5,539 indicates.

Pressure.—The term pressure is used in its ordinary sense in terms of pounds per square inch.

At 62° Fahr. the pressure per square inch of a column of water of one foot head is .43302. or 433 lbs. At this temperature one cubic foot of water would weigh .433×144=62.352 lbs. On this basis the pressure in pounds per square inch for different heads of water is as given in the following table.

Pressure per Lb. per Sq. In. for Various Heads of Water

Head feet	0	1	2	3	4	5	6	7	8	9
0		0.433	0.866	1 299	1.732	2 165	2.598	3.031	3.464	3.897
10	4.330	4.763	5.196	5.629	6.062	6.495	6.928	7.361	7.794	8.227
20	8.660	9.093	9.526	9.959	10 392	10.825	11.258	11 691	12.124	12.557
30	12.990	13.423	13.856	14.289	14 722	15.155	15.588	16.021	16.454	16.887
40	17.320	17.753	18.186	18.619	19.052	19.485	19.918	20.351	20.784	21.217
50	21.650	22.083	22.516	22.949	23.382	23.815	24.248	24.681	25.114	25.547
60	25.980	26.413	26.846	27.279	27.712	28 145	28.578	29.011	29.444	29.877
70	30.310	30.743	31 176	31.609	32.042	32 475	32.908	33.341	33.774	34.207
80	34.640	35.073	35 506	35.939	36.372	36 805	37.238	37 671	38.104	38.537
90	38.970	39.403	39 836	40.269	40 702	41 135	41.568	42 001	42 436	42.867

Head in Feet of Water for Various Pressures

Pressure	0	1	2	3	4	5	6	7	8	9
0		2.309	4.619	6.928	9.238	11.547	13.857	16.166	18.476	20.785
10	23.0947	25.404	27.714	30.023	32.333	34.642	36.952	39.261	41.570	43.880
20	46.1894	48.499	50.808	53.118	55.427	57.737	60.046	62.356	64.665	66.975
30	69.2841	71.594	73.903	76.213	78.522	80.831	83.141	85.450	87.760	90.069
40	92.3788	94.688	96.998	99 307	101.62	103.93	106.24	108.55	110.85	113.16
50	115.4735	117.78	120.09	122.40	124.71	127.02	129.33	131.64	133.95	136.26
60	138.5682	140.88	143.19	145.50	147.81	150.12	152.42	154.73	157.04	159.35
70	161.6629	163.97	166.28	168.59	170 90	173.21	175.52	177.83	180.14	182.45
80	184.7576	187.07	189.38	191.69	194.00	196.31	198.61	200.92	203.23	205.54
90	207.8523	210.16	212.47	214.78	217 09	219.40	221.71	224.02	226.33	228.64

In ordinary calculation, it is common practice to estimate that every foot head is equal to one-half pound pressure per square inch, as this allows for ordinary friction in pipes.

Lift.—When the barometer reads 30 inches at sea level, the pressure of the atmosphere at that elevation is 14.73 lbs. per sq. in., that is to say, this pressure will maintain or balance a column of water 34.019 ft. high when the column is completely exhausted of air, and the water is at a temperature of 62° Fahr.

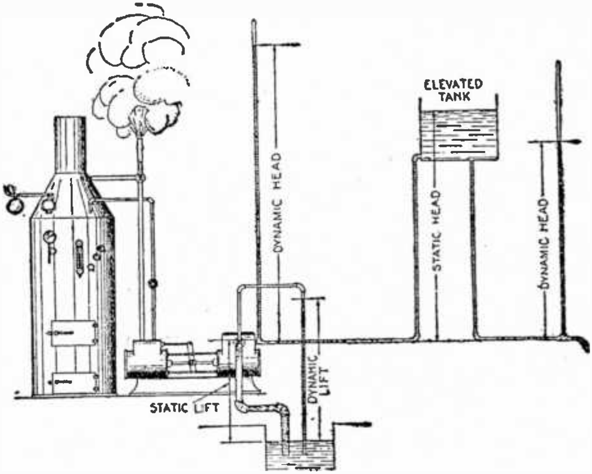


Fig. 8,805.—View of elevated tank with pump in operation maintaining the supply which is being drawn upon as shown, illustrating the terms static lift, dynamic lift, static head, and dynamic head.

In other words, the pressure of the atmosphere then *lifts* the water to such height as will establish equilibrium between the weight of the water and the pressure of the air. Similarly in pump operation, the receding piston or plunger establishes the vacuum and the pressure of the atmosphere lifts the water from the level of the supply to the level of the pump.

Lift as relating to pump operation may be defined as *the height in feet from the surface of the intake supply to the pump.*

Strictly speaking, it is the height to which the water is elevated by atmospheric pressure, which in some pumps may be measured by the elevation of the inlet valves and in others by the elevation of the piston.

In the case of pumps handling water at ordinary temperature (not hot water) the practical limit of lift is from 20 to 25 ft. when the barometer reads about 30 ins. In high altitudes it is less. Why?

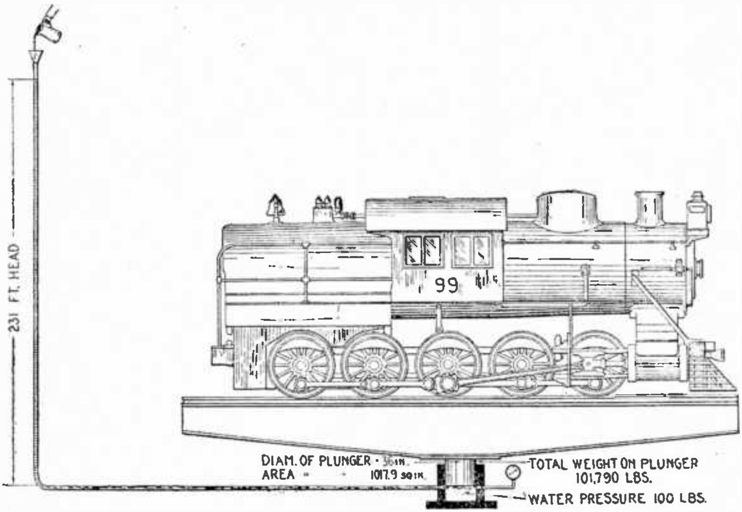


FIG. 8,806.—***Hydraulic principles:*** ***3.*** Any quantity of water however small may be made to balance any weight however great. The figure shows a locomotive on a turn table balanced by a hydraulic pivot or plunger. Assuming no leakage or friction at the joint, and that the vertical pipe leading to the plunger cylinder is very small, it is evident that it could be filled to the elevation shown with a very small quantity of water—say one quart. If the total weight of locomotive, turn table, etc., and the plunger be 101,709 lbs., and the plunger area be 1,017.9 sq. ins., then the water pressure per sq. in. on the piston necessary to balance the load =101,796÷1,017.9=100 lbs. Hence the load will be balanced when the pipe is filled with water to a height of 100×2.31=231 ft.

For increasing temperature of the water the limit of lift is reduced because the boiling point of water corresponds to the pressure.

Theoretically a perfect pump will draw water from a height of 34 ft. when the barometer reads 30 ins., but since a perfect vacuum cannot be obtained on account of valve leakage, air contained in the water *and the vapor of the water itself*, the actual height is generally less than 30 feet, and for warm or hot water considerably less.

The following table shows the theoretical maximum lift for different temperatures, leakage not considered.

Theoretical Lift for Various Temperatures

Temp. Fahr.	Absolute pressure of vapor lbs. per sq. ins.	Vacuum in inches of mercury	Lift in feet	Temp. Fahr.	Absolute pressure of vapor lbs. per sq. ins	Vacuum in inches of mercury	Lift in feet
102.1	1	27.88	31.6	182.9	8	13.63	15.4
126.3	2	25.85	29.3	188.3	9	11.6	13.1
141.6	3	23.83	27	193.2	10	9.56	10.8
153.1	4	21.78	24.7	197.8	11	7.52	8.5
162.3	5	19.74	22.3	202	12	5.49	6.2
170.1	6	17.70	20	205.9	13	3.45	3.9
176.9	7	15.67	17.7	209.6	14	1:41	1.6

NOTE.— ***Head.*** The head instead of being an actual distance between levels, may be caused by pressure, as by a pump, in which case the head is calculated as a vertical distance corresponding to the pressure, 1 lb. per sq. in. = 2.309 ft. head or 1 ft. head = .433 lb. per sq. in. The total head operating to cause flow is divided into three parts: 1, the *velocity head*, which is the height through which a body must fall in a vacuum to acquire the velocity with which the water flows into the pipe $= v^2 \div 2g$, in which v is the velocity in ft. per sec. and $2g = 64.32$; 2, the *entry head*, that required to overcome the resistance to entrance to the pipe. With sharp edged entrance the entry head = about ½ the velocity head; with smooth rounded entrance the entry head is inappreciable; 3, the *friction head*, due to the frictional resistance to flow within the pipe. In ordinary cases of pipes of considerable length the sum of the entry and velocity heads required scarcely exceeds 1 ft. In the case of long pipes with low heads the sum of the velocity and entry heads is generally so small that it may be neglected.

NOTE.—***When the water is warm*** the height to which it can be lifted decreases, on account of the increased pressure of the vapor. That is to say, for illustration, a boiler feed pump taking water at say 153° Fahr., could not produce a vacuum greater than 21.78 ins. because at that point the water would begin to boil and fill the pump chamber with steam. Accordingly, the theoretical lift corresponding would be

$$34 \times \frac{21.78}{30} = 24.68 \text{ ft. approximately}$$

The result is approximate because no correction has been made for the 34 which represents a 34 foot column of water at 62°; of course, at 153° the length of such column would be slightly increased. It should be noted that the figure 24.68 ft. is the *approximate* theoretical lift for water at 153°; the *practical* lift would be considerably less.

TEST QUESTIONS

1. *Define the term hydraulics.*
2. *What is the difference between hydrostatics and hydrodynamics?*
3. *Mention some of the properties of water.*
4. *What is the most remarkable characteristic of water?*
5. *What is the relation between head and pressure?*
6. *What are the four kinds of head?*
7. *What is the effect of water flowing through pipes?*
8. *What is the difference between lift and head?*
9. *Draw a sketch illustrating dynamic lift and dynamic head.*
10. *How is pressure measured?*
11. *What effect has temperature on lift?*
12. *What is the maximum possible lift?*

CHAPTER 228

Elementary Pumps

There are three elements necessary for the operation of a pump:

1. Inlet or suction valve;
2. Piston or plunger;
3. Discharge valve.

Simple pumps may be divided into two classes:

1. Lift pumps;
2. Force pumps.

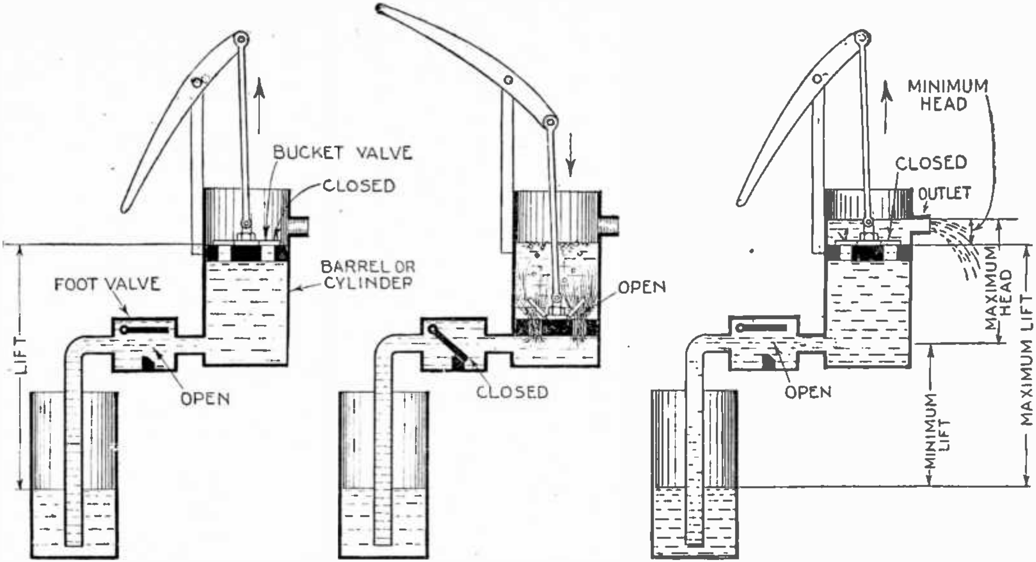
A lift pump is one which does not elevate the water higher than the lift; a force pump operates against both lift and head.

Lift Pumps.—The essentials and working principles of a simple lift pump are shown in figs. 8,807 to 8,809.

In construction there are two valves in this type of pump, which are known as the foot valve and the bucket valve. ***In operation*** during the up stroke the bucket valve is closed and foot valve opens, allowing the atmosphere to force the water into the cylinder.

When the piston begins to descend, the foot valve closes and bucket valve opens, which transfers the water in the cylinder from the lower side of the piston to the upper side as in fig. 8,808.

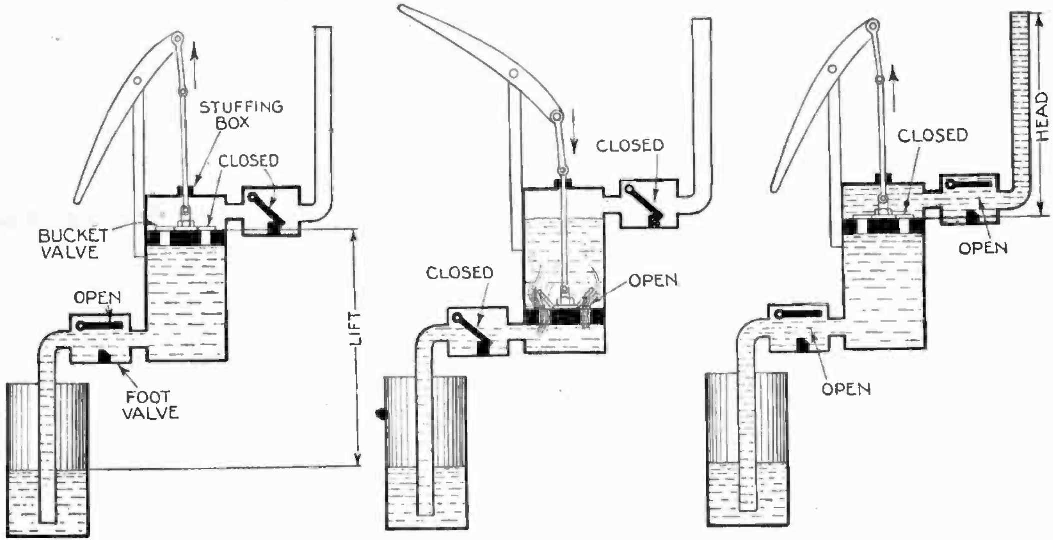
During the next up stroke, the water, already transferred to the upper side of the piston, is discharged through the outlet as in fig. 8,809.



FIGS. 8,807 to 8,809.—Elementary single acting lift pump showing essential features and cycle of operation.

It will be noted that as the piston begins the up stroke of discharge it is subject to a small maximum head, and at the end of the up stroke to a minimum head as indicated in fig. 8,809. This variable head is so small in comparison to the head against which a force pump works that it is not ordinarily considered.

Force Pumps.—There are two general classes of force pumps:



FIGS. 8,810 to 8,812.—Elementary single acting force pump showing distinguishing feature of closed cylinder.

1. Single acting:

   a. Piston;

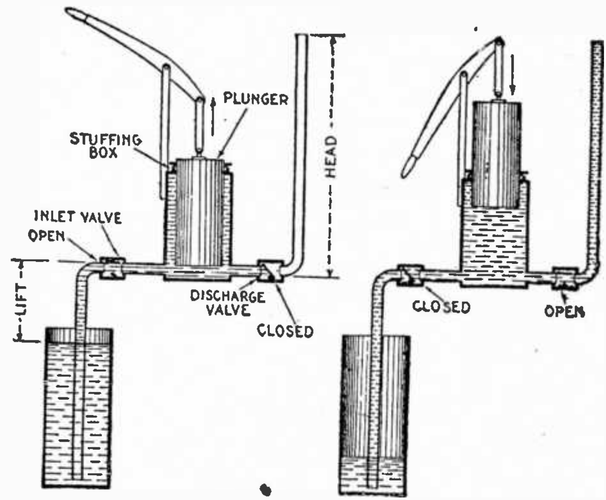
   b. Plunger.

2. Double acting:

   a. Piston;

   b. Plunger.

Single Acting Force Pumps.—The essential feature of a force pump which distinguishes it from a lift pump is that *the cylinder is always closed*, whereas in a lift pump it ***is alternately closed and open*** when the piston is respectively at the upper and lower ends of its stroke.



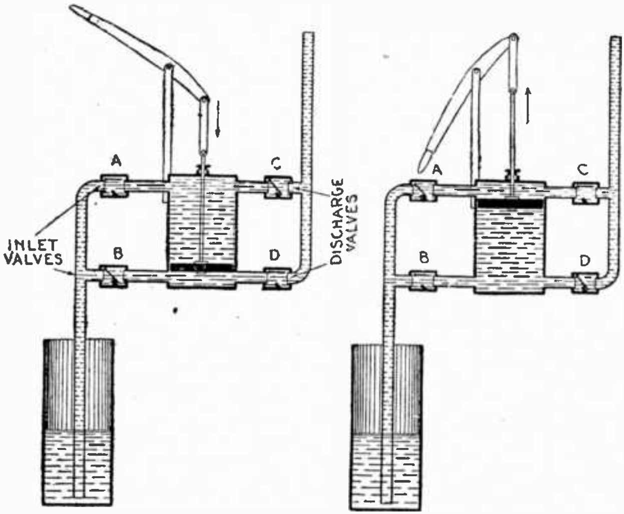
FIGS. 8,813 and 8,814.—Elementary single acting plunger pump showing essential parts. The distinction between a plunger and a piston should be carefully noted. *In operation* during the up stroke water fills the cylinder, inlet valve opens, and outlet valve closes, as shown in fig. 8,813. During the down stroke, the plunger "displaces" the water in the barrel, forcing it through the discharge valve against the pressure due to the head.

As shown in figs. 8,810 to 8,812, the cylinder top is closed by a cover, the piston rod passing through a stuffing box; this keeps the cylinder closed.

In addition to the foot and bucket valves of the lift pump, a head valve is provided.

In operation, during the up stroke, atmospheric pressure forces water into the cylinder as in fig. 8,810; during the down stroke this water is transferred from the lower to the upper side of the piston as in fig. 8,811; during the next up stroke, the piston forces the water out of the cylinder through the head valve which closes when the piston reaches the end of the stroke, as in fig. 8,812, and the cycle is repeated. The positions of the valve are shown in the cuts.

A simple form of force pump, is one known as a single acting plunger pump, a type extensively used, its cycle of operation being shown in figs. 8,813 and 8,814. The figures show the distinguishing features, such as closed cylinder, plunger, and only two valves.



FIGS. 8,815 and 8,816.—Elementary double acting force pump. It is a combination of two single acting pumps and gives a nearer uniform flow than the single acting pump. *In operation* during the down stroke, water follows the upper face of the piston through valve A. At the same time the previous charge is forced out of the cylinder through valve D, by the lower face of the piston. During these simultaneous operations, valves A, and D, remain open, and B, and C, closed, as in fig. 8,815. During the up stroke, water follows the lower face of the piston through valve B. At the same time, the previous charge is forced out of the cylinder through valve C, by the upper face of the piston. During these simultaneous operations, valves B, and C, remain open, and A, and D, closed.

In operation during the up stroke water fills the cylinder, inlet valve opens, and outlet valve closes, as shown in fig. 8,813. During the down stroke, the plunger "displaces" the water in the barrel, forcing it through the discharge valve against the pressure due to the head.

The careless misuse of the term piston and plunger should be carefully avoided. The difference between a piston and a plunger is:

A piston is *shorter* than the stroke, whereas a plunger is *longer* than the stroke.

Double Acting Force Pumps.—*By fitting a set of inlet and outlet valves at each end of a pump cylinder it is rendered* **double acting,** that is, a cylinder full of water is pumped each stroke instead of every other stroke.

With this arrangement the piston need have approximately only half the area of the single acting piston for equal displacement, and accordingly the maximum stresses brought on the reciprocating parts are reduced approximately one-half, thus permitting lighter and more compact construction.

In the double acting pump there are no bucket valves, a solid piston being used. The essential features and operation are plainly shown in figs. 8,815 and 8,816. There are two inlet valves A. B, and two discharge valves C, D; the cylinder being closed and provided with a piston.

Air Chambers.—These are placed upon pumps on the head or discharge side of the discharge valve, and contain air for the purpose of introducing an *air cushion* to counteract the solidity of the water, thus preventing shocks or *water hammer* as the water flows through the valves; and also for the purpose of securing a steady discharge of water.

The water being under pressure in the discharge chamber, compresses the air in the air chamber during each stroke of the water piston and, when the piston stops momentarily at the end of the stroke, the air expands to a certain extent and tends to produce a gradual stopping of the flow of water, thus permitting the valves *to seat easily and without shock or jar.*

Fig. 8,818 shows an air chamber.

Air chambers are useless unless means be provided to keep air in them.

In large pumping plants small air pumps are employed for keeping the air chambers properly charged. In smaller plants an ordinary bicycle pump and a piece of rubber tubing are used to good advantage.

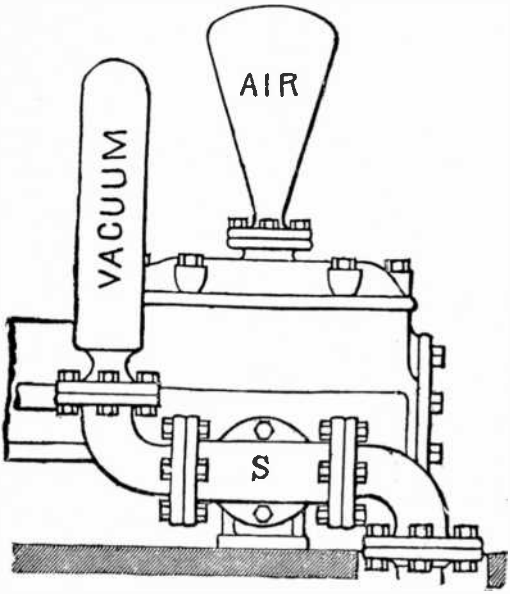


FIG. 8,817.—Air and vacuum chambers. The air chamber is for the purpose of introducing an air cushion to counteract the solidity of the water, thus preventing shocks as the water flows through the valves.

To avoid the air chamber and its defect just mentioned the author substituted a spring cushion on the high speed direct connected boiler feed pump of his marine engine, as shown in fig. 8,819, and further described in Chapter 52, Audels Engineers and Mechanics Guide No. 4.

This gives a positive cushion at any speed and does away with the air chamber.

Vacuum Chamber.—Sometimes a vacuum chamber is attached to the suction pipe. When the column of water in the suction pipe of a pump is once set in motion, it is quite important, especially under high speeds and long intake lines, to keep the water in full motion, and when it is stopped, to stop it gradually and easily.

This is accomplished by placing a vacuum chamber on the suction pipe, as shown. *The action of the vacuum chamber is practically the reverse of that of the air chamber*. The object of the vacuum chamber is to facilitate changing continuous into intermittent motion. The moving column of water compresses the air in the vacuum chamber at the ends of the stroke of the piston, and when the piston starts the air expands (thus creating a partial vacuum above the water) and aids the piston in setting the column of water in motion again.

Fig. 8,817 shows a pump fitted with both air and vacuum chambers.

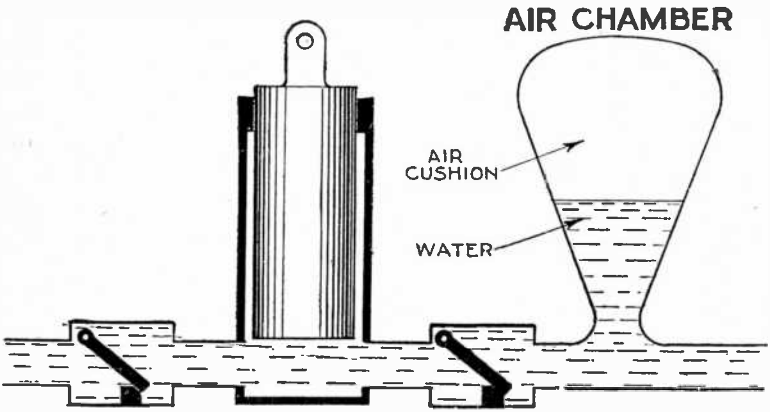
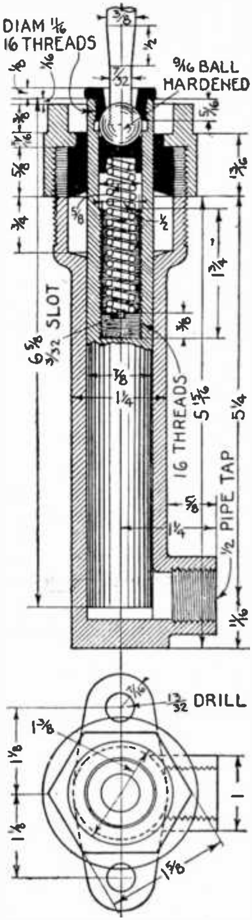


FIG. 8,818.—Elementary boiler feed pump with air chamber. In small sizes these are sometimes direct connected to the engine and often run at high speeds. Obviously some form of cushion against water hammer is necessary. Fig. 8,819 shows a better and more up to date method of cushioning water hammer.

Capacity of Pumps.—By definition capacity is *the amount of water a pump is able to deliver when operated at a given speed.* There are two kinds of capacity:

1. Theoretical capacity;
2. Actual or net capacity.

The theoretical capacity represents the pumping ability of a perfect



pump, and is expressed as *the volume in cubic feet or gallons displaced by the pump per minute*.

Since it is impossible to construct a perfect pump, it is customary in computing capacity, to first calculate the theoretical capacity and then make allowance for the various losses due to slip, leakage, etc.

Slip, Leakage and Short Strokes.—These three factors are the causes which prevent pumps operating up to theoretical capacity. Note the following definitions:

Slip.—The back flow of water through the valves while they are in the act of closing.

Leakage.—Loss of water through the stuffing box, valves, piston and joints and entrance of air on the suction side.

Short Strokes.—The failure of direct acting steam pumps to operate at full stroke.

How to Figure Capacity.—*RULE Multiply the area of the piston in sq. ins. by the length of the stroke in ins., and by the number of delivery strokes per minute, divide the product by* **1,728,** *to obtain the theoretical capactiy in* **cu. ft.,** *or by* **231**

FIGS. 8,819 and 8,820.—Feed pump. Note the absence of air chamber. The author, who had several years' experience designing large pumps for city water works found that the so-called air chambers were virtually water chambers, because unless means were provided to keep them filled with air, they soon became filled with water and ceased to perform their function of cushioning the shocks. Accordingly, such device is here dispensed with, and a spring cushion provided which is expected to absorb the shocks even at high speed. No valves are built into the pump casting, a tee fitting and two check valves being used, connected with close nipples. See *Audel's Engineers' and Mechanics' Guide No. 4,* page 1,724.

to obtain theoretical capacity in **U. S. gallons.** *The result thus obtained is to be multiplied by an assumed* **factor** *representing the hydraulic efficiency of the pump to obtain the* **approximate** *net capacity.*

The rule expressed as a formula is

$$\text{Approximate net capacity} = \frac{.7854\,D^2 \times L \times N}{1{,}728} \times (1-f) \text{ cu. ft., or}$$

$$= \frac{.7854\,D^2 \times L \times N}{231} \times (1-f) \text{ gallons}$$

in which

D^2 = square of piston or plunger diameter in sq. ins.;

L = length of stroke in ins.;

N = number of delivery strokes per minute;

f = factor representing assumed slip in per cent of displacement;

1,728 = cu, ins. in one cu, ft.;

231 = cu, ins. in one U. S. gallon.

Example.—What is the approximate net capacity of a 3×5 double acting power pump running at 75 revolutions per minute with an assumed slip of 5 per cent, applying this formula?

$$\text{Approximate net capacity} = \frac{.7854 \times 3^2 \times 5 \times 150}{1{,}728} \times (1-.05) = 2.91 \text{ cu. ft.}$$

$$= \frac{.7854 \times 3^2 \times 5 \times 150}{231} \times (1-.05) = 21.8 \text{ galls.}$$

Horse Power of Pumps.—The power required to elevate water at a given rate to a given elevation is expressed in horse

NOTE.—*A single acting lift pump* having bucket valves will deliver more than its theoretical capacity (especially when operated at high speed) because the column of water does not cease flowing when the bucket descends, that is, especially at high speeds the foot and head valves remain open all the time, and the bucket valve accordingly under such conditions is the only valve essential to operation.

power, as theoretical or actual, according to whether the various losses are considered. In a pump there is to be considered the horse power at the water end, and also at the power end. The horse power at the power end represents the actual power to be applied and includes that lost by friction.

Theoretical Horse Power at the Water End.—The theoretical horse power required to raise water at a given rate to a given elevation is obtained by the following formula:

$$\text{T. H. P.} = \frac{V \times W \times (L+H)}{33{,}000}$$

in which

V = volume in cu. ft. per minute;

W = weight of one cu. ft. of water;

L = lift in ft.;

H = head in ft.

Example.—What is the theoretical horse power required to raise 100 cu. ft. of water 200 ft., with a 10 ft. lift when the water is at a temperature of 75° Fahr., and when at 35° Fahr.?

For a temperature of 75°, one cu. ft. of water according to the table (page 5,534) weighs 62.28 lbs. Substituting this and the other data in the formula,

$$\text{T. H. P.} = \frac{100 \times 62.28 \times (10+200)}{33{,}000} = 39.63$$

Now if the water have a temperature of only 35°, as might be in very cold weather, the weight of one cu. ft. will increase to 62.42, and the horse power would accordingly increase in proportion to the ratio of the two weights, or

$$\text{T. H. P. (at 35° Fahr.)} = 39.63 \times \frac{62.42}{62.28} = 39.7$$

By observing the very slight difference in the two results it will be seen that, for ordinary calculation, the temperature need not be considered, taking the usual value 62.4 lbs.

Horse Power Absorbed at the Water End.—The actual horse power required at the water end of a pump (not including slip or mechanical efficiency) is equal to *the theoretical horse power plus an allowance for the friction of the water through the pipes and pump passages.* The latter being usually very small as compared with the former, may be neglected.

There is also friction of water in the elbows which is usually taken into account.

The tables on pages 5,537 and 5,539 give the approximate friction of water in pipes and elbows, from which the virtual head to be used is easily found and which when inserted in the T. H. P. formula will give the "actual horse power" as above defined.

Electrical Horse Power.—The number of watts required by the motor of an electric pump must be sufficient to furnish power for:

1. Lifting the water;
2. Loss due to slip;
3. Overcoming the friction of water in traversing the system from intake to point of delivery;
4. Overcoming the friction of pump and gearing;
5. Overcoming the friction of the motor;
6. Electrical losses in motor.

Accordingly, as must be evident, the actual power to be supplied to the motor is considerably more than the theoretical power required to lift the water.

For illustration, assuming that a certain pump have an efficiency of 85 per cent and the motor which runs it, 88 per cent, then the combined efficiency, or efficiency of the system is $.85 \times .88 = .75$. That is to say,

NOTE.—If the quantity of water be given in gallons, W is taken as 8⅓ lbs., instead of 62.4 lbs.

if the electrical power delivered to the motor be 100 horse power and the efficiency of the system be 75 per cent, then only

$$100 \times .75 = 75 \text{ horse power}$$

is available for elevating the water.

How to Figure the Cost of Electric Pumping.—To get the actual electrical power required, first, the theoretical head should be increased by the loss of head in feet due to friction in the pipe line, as determined from the accompanying tables. The result determined in this way must then be considered for the power loss in the pumping unit. This is determined by dividing the theoretical horse power by the efficiency of the system expressed as a decimal, thus:

$$\text{H. P. required by motor} = \frac{W \times H}{33{,}000 \times E} \quad \ldots\ldots\ldots\ldots (1)$$

in which

W = weight of water pumped per minute in pounds;

H = total dynamic head;

E = efficiency of the system comprising pump, motor, and gearing connecting them.

Example.—It is required to pump 300 gallons of water per minute against a combined static iift and head of 200 ft. The pipe line is 400 ft. iong and contains 5 ninety degree elbows.

From the table showing friction of water in pipes (page 5,537), the friction loss in 100 ft. of 5 in. pipe, discharging 300 gals. per min. is 2.25 ft. Accordingly for 400 ft. it is $4 \times 2.25 = 9$ ft. From the table showing friction of water in elbows (page 5,539), one 5 in. 90° elbow, discharging 300 gals. per min. = .36 ft. Five elbows = $5 \times .36 = 1.8$ ft.

The total dynamic head is therefore, $200 + 9 + 1.8 = 210.8$ ft. Now the weight of water pumped per minute is $8\frac{1}{3} \times 300 = 2{,}500$ lbs.

Assuming an efficiency of 75 per cent for the system, and substituting in (1)

$$\text{H. P.} = \frac{2{,}500 \times 210.8}{33{,}000 \times .75} = 21.3 \text{ horse power}$$

Having determined the actual horse power to be delivered to the motor, the cost per hour for operating the pump can be readily determined by multiplying the horse power just obtained by .746 and by the central station charge per kw. hour. Thus, if the charge be 10c, then

$$\text{Cost of pumping} = 21.3 \times .746 \times .10 = \$1.59 \text{ per hour}$$

TEST QUESTIONS

1. *What is the difference between a lift pump and a force pump?*
2. *Name two general classes of pumps.*
3. *How does a single acting force pump work?*
4. *Describe the double acting force pump.*
5. *What is the object of air and vacuum chambers?*
6. *Name three conditions which reduce the capacity of a pump.*
7. *How is the capacity of a pump figured?*
8. *How is the horse power of a pump calculated?*
9. *What is the formula for theoretical horse power at water end?*
10. *What determines the number of watts required in electric drive?*
11. *How is the cost of pumping figured?*
12. *What is the difference between a plunger and a piston?*

CHAPTER 229

Power Pumps

A power pump is *a machine for the transfer of liquid or gases from one location to another and driven by any prime mover either direct connected or geared*, as by belt, chain or toothed gears.

Briefly, any pump having a shaft to which the motive power is applied is a power pump.

A power pump differs essentially from a steam pump in many of its operating characteristics. These differences should be clearly understood, as often a power pump replacing a steam pump does not give complete satisfaction until the user becomes educated to the requirements for satisfactory power pump operation.

A power pump is essentially a constant speed machine.* It does not have the flexibility as regards speed and capacity that a steam pump has. Therefore, more care must be taken to insure that the power pump speed is correct for all the conditions to be met.

If the suction pipe be too long or too small, or if a full supply of water be not available, a steam pump can readily be slowed down until its capacity is equal to the maximum amount of water which can be drafted through the suction line. A power pump under similar conditions must run along at full speed, but only partially filling. This causes severe pounding and, eventually breakage.

If excess pressure be put on the discharge line, as may happen from a closed or partially closed valve, the steam pump automatically slows down and often stalls if the pressure become high enough. Under the same conditions the power pump goes right along at full speed until the motor burns out under overload, or until something breaks on the pump. It is, therefore, essential that a power pump be protected by a spring relief valve to prevent the discharge pressure becoming too great.

*NOTE.—***An exception*** is the direct connected marine pump whose speed is governed by the main engine.

Classification.—Pumps may be classified:

1. With respect to the cycle of operation, as

   a. Reciprocating {single acting; double acting;
   b. Rotary;
   c. Centrifugal {single stage; multi-stage;

2. With respect to the number of cylinders, as

   a. Single cylinder;
   b. Duplex;
   c. Triplex;
   d. Quadruplex, etc.

3. With respect to the position of the cylinder, as

   a. Vertical;
   b. Horizontal.

4. With respect to the reciprocating part, as

   a. Piston;
   b. Plunger.

5. With respect to the stuffing box, as

   a. Inside packed;
   b. Outside packed.

6. With respect to the valve arrangement, as

   a. Single valve;
   b. Multi-valve;
   c. Bucket valve;
   d. Pot valve.

7. With respect to the pressure, as

a. Low pressure;

b. Medium pressure;

c. High pressure.

8. With respect to the velocity reduction of the drive, as

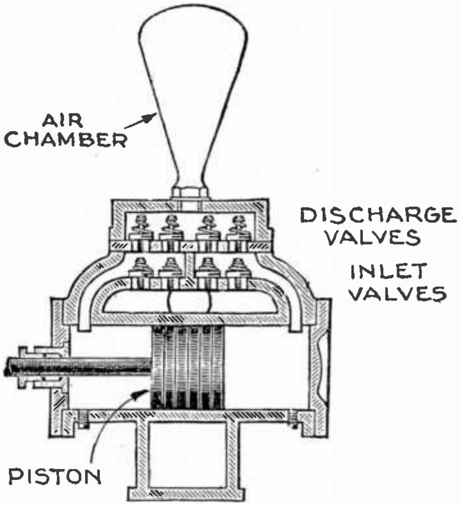


FIG. 8,821.—Double acting piston pump, water end, showing sectional view of piston, cylinder, stuffing box, valves, and water passages. The lower row of valves are the inlet valves, and the upper row the discharge valves.

a. Single reduction;

b. Double reduction;

c. Multi-reduction.

9. With respect to the drive construction, as

a. Spur gear;

b. Spiral gear;

c. Worm gear;

d. Combination silent chain and toothed gear;

e. Combination belt and toothed gear.

Construction Details.—There are four general types of pump cylinder classed with respect to the piston or plunger:

1. Piston.

2. Inside packed plunger.

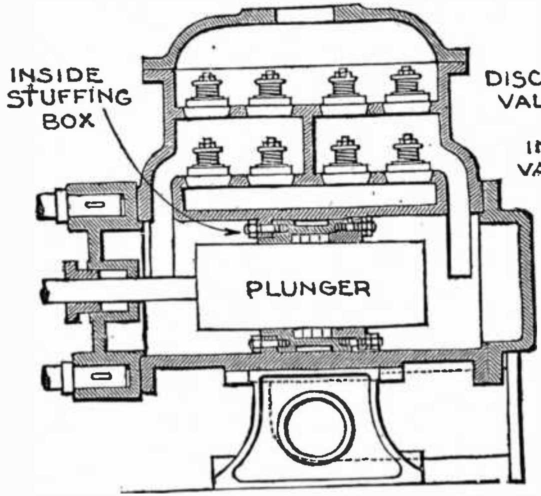
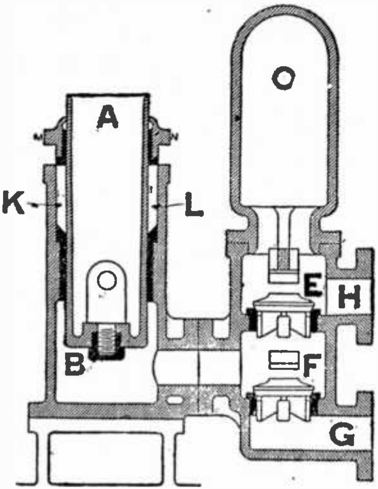


FIG. 8,822.—Double acting inside packed plunger pump, water end showing sectional view of working parts.

3. Single acting outside packed plunger.

4. Double acting outside packed plunger.

These general types are shown in figs, 8,821 to 8,824.



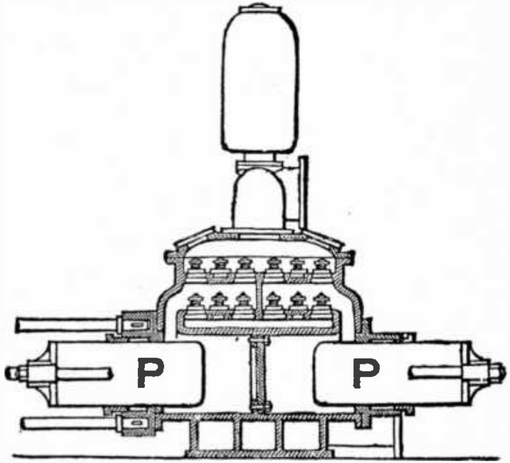


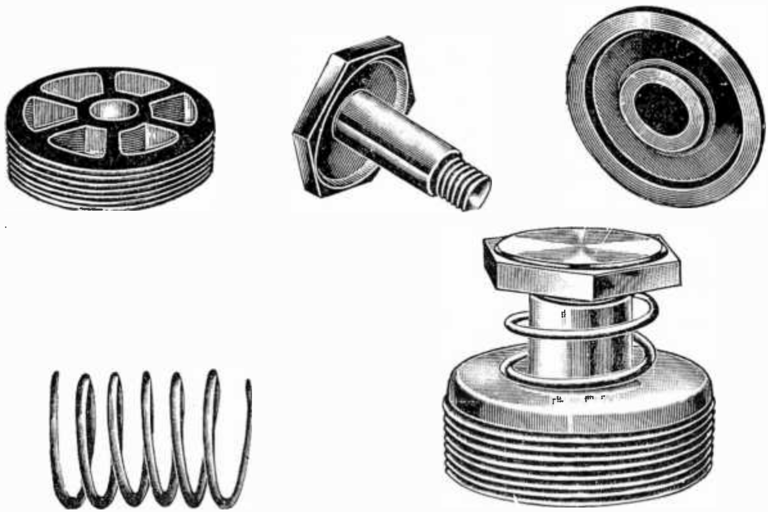
FIG. 8,823.—Single acting outside packed plunger pump. ***In construction,*** the moving parts consist of the plunger **AB** working in the stuffing box **KL**. There are two valves or sets of valve **F** and **E**. The stuffing box **KL** being on the outside can be kept in perfect adjustment, and with proper design the suction and discharge valves may be examined by the simple removal of a bonnet. The strong points of this pump are its simplicity, and the ready accessibility for examination and adjustment of all parts on which the operation of the pump may depend. Water enters at **G**, and discharges at **H**. **O** is the air chamber.

FIG. 8,824.—Double acting outside packed plunger pump. The plungers are connected by yokes and outside rods, the yokes and a portion of the rods being shown in the figure. The construction is virtually a combination of two single acting plunger pumps so connected as to give the equivalent of a double acting pump cycle.

Pump Valves.—The valve apparatus is perhaps the most important part of any form of pump and its design has a material bearing upon its efficiency.

Figs. 8,825 to 8,831 show ordinary types of large and small valve construction.

The Drive or Transmission.—The reciprocating pump, because of the necessarily low speed at which it must operate,



Figs. 8,825 to 8,829.—Metal valve with screw seat details. Fig. 8,825, screw seat; fig. 8,826, stud; fig. 8,827, metal valve; fig. 8,828, spring. fig. 8,829, assembly.

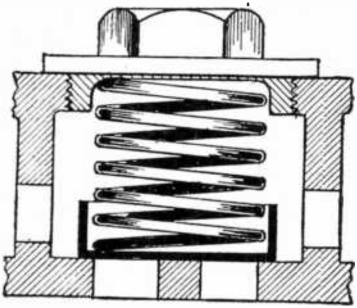
requires a high velocity reduction between the power unit and pump, especially in the case of electric motors. Accordingly some form of gearing which constitutes the "drive" or transmission must be interposed between the two machines.

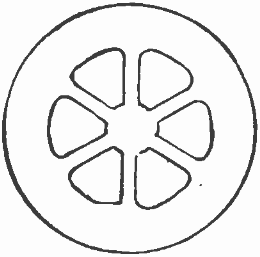
The various types of drive are

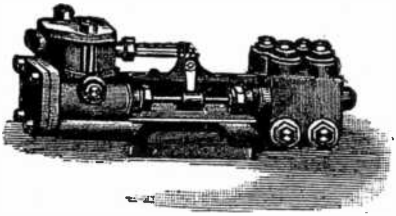
1. Belt:
   a. Single reduction;
   b. Double reduction.
2. Toothed gear.
3. Combined belt and toothed gear.
4. Chain.

These drives are shown in figs. 8,842 to 8,845.

Belt drives are simple,, flexible inexpensive and quiet.



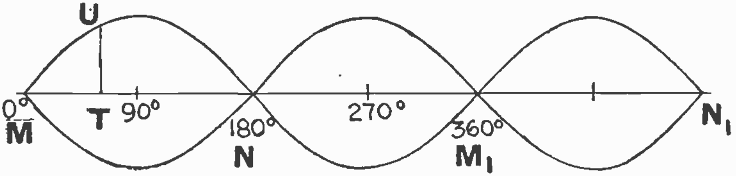


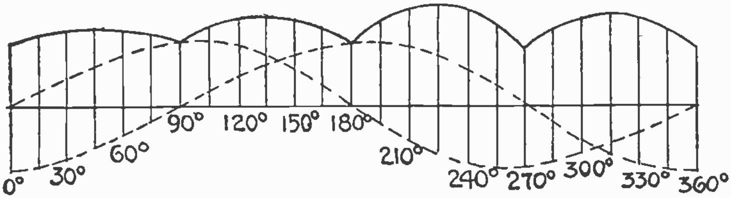


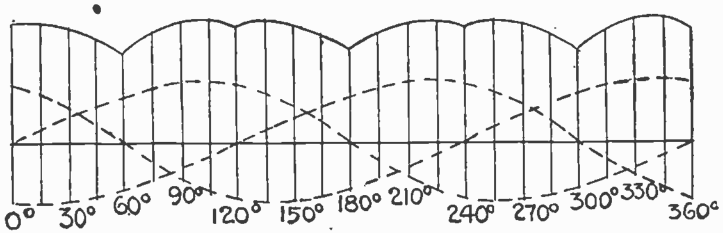
FIGS. 8,830 and 8,831.—Metal valve and seat as used on small units such as boiler feed pumps.

FIG. 8,832.—A very small Worthington duplex pump. Its dimensions are as follows: 2 inch diam. steam cylinder; 1⅛ inch water cylinder; 2⅜ in. stroke. Steam pipe, ⅜ in.; exhaust pipe, ½ inch; suction pipe, 1 inch; discharge, ¾ inch. Floor space occupied, 1′ 9″ ×7″ wide.

Multi-Cylinder Pumps.—The following types, as here described, are in general use:







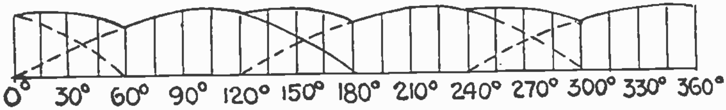
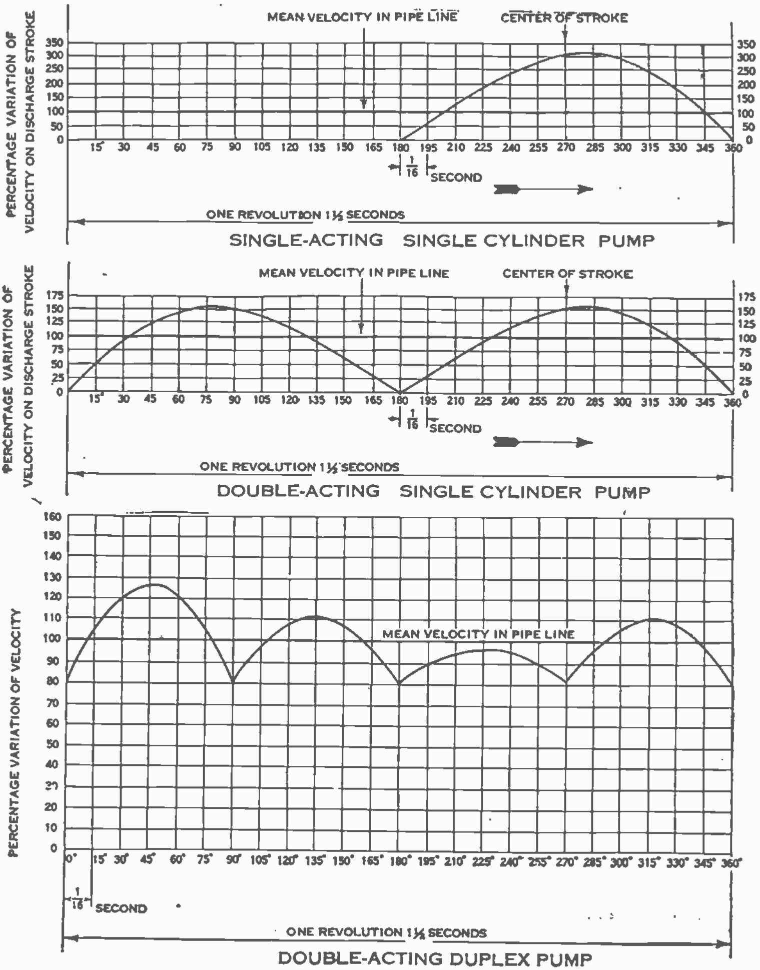


FIG. 8,833.—Flow curve of single double acting power pump.

FIG. 8,834.—Flow curve of duplex double acting power pump.

FIG. 8,835.—Flow curve of triplex double acting power pump.

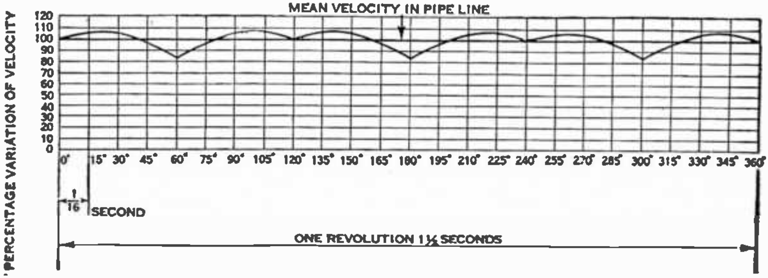
FIG. 8,836.—Flow curve of triplex single acting power pump.



FIGS. 8,837 to 8,839.—Diagrams showing rate of delivery of single cylinder and duplex reciprocating pumps expressed in percentage of mean velocity in pipe line.

1. *Single power pump.*—This type has one crank which operates one double acting piston, or plunger, or two single acting plungers.

2. *Duplex power pump.*—A pump having two double acting pistons (or plungers), or four single acting plungers operated by cranks 90° apart.



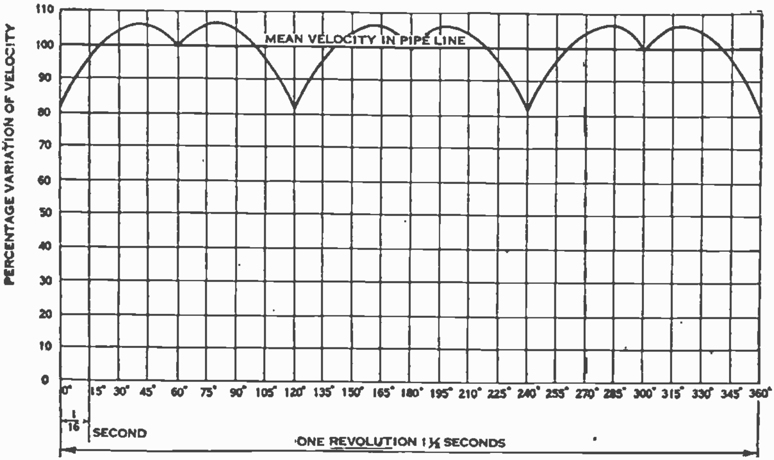


FIG. 8,840.—Diagram showing rate of delivery of single acting triplex pump expressed in percentage of mean velocity in pipe line.

FIG. 8,841.—Diagram showing rate of delivery of double acting triplex pump expressed in percentage of mean velocity in pipe line.

3. *Triplex power pump.*—In this arrangement there are three pistons or plungers operated by cranks 120° apart. They may be either single or double acting type.

The merits of the three types may be fully understood by a study of the flow curves shown in figs. 8,833 to 8,836. Fig. 8,833 shows that the flow from one single acting plunger is subject to considerable fluctuation in both suction and delivery lines. This led to the addition of two more plungers with their connecting rods, cranks, shaft, etc., setting all three cranks 120° apart, which, as the curves indicate, gives a nearer uniform flow.

Electric Motor Drive.—The electric motor is extensively used for driving power pumps. To obtain the best results, it is essential that the motor selected for driving the pump be of the proper size and type.

The capacity and rating of the motor are of great importance, especially when power is purchased on the rating of the motor.

If the motor be too small, it will be constantly overloaded, and if too large, the customer pays for power not used.

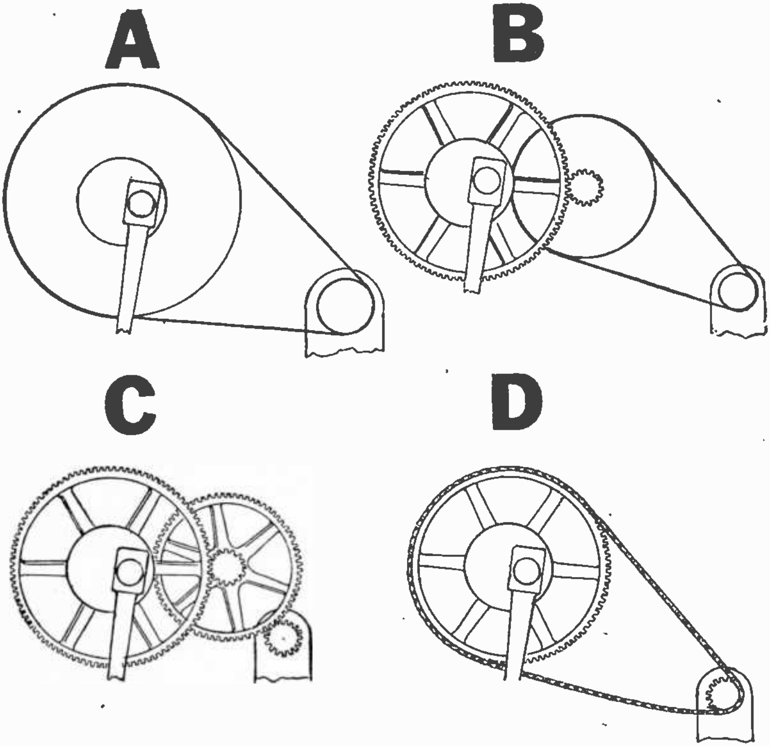
Local conditions may govern to some extent the type of motor and controlling equipment to use for some specific installation. In the majority of cases, however, the selection will be governed by the characteristics of the pump, the variations in load during operation, the characteristics of the motor and the characteristics of the pump and motor as a whole.

All motors used for driving pumps should have a high grade of moisture resisting insulation. Where excessive moisture is encountered, as in deep, poorly ventilated pump pits, damp mines, etc., a special moisture resisting insulation should be specified.

The following will serve as a guide in selecting the proper motor:

For Positive Displacement Pumps

Power Supply	*Type of Motor*
Direct current	Compound wound
Alternating current	Single phase commutator type



FIGS. 8,842 to 8,845.—Various forms of drive for power pumps. **A**, belt, single reduction; **B**, combined belt and toothed gear, double reduction; **C**, tooth gear, double reduction; **D**, chain, single reduction.

NOTE.—*The method of driving* any power pump can be varied to suit the conditions prescribed by the purchaser. In hotels, office buildings, apartment houses, etc., where noise is objectionable, the belt drive is recommended.

NOTE.—*Belt drives* are simple, flexible, inexpensive and especially when compared to double reduction gear drives, the belt drive is quiet and easy to keep in order. The double reduction gear drive gives noisy operation and with high speed gearing its operation is extremely noisy. The double reduction gear drive is less efficient than the belt drive. Moreover, all shocks are transmitted directly from the pump through the gears to the motor.

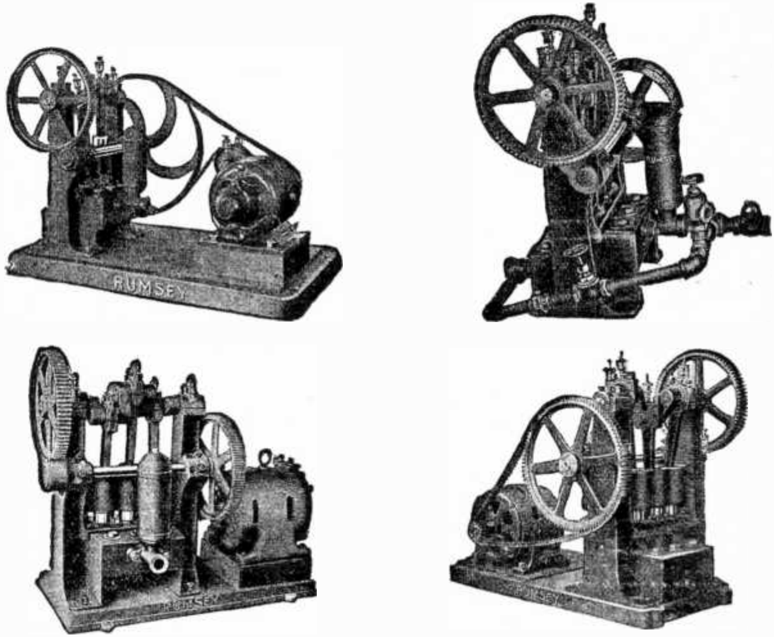
NOTE.—*With the belt drive* a higher speed motor can usually be used than with double reduction gears. Hence, the belt driven outfit is cheaper. The belt driven machine is cheaper since the motor sub-base and motor gears are not required for the belt drive. Moreover, with large motors, double reduction gear drive requires an outboard bearing.

A.c. two or three phase.............. {
5 *h.p.* and smaller squirrel cage
40 *h.p.* and smaller wound rotor self-starting
All capacities slip ring motors }

For Constant Speed Service, Centrifugal Pumps

Direct current........................Compound wound

A.c. single phase....................Commutator type



FIGS. 8,846 to 8,849.—Various drives as used on Rumsey single acting triplex pumps. Fig. 8,846, belt with idler; fig. 8,847, single reduction, toothed gear; fig. 8,848, double reduction toothed gear; fig. 8,849, chain.

A.c. two or three phase.............. {
Squirrel cage up to 500 *h.p.*
Slip ring, 550 *h.p.* and above
75 *h.p.* and larger synchronous motors }

For Variable Speed Service, Centrifugal Pumps and Positive Displacement Pumps

Direct current	Compound wound
A.c. single phase	Brush shifting motor
A.c. two or three phase	Brush shifting motor Slip ring when speed reducing is small

The power driven positive displacement pump with tightly packed stuffing boxes and pistons and full discharge head may require a starting torque equal to 125 to 250% of the normal full load torque, depending largely upon the care used in packing the pump. These starting requirements may be improved by the use of a by-pass which circulates the liquid from the discharge back into the suction.

It will be found in nearly all cases that the starting duty of centrifugal pumps will permit the use of practically any type of motor. However, there are features such as permissible starting current, frequency of starting. motor speed and speed variations which are important factors in selecting a motor.

The *d.c.* motor does not attain constant speed until it has run long enough to get thoroughly warmed up, which requires about two hours.

At starting the speed may be 5% below normal, and will gradually increase as the motor warms up, until the normal speed is attained. During this period the pump does not deliver its rated capacity, and if the service be intermittent, the pump may never deliver rated capacity as motor may not operate long enough at a time to reach full speed. This operating condition is not encountered with *a.c.* drive.

The series motor is not used for driving pumps.

The shunt motor is used extensively for driving pumps where the head is practically constant, and for intermittent service.

For adjustable speed service the compound wound motor is always used.

The features of synchronous motor drive, especially in large units, are:

Advantages.—1, Unvarying speed at all loads; 2, power factor variable at will by change of the exciting current, can be made approximately unity at any load; 3, cheaper than induction motor for large slow speed units; 4, efficiency is generally higher than that of the induction motor; 5, especially adapted to high voltage winding; 6, when used in combination with inductive loads the synchronous motor will improve the electrical efficiency of the system, since it can be built to operate at a leading power factor (leading magnetizing current) so as to counterbalance in whole, or in part, lagging magnetizing currents taken by induction motors.

For slow speed centrifugal pumps, synchronous motors are doubly desirable from the standpoint of both power factor and first cost.

Before purchasing a synchronous motor for driving a pump, the operating conditions must be carefully analyzed in order to determine if this type of motor be suited for the service.

Unless all phases of the pump and motor characteristics are carefully investigated, a successful installation cannot be assured.

Disadvantages.—1, It is not adapted to work requiring variable speed, as no independent speed regulation is possible; 2, the standard line of synchronous motors is designed for a starting torque of 50%, pull in torque of 50% with 70% voltage applied. Greater pull in torque will be obtained by applying full voltage with the field switch open; 3, on a centrifugal pump load, a well designed synchronous motor will not hunt. When applied to a reciprocating pump, however, great care must be used, for unless the design of the motor be carefully checked, it may tend to oscillate, causing pulsations injurious to the motor; 4, it requires an exciting current which must be supplied from an outside source; 5, it requires the most skillful and intelligent attention; 6, the synchronous motor in starting must attain synchronous speed before it will lock into electrical step with the incoming current.

The super synchronous motor is especially well adapted for pump loads requiring especially high starting and pull in torques.

A special mechanical feature of this motor is that the stator can rotate during the starting period.

The Fynn-Weichsel motor is a general purpose motor that combines the operating characteristics of the synchronous motor and the slip ring motor.

Advantages.—1, If a Fynn-Weichsel motor be paired with an induction motor of the same horse power and speed, the power factor of the combined load will be substantially unity; irrespective of the loads on the two types of motors; 2, unvarying speed for loads up to 150% rating; 3, heavy starting torque without excessive starting current; 4, pull in torque equal to starting torque; 5, overload capacity equal to that of the induction motor.

Disadvantages.—1, Not adapted to work requiring variable speed; 2, its cost is higher than induction motors; 3, maintenance is equal to that of *d.c.* motors.

Induction motors are commonly divided into two types, the squirrel cage and the slip ring.

When an induction motor is running without load, its speed is nearly equal to the speed of the rotating magnetic field; namely, synchronous speed.

When the motor is loaded, its speed decreases to about 98% of the synchronous speed in the case of large motors, and to about 92% of the synchronous speed in small motors, at full load. The decrease in speed expressed as a percentage of synchronous speed is called the *slip* of the motor.

A squirrel cage motor will develop sufficient torque to start satisfactorily with from 40% to 60% of the rated voltage applied to the primary member.

Therefore, the current required for starting may be greatly reduced by supplying the primary member at starting with current through a step down transformer, usually of the auto-transformer type.

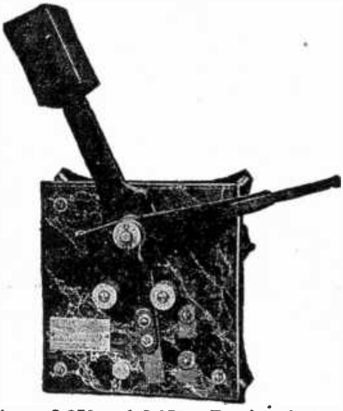
The slip ring motor is used only where a starting torque, not greatly in excess of full load torque, is required.

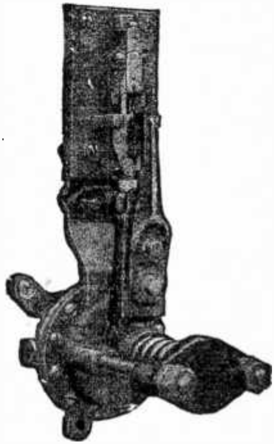
This motor has the advantage of not taking excessive current at starting, and will start, therefore, without producing excessive drop of voltage in the system from which the motor receives its power.

As the motor increases in speed the resistance is cut out in as many successive steps as there are contact points, allowing the pump to come up to speed more quickly and with more nearly uniform acceleration than is possible with the squirrel cage motor. This is a very desirable feature in centrifugal pump operation. Large size motors are always of the slip ring type except in mine installations.

The *a.c.* commutator motor is seldom required for driving centrifugal pumps, but is sometimes desirable for driving positive displacement pumps.

These commutator type motors should be considered for applications where the pumps run at greatly reduced speeds for considerable periods, as the efficiency and power factor are both higher than those of the corresponding slip ring induction motors under these conditions and a considerable saving in power will result from the use of commutator motors.





FIGS. 8,850 and 8,851.—Deming single pole float switch, and diaphragm pressure regulator. Fig. 8,850, switch; fig. 8,851, regulator. The switch is of the single pole sliding contact type for use with self-starter for automatically starting and stopping the pump motor with open tank systems. This switch is intended to break solenoid currents only and must not be used to handle main line currents. The diaphragm pressure regulator controls a single pole switch designed primarily as a pilot switch for use with a self starter, although it may also be used for throwing a small motor directly on the line in such cases where a single pole switch only is required. Direct or alternating current motors in capacity not over ¼ horse power, 110 volts, and ½ horse power, 220 volts to 250 volts can be handled in this way.

Control Devices; Water End.—For the proper operation of pumps under different conditions various devices have been applied to effect the proper control.

Hand operated control for starting or speed regulating should be used only when an operator is available.

Magnetic or remote control may be used with motors of any size.

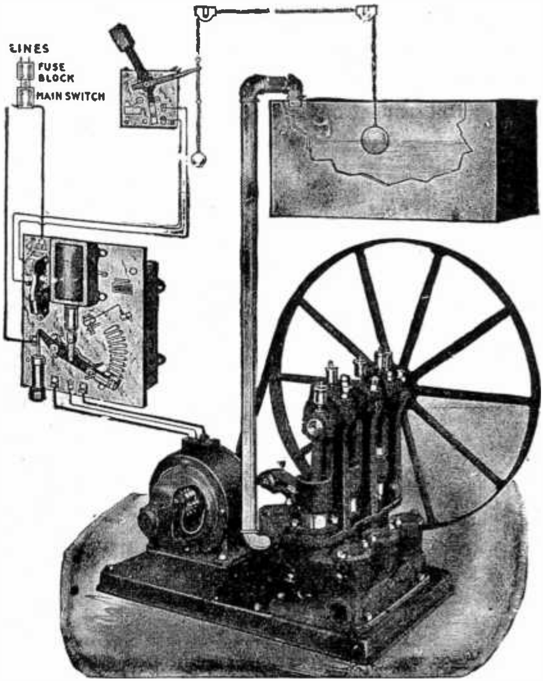


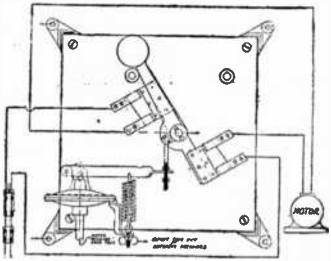
FIG. 8,852.—Automatic control for electric house pump, consisting of float switch, starter, and connection, as shown.

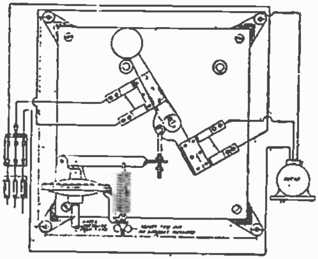
Magnetic equipments are available for operation from push button stations when it is desired to start or stop the pump from points remote from the starter. Push button control is suitable for all large and small motors.

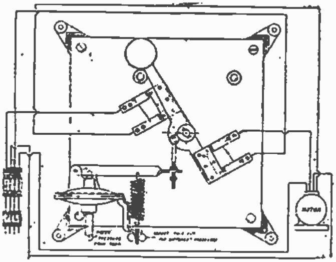
Automatic magnetic equipments are available for operation by means of float switches, pressure switches, thermostats or pressure regulators.

A float switch, pressure governor or thermostat is used for maintaining prescribed limits of liquid levels, pressures or temperatures.

Pressure regulator controls are for pumps that run for comparatively long periods and the speeds of which must be changed to conform to rapidly fluctuating demands for the liquid delivered by the pump.







FIGS. 8,853 to 8,855.—Wiring diagrams for Hill double pole automatic pressure tank switch. Fig. 8,853, direct, or alternating current, single phase, two wires; fig. 8,854, alternating current, three phase, three wire; fig. 8,855, alternating current, two phase, four wire.

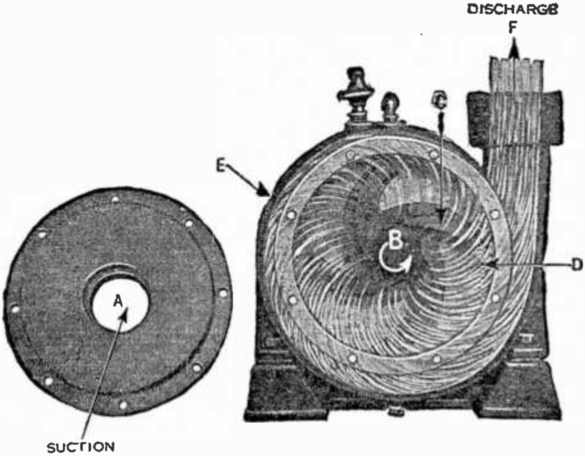
Hints on Motor Selection.—For centrifugal pump drives, be sure that motor will come up to speed rapidly and will develop sufficient torque to start the pump effectively, otherwise the pump will lose its suction.

For small centrifugal pumps, the squirrel cage motor is most commonly used. Up to 5 *h.p.* they may be thrown directly across the line.

For mine service or for service where excessive moisture is encountered, the squirrel cage induction motor is preferable to the slip ring or brush commutator type. It is best, however, to consult the manufacturer in all cases where excessive moisture is met.

For driving positive displacement pumps the compound wound *d.c.* motor is recommended, and for *a.c.* the wound rotor or slip ring motor.

Centrifugal Pumps.—This type of pump may be defined as *one in which curved vanes or impellers, rotating inside a close fitting casing, draw in the liquid at the center and, by virtue of* **centrifugal force,** *throw out the liquid through an opening at the periphery of the casing.*



FIGS. 8,856 and 8,857.—Centrifugal pump with side removed showing flow of water. A, suction or inlet; B, impeller; C, vane; D, outward flow of water; E, case; F, discharge.

Centrifugal pumps are divided into four classes:

1. Simple;
2. Conoidal;
3. Volute;
4. Screw;
5. Turbine {single stage; multi-stage.

The simple or ordinary type consists of a series of blades, which are rigidly fixed on a shaft and enclosed in what is called the whirlpool chamber. When the blades are rapidly revolved, the centrifugal force thus created throws the water through the outlet in the casing.

The general appearance of the conoidal pump (named from the cone shaped impeller) is somewhat different from the ordinary centrifugal pump,

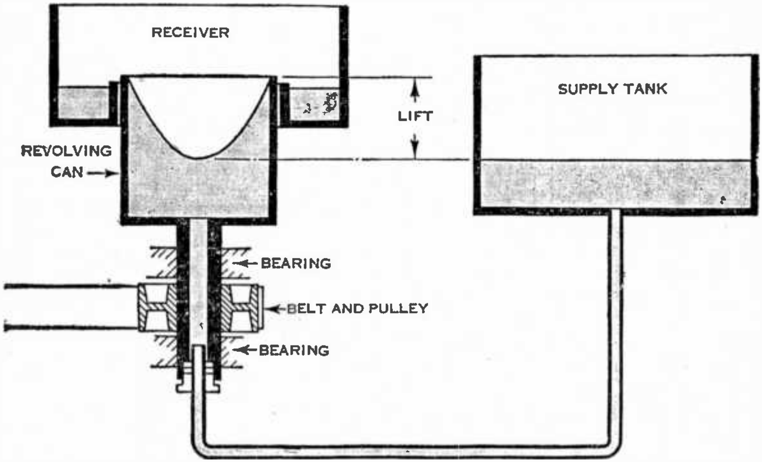


FIG. 8,858.—*How a centrifugal pump works 1.* The theory of the centrifugal pump can best be understood by discussing separately the impeller and case. Consider a cylindrical can, with radial vanes to force the liquid in it to revolve with the can. As the can speeds up the liquid level at the circumference of the can rises more and more until some of the liquid spills over into the receiver. By this means liquid has been lifted, as shown in the figure. If connection be made to a supply tank through the hollow shaft, liquid will be pumped by this crude arrangement which illustrates the principle of the centrifugal pump impeller. The liquid which spills over the top has a high velocity, equal to the rim speed. This kinetic energy is here wasted. The maximum efficiency is only 50% as a device for lifting liquid, and friction and bearing losses reduce this value still further. If, instead of rotating the whole can, the vanes only be rotated, the same result will be found.

on account of the widening of the pump chamber to receive a special form of impeller, which consists of a double conical shaped core, on which radial vanes are cast or mounted. The peculiar shape of this core serves to modify gradually the direction of the incoming current, thereby preventing waste of power.

The pump chamber is divided into two parts by a radial partition, which extends entirely around the interior of the chambers and encloses the base of the conoidal impellers. This partition prevents the impingement and consequent disturbance of the two entering columns of water.

Conoidal pumps are especially suitable for supplying water to surface condensers, or for irrigation, pumping sewage, or purposes where the liquid pumped is accompanied by sand, mud, silt, etc. They are comparatively

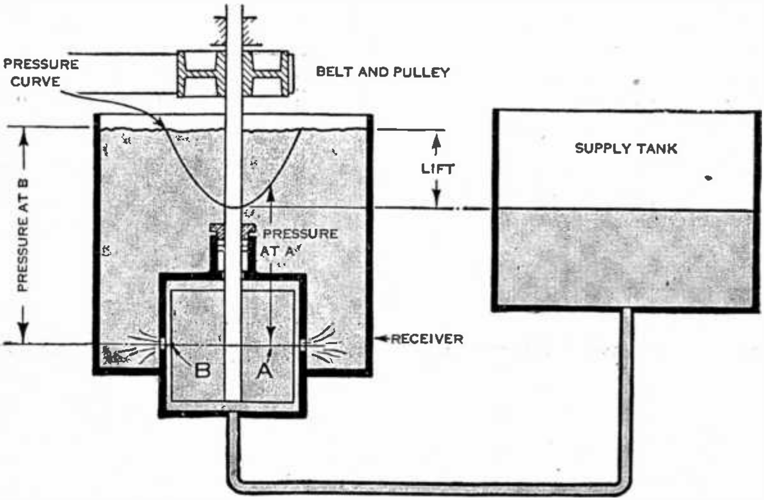
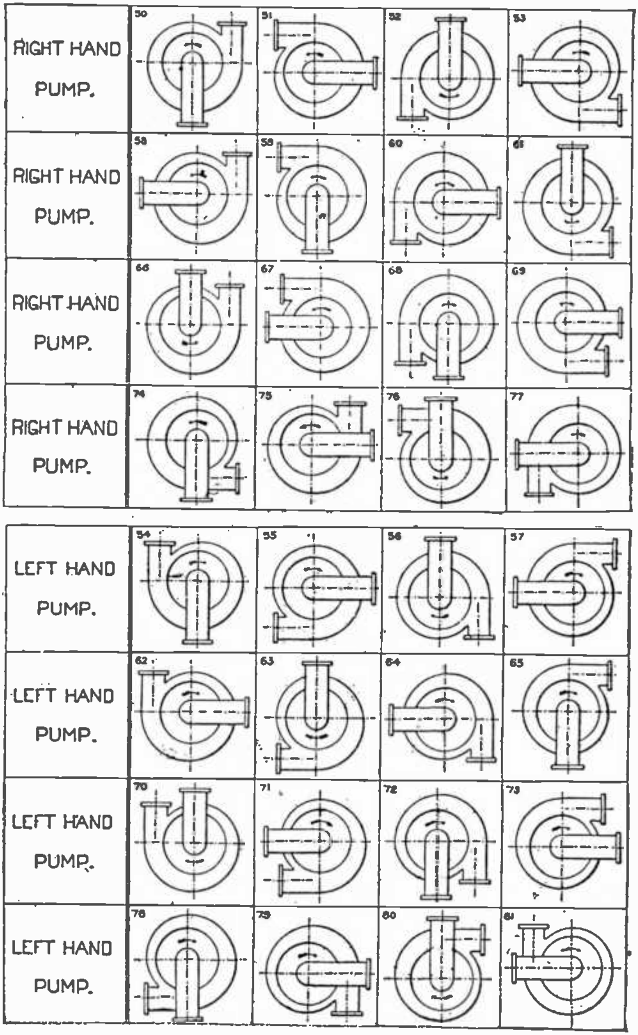


FIG. 8,859.—***How a centrifugal pump works 2.*** Consider a cylindrical can similar to fig. 8,858 but having a top. In rotating, the liquid level can no longer rise when it is rotated by the vanes on the revolving shaft. Instead, a pressure difference will be set up which is illustrated by the pressure curve showing the pressure in feet of the liquid at points distant from the axis of rotation. This pressure curve shows the height to which the liquid would rise with the arrangement of fig. 8,858. As before, put a receiver around the can. Punch some small holes through the can so that liquid can pass into the receiver. With the vanes rotating, the pressure at the circumference of the can, as at B, is communicated to the receiver and liquid will flow out of the can, through the holes, to the receiver until the height of liquid in the receiver is equal to the pressure inside the can. The liquid is lifted just as before. With increased speed of the rotating vanes, the height will increase. This constitutes a crude centrifugal pump, of low efficiency because the velocity of the water through the holes in the can is lost in the receiver, where no attempt is made to conserve that kinetic energy. The last step is the substitution of a properly designed case. to replace the receiver, in which kinetic energy of the water is changed to pressure energy as the liquid flows through. By making all passages through the vanes and case to conform as nearly as possible to the directions in which the liquid would most naturally follow. results in a modern, high efficiency centrifugal pump.



FIGS. 8,860 to 8,891.—Various patterns of centrifugal pumps.

inexpensive and the space required by them, relative to the quantity of water delivered, is claimed to be about one-half that of a centrifugal pump of the ordinary pattern. They are designed for a maximum head of 30 feet.

Volute pumps are built for medium lifts, but for all capacities. They are desirable for heads up to 70 feet, without necessitating the use of pumps, which are either especially large or very expensive. Volute pumps run at moderate speed.

The turbine type may be defined as *a centrifugal pump having stationary guides or diffusion vanes inside the casing*. The diffusion vanes are placed between the periphery of the impeller and the case which take the place of the usual whirlpool chamber and assist in guiding the water to the outlet without internal shock or commotion.

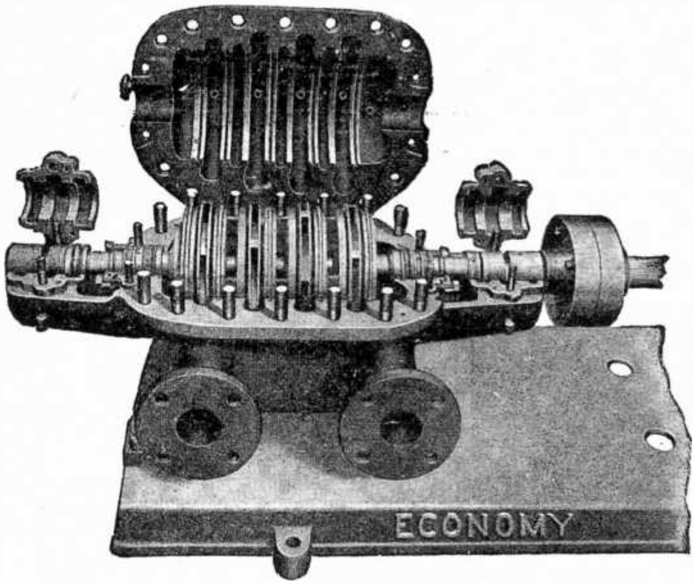
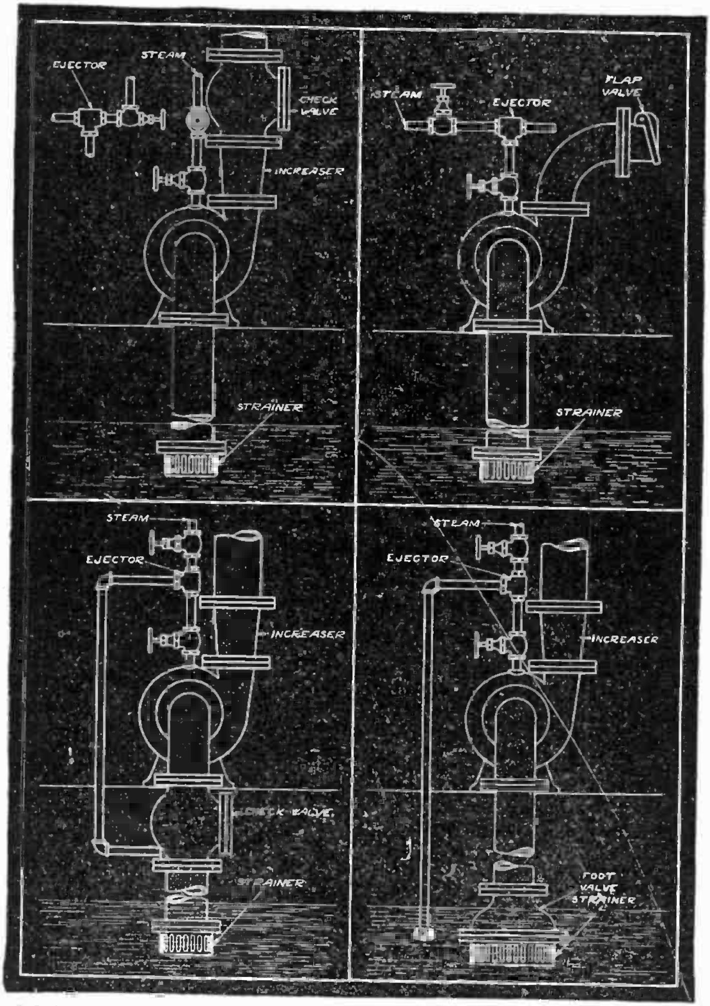


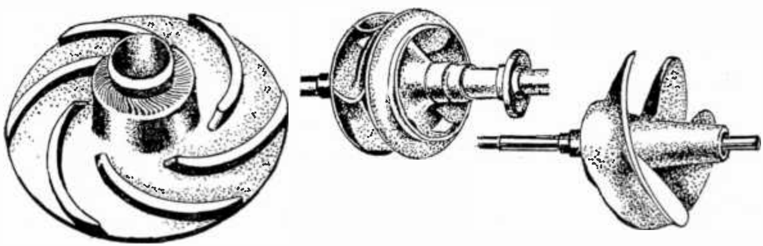
FIG. 8,892.—Economy four stage centrifugal pump, with cover lifted showing one piece bronze diaphragm.

NOTE.—***How to determine right or left hand pumps.*** If when standing at the suction end of pump, looking over the pump shell toward the pulley, the top of the shaft revolve from right to left, or *against the hands of clock*, the pump is *right hand*, and from left to right, or *with the hands of clock*, it is *left hand*.



FIGS. 8,893 to 8,896.—Various methods for priming centrifugal pumps using a steam primer ejector. The best method to adopt is governed by the conditions of each installation.

Multi-Stage Centrifugal Pumps.—The very limited head at which it was possible to operate the earlier pumps with economy has been overcome by connecting two or more units upon one shaft and operating them in series, that is, passing the water through each unit in succession, thus the head is divided between the units by a multi-stage operation and by providing a sufficient number of units or stages, they may be operated with heads even exceeding two thousand feet without impairing the economy.



Figs. 8,897 to 8,899.—Three forms of vane. Fig. 8,897, straight type; fig. 8,898, Francis mixed flow; fig. 8,899, impeller or screw, axial flow.

Forms of Vane.—There are three distinct classes of vane known as:

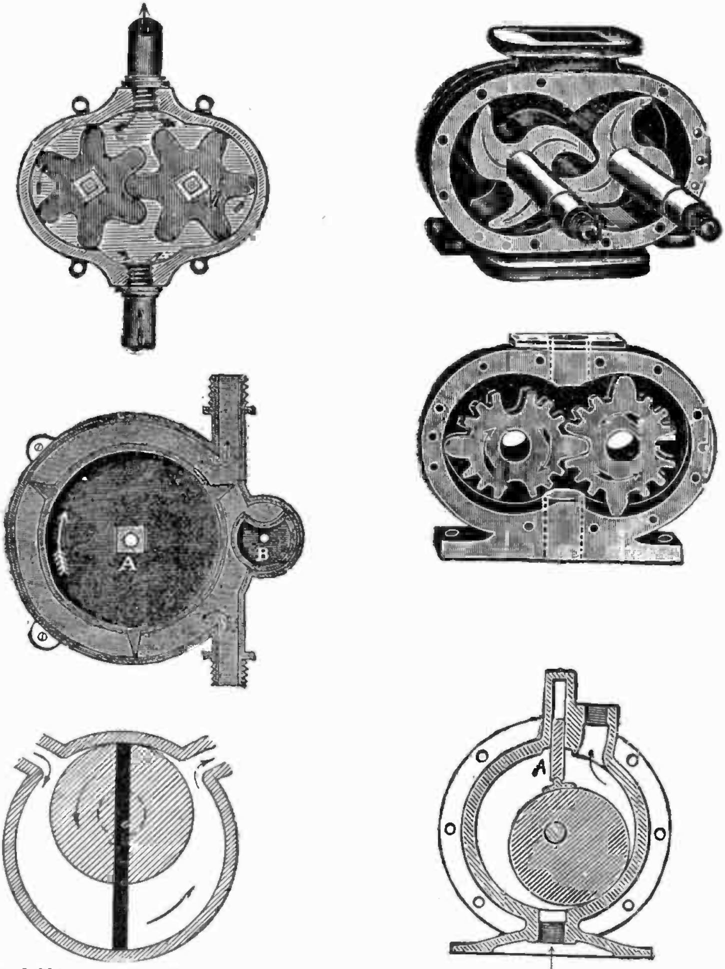
1. Straight;

2. Francis mixed flow;

3. Impeller or screw, axial flow.

Figs. 8,897 to 8,899 show these three classes.

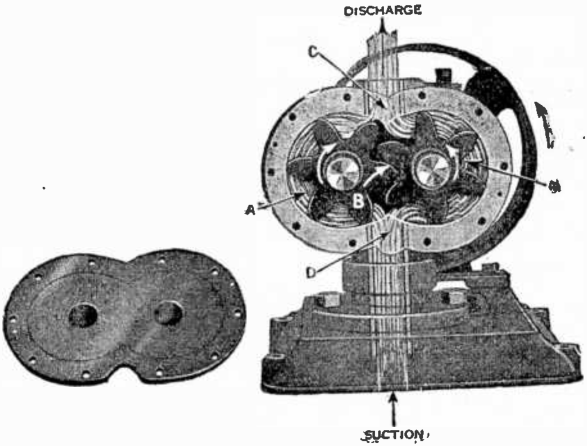
Rotary Pumps.—This type is defined as *one having a revolving piston, or pistons which partake of the nature of cams,* *rotating upon an axis and being in contact at one or more points with the walls of the enclosing chamber.* In operation, a rotary



Figs. 8,900 to 8,905.—Various types of rotary pump.

pump continuously "scoops" the water from its chamber, the operation being somewhat similar to bailing a boat with a scoop.

Rotary pumps may be divided into several classes according to the forms of, and methods of working the pistons or impellers, as they are usually called, that is, according to the construction and arrangement of the abutment.



Figs. 8,906 and 8,907.—Gould's rotary pump with side of case removed showing operation. In this pump there are two cams for gears, meshed together, and revolving in opposite directions. The case surrounding these cams is a close fit on the ends and also on the sides. Any liquid which fills the space A, between two teeth of the cams must follow along with them as they revolve. In the part where the two cams mesh B, there is but little space for liquid, and that which was drawn through in spaces like A must pass on into the discharge pipe C. As each space comes down the center and the cams separate, liquid flows into it from the suction pipe D. With the number of teeth in the cams usually used, this sequence of operations is practically continuous, some spaces carrying liquid to the discharge pipe and some spaces filling from the suction pipe. The action is positive; each revolution transfers a quantity of liquid from suction to discharge, which depends upon the size and shape of the cam teeth. In this respect it is like a reciprocating pump.

The abutment receives the force of the water when driven forward by the pistons or impellers and also prevents the water being carried around the cylinder, thus compelling it to enter the delivery pipe.

In the construction of the impellers or pistons, and of the abutments, lie the principal differences in rotary pumps.

In some pumps the abutments are movable, and are arranged to draw back, as shown in fig. 8,905, to allow the piston to pass. In others the pistons give way when passing fixed abutments, and in others the pistons are fitted with a movable wing, as in fig. 8,904, which slides radially in and out when passing the abutment.

Rotary pumps are especially suitable for low pressures, and the absence of close fitting parts renders it possible to handle water containing a considerable quantity of impurity, such as silt, grain and gravel. This type of pump is compact and is generally self-contained, especially in the smaller sizes, and will deliver more water for a given weight and space occupied than the reciprocating types, while its simplicity of construction not only lessens the liability to derangement, but enables persons having a limited knowledge of machinery to set up and operate these pumps successfully.

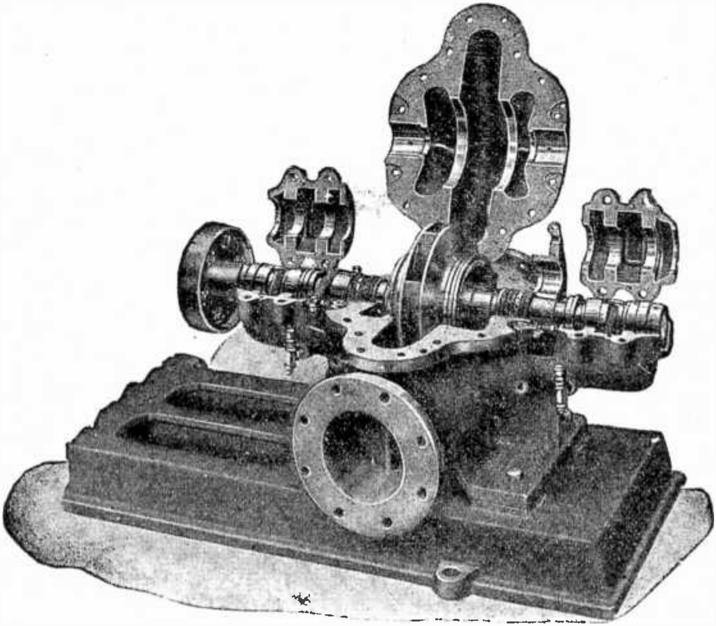


Fig. 8,908.—Economy single stage centrifugal pump with cover raised showing bearings and rotor construction

TEST QUESTIONS

1. *What is a power pump?*
2. *How does a power pump differ from a steam pump?*
3. *Give classification of power pumps.*
4. *Name four types of pump cylinder.*
5. *What is the difference between a plunger and a piston?*
6. *What kind of valves are used?*
7. *What duty is performed by the drive or transmission?*
8. *Name the various types of drives.*
9. *Why are multi-cylinder pumps used?*
10. *Name the different types of multi-cylinder pumps.*
11. *Draw curves showing delivery flow of various multi-cylinder pumps.*
12. *What precautions should be taken in selecting electric motor drive?*
13. *State the adaptation of the various types of electric motors.*
14. *Describe the control devices at the water end.*
15. *Draw a sketch showing automatic control for electric house pump.*
16. *What is the adaptation of pressure regulated control?*
17. *Draw wiring diagrams for automatic pressure tank switch.*

CHAPTER 230

Water Supply

For domestic use, water is usually obtained from: 1, wells; 2, springs; and 3, city mains.

In some cases rain water is used by collecting the supply which falls on the roof.

Wells.—There are numerous kinds of wells and they may be classified as:

1. Shallow;
2. Deep;
3. Artesian.

The chief advantages of a well of large diameter are the storage that it affords and the possibilities of placing the pumps at a low level to obtain a short suction pipe.

Large wells are useful especially in cases where the ground water flows through fine material with low velocity.

Dug wells avoid the clogging that occurs in driven wells located in iron bearing sands.

The ordinary driven well consists of a wrought iron or steel tube, 2 to 8 ins. in diameter, with a strainer near the bottom. It is forced into the ground by a hammer or by the use of a falling weight or with the aid of a jet of water carried through a small pipe to loosen the material in advance of the point.

Water Supply Systems.—There are numerous methods of water supply, due to the varied conditions met with. These

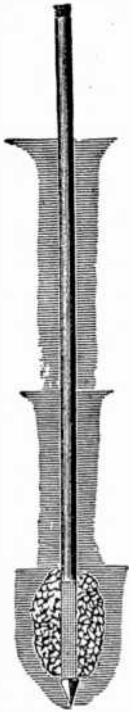


FIG. 8,909.—Driven well, showing pipes and perforated well point.

FIG. 8,910.—Method of driving pipe and perforated point with monkey.

systems may be classed according to the method employed in raising the water, as by:

1. Hand pumps;

2. Wind mill;
3. Power pump;

   a. Steam } drive
   b. Gas engine } drive
   c. Electric } drive
   d. Hot air engine } drive

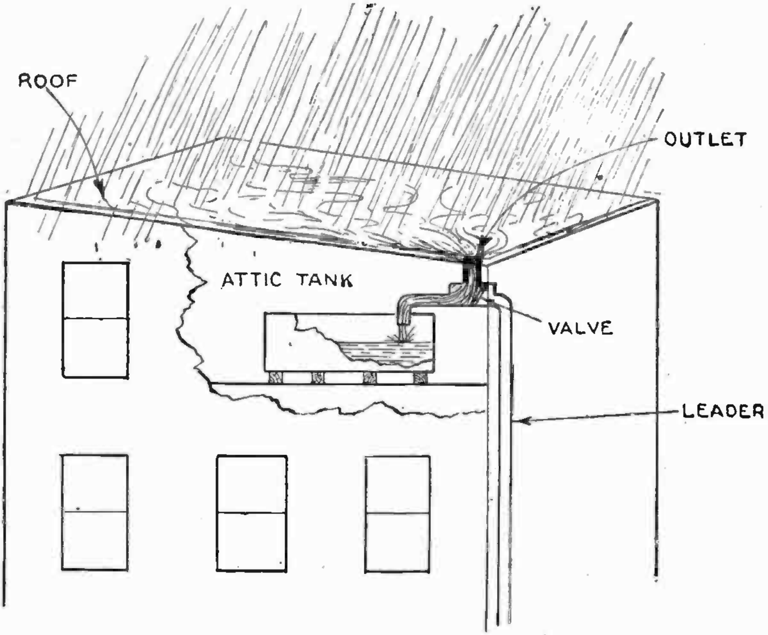
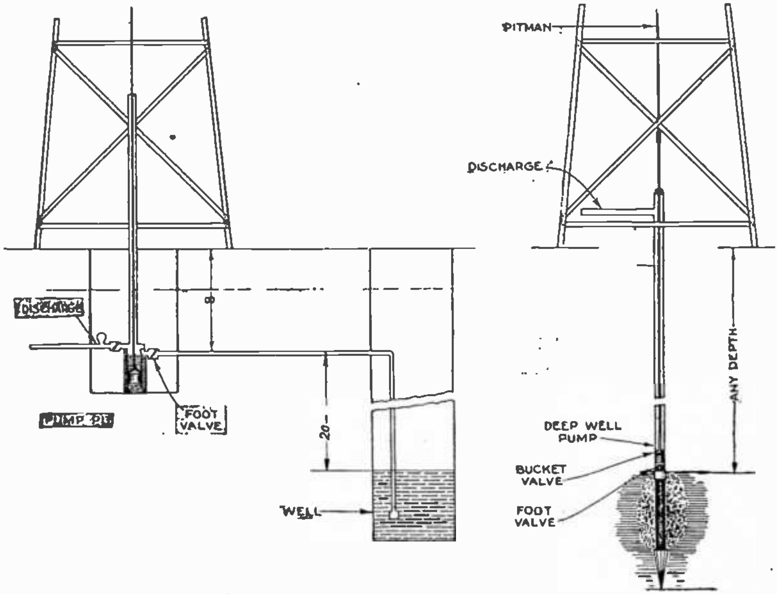


FIG. 8,911.—Rainfall system of water supply showing attic tank receiving its supply of water from roof, a valve being interposed as shown so that when the tank is full, excess water may be carried off through a leader.

4. Hydraulic ram;
5. Water wheel;
6. Compressed air;
7. Air lift.

Small Pumps.—The syphon type pump is used to force water from shallow wells to elevations. The cylinder or barrel is placed within the standard and is always primed.

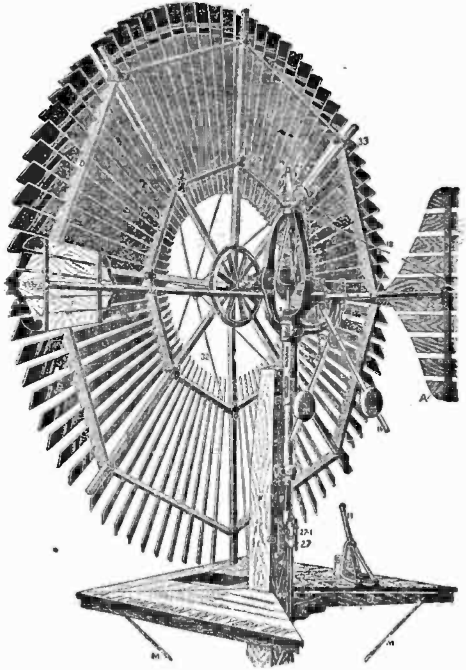
Where the distance from water level in well to ground level is over say 20 ft., the pump should be lowered to bring the lift within this limit; that is, the suction valve on pump should not be over 20 ft. elevation from the water level in the well.



FIGS. 8,912 and 8,913.—Pump connections at residence of the author at *Stornoway*, near Sea Bright, N. J., illustrating location of pump in pit to reduce lift to practical limit. As shown in fig. 8,912 the well was about 50 ft. from the tower and the arrangement of buildings prevented placing wind mill tower directly over well, otherwise a deep well pump would have been installed, as shown in fig. 8,913.

In cases where pump cannot be lowered conveniently, a deep well pump should be used.

Fig. 8,912 is an example where pump was lowered to bring lift within limit. In this case a deep well pump could not be used as the wind mill



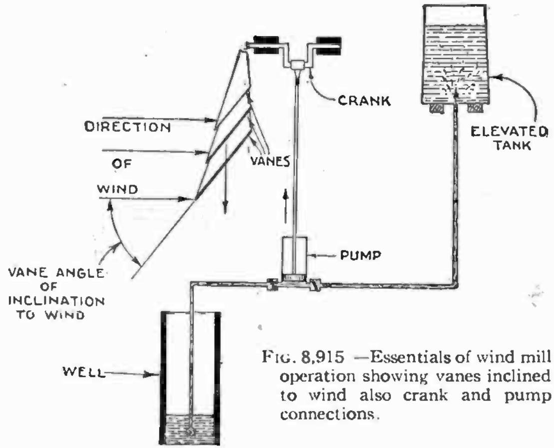
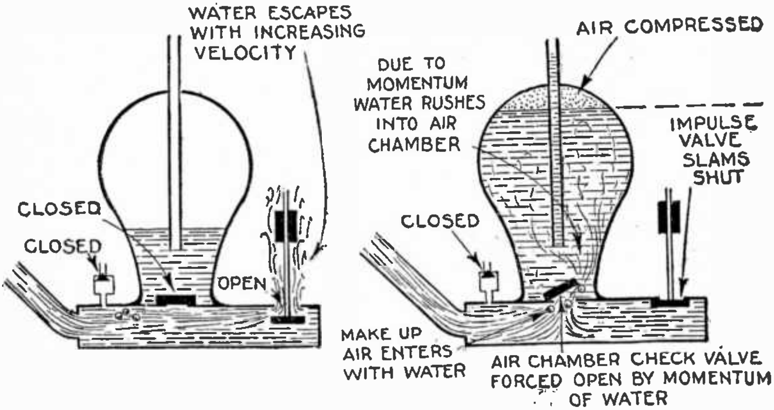


FIG. 8,915 —Essentials of wind mill operation showing vanes inclined to wind also crank and pump connections.

FIG. 8,914.—Corcoran direct stroke wind mill with wooden vanes. ***In construction,*** the mill is made mostly of steel, wrought and malleable iron, the whole central iron work being concentrated in the main frame No. 3, which is a piece of wrought iron hydraulic tubing with the bearing frame which supports the wind wheel shaft cast upon it. No. 3 rests and turns on an anti-friction washer, and the hydraulic tube No. 3 passes down through guide No. 2 and is held firmly in place by collar No. 4, on the bottom of No. 3. The object of this tubing coming down the mast H as far as the point on the wind mill arm H, is to give the main frame of wind mill equal leverage with the strain brought upon the arms C, thereby preventing any rocking motion of the mill or mast in variable winds, or working of the crank on the various centers, all being supported in the same frame and effectually kept in line, and to entirely obviate the possibility of their being blown away. The pitman No. 10 and 11, work in bearings lined with Babbitt metal, so that in case of wear from neglect of oiling, the part, instead of being thrown away, can be relined by any ordinary mechanic.

tower could not be placed over the well. Where a deep well is located directly under a wind mill tower a deep well pump is used, as in fig. 8,913, thus avoiding the necessity of digging a separate pump pit.

The plumber should understand the construction of the various types of pumps as shown in the accompanying illustrations in order to properly make repairs.



Figs. 8,916 and 8,917.—How a hydraulic ram works. Just after an "impulse," the impulse valve drops or opens. Water begins to escape through the impulse valve and the air valve which opened and admitted some air due to the slight vacuum caused by the rebound, now closes. Water continues to escape through the open impulse valve with increasing velocity which finally causes the impulse valve to slam shut, thus suddenly stopping further flow of water through the impulse valve. Owing to the momentum of the long column of water, a sudden pressure is produced great enough to open the air chamber check valve thus forcing the water (and air) into air chamber. The inflow of water compresses the air in the air chamber which cushions impulse and forces water out to delivery pipe. Impulse valve again drops and the cycle begins again.

Small Power Pumps.—The term *power pump* ordinarily signifies a pump driven by belt, gears or other transmission, receiving its power from some external source. They are usually classified according to the number of cylinders, as:

1. Single;
2. Duplex;
3. Triplex;
4. Quadruplex, etc.

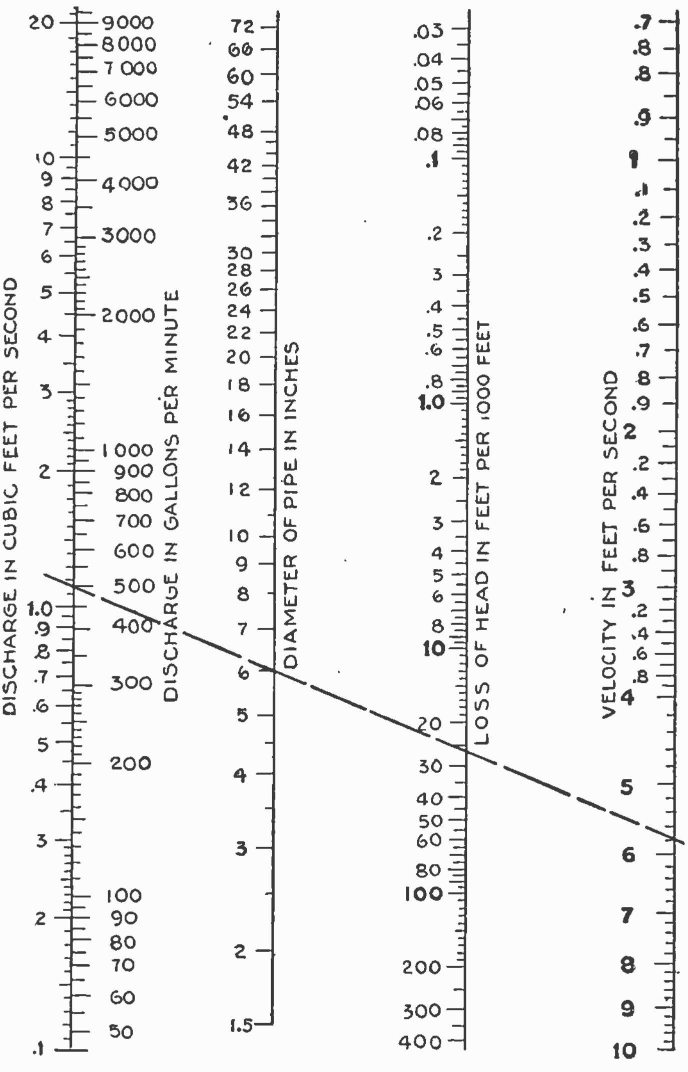


FIG. 8,918.—Diagram for calculating pipe sizes, discharge velocities and loss of head in water pipe. Lay a straight edge on scales at the points for any two known quantities and the unknown quantities will lie at the intersection of the straight edge with the other scales. *Example.*—To discharge 500 gals. per minute through a 6 in. pipe following the dotted line would show a loss of head for 1,000 ft. of approximately 25 ft. head and a velocity of 5.8 ft. per second.

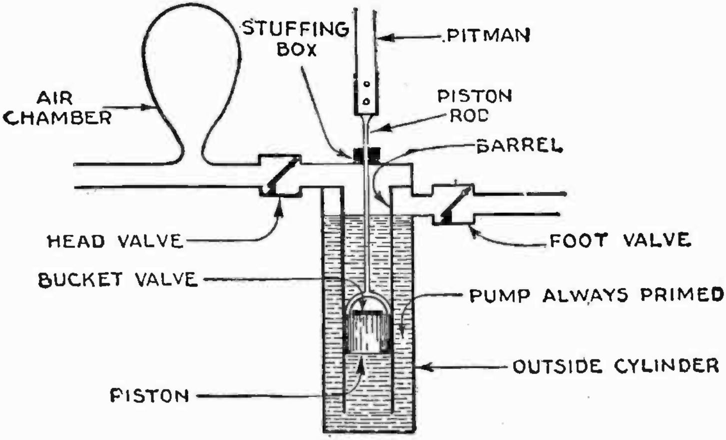


FIG. 8,919.—Elementary so called syphon pump showing pump barrel projecting down into a concentric or outside cylinder providing an annular space which traps water so that the pump is always primed. Anyone having any experience with pumps, especially old and worn pumps, will appreciate this feature.

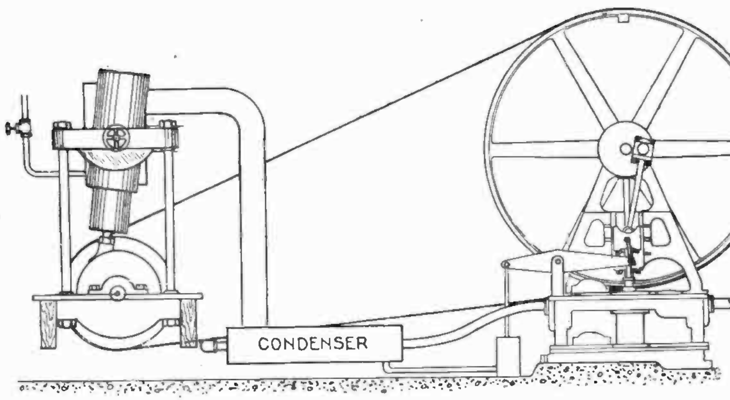


FIG. 8,920.—Graham jacketted, transfer expansion oscillating engine, and Dunham power pump with belt transmission. *It must be evident* that this arrangement permits the engine and pump to work under the most favorable conditions for economy. Hence by proper proportion of pulleys, the engine may run at *high speed,* thus reducing the size of the cylinder and loss by condensation, leakage, etc., and the pump may be run at *slow speed,* thus eliminating water hammer, slamming of valves, etc.

Evidently, a belt or gear transmission between the pump and power unit will permit any velocity ratio; thus when the pump for instance is connected to a steam engine by belt as in fig. 8,920, by proper selection of pulley sizes the pump may be driven at a low speed with engine running at relatively high speed, which is desirable for economy of steam. Moreover, any degree of economy may be obtained according to the type of engine selected.

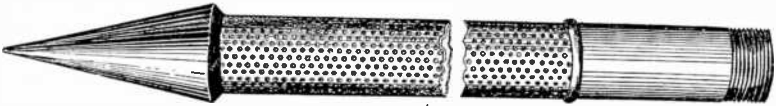


FIG. 8,921.—View of driven well point showing conical end and perforations through which water enters the pipe

The accompanying illustrations show power pumps operated by various power drives; these illustrations also show the construction.

With electric motor drive the necessary high reduction in rotative speed is easily obtained by belt or gear transmission.

Points Relating to Pumps.—The following information will be found useful to those who have to install or service small pumps:

1. The necessary parts of a pump are the cylinder, the plunger, or the piston with its bucket valve, the lower check valve (or foot valve), the suction pipe, and the piston rod and connecting rod. In order that the pump work properly, all of these parts should be in perfect condition. The

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NOTE.—A sucker rod coupling is used to connect ends of wooden sucker rods for *deep* well pumps. Each half of coupling is secured to the end of wooden rods by three bolts. The ends of the couplings are joined by male and female threads in the usual way. Either bolts or rivets may be used to attach the rods to the couplings.

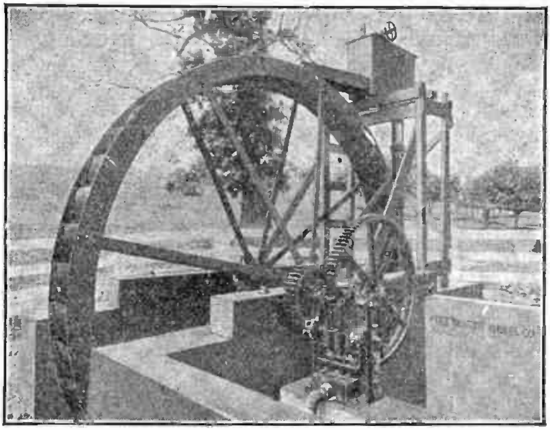


FIG. 8,922.—Fitz overshoot water wheel direct coupled to Goulds triplex pump to supply water to country estates and villages. The pump should be housed over in cold climates. A dynamo may be added to furnish light and power for farm purposes. The water to drive the water wheel may be conveyed from the dam by an underground pipe or through an overhead flume, as preferred.

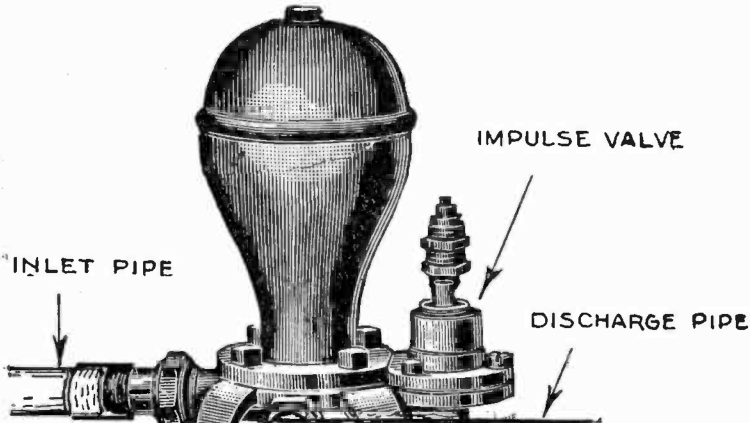


FIG. 8,923.—Columbiana hydraulic ram made in sizes ranging from ¼ to 2 gal., per minute, to 6 to 14 gals. per minute.

cylinder should be true, the piston (or plunger) should fit the cylinder accurately, and the check valves should set square and tight.

2. Do not place a pump more than 25 ft. above the water.

3. Suction pipes should be short and as straight as possible, with few or no valves, elbows and fittings, and arranged to have no "pockets" where air can collect. Long suctions or high lifts should always have a

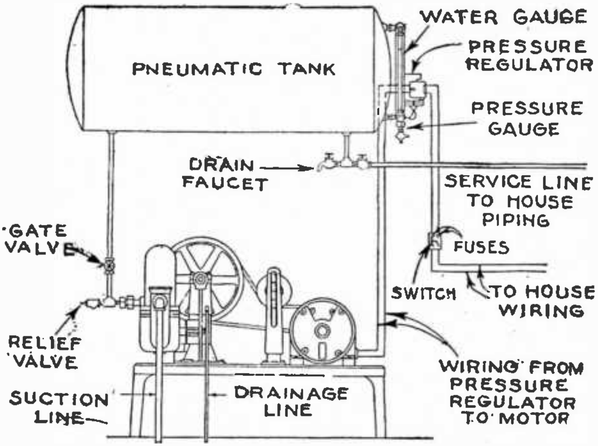


FIG. 8,924.—Goulds automatic pneumatic water pumping system showing typical piping and wiring connections for use with pneumatic tanks when installed either on the floor back of pumping outfit, along side or overhead. Wherever the construction of the tank allows, it is recommended that it be set vertically. The pressure regulator and pressure gauge are attached to the lower gauge fitting. This installation is recommended for locations where there is limited space. Both the tank and pump should be installed in the basement or other place where they will be protected from freezing temperature.

vacuum chamber at the pump and a foot valve should be used, the area of which should be as great as the pipe. The suction pipe below the cylinder should not be longer than one length of pipe—from one to sixteen feet.

4. Every part of a pump and its suction line should be air tight.

5. Put a strainer on end of suction pipe to prevent entrance of sand or other foreign matter.

6. Discharge pipes should be amply large to reduce friction and avoid unnecessary loss of power.

Pneumatic System.—This system furnishes a supply of water for house requirements, forcing it to the upper floors without the necessity of providing an elevated tank.

Fig. 8,924 shows the details of the system; the principle is very simple. An air-tight steel tank is put in basement of house, and air and water is pumped into the tank, thus compressing the air in it. This compressed air furnishes the power to distribute the water.

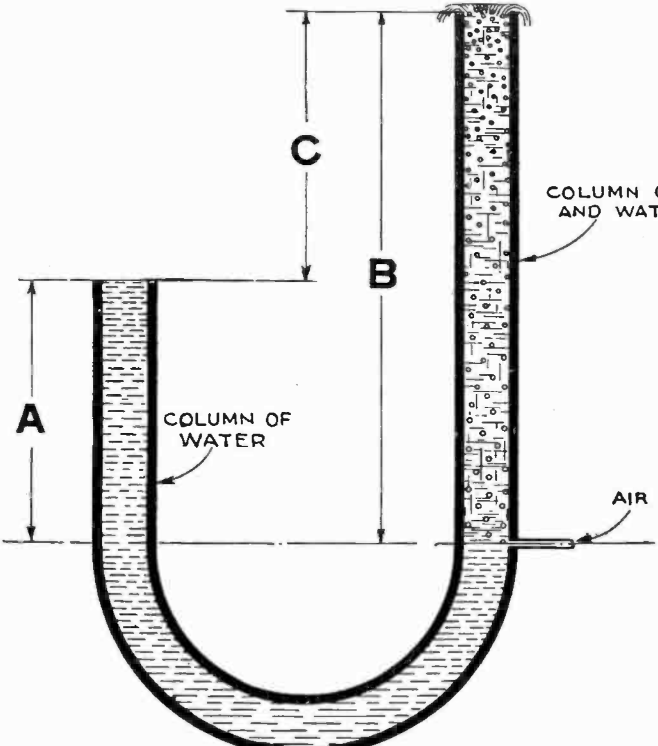


FIG. 8,925.—Principle of air lift. The injection of air at the point indicated produces a column of mixed air and water **B**, which has less weight than the solid column of water **A**. Thus the weight of the column **A**, causes the water to rise the distance **C**, and overflow.

When the air is compressed to a predetermined certain number of pounds pressure, the back pressure operates the diaphragm controller, which works the regulator, and the mill is pulled out of gear and stops pumping.

When sufficient water is drawn to reduce the pressure inside the tank to a given degree, the mill is put back into gear, and starts pumping again, putting more air and water into the tank for further use.

Electric motor or gas engine power may also be used instead of the wind mill. The pneumatic system should not be confused with the Pohle air lift method of pumping water.

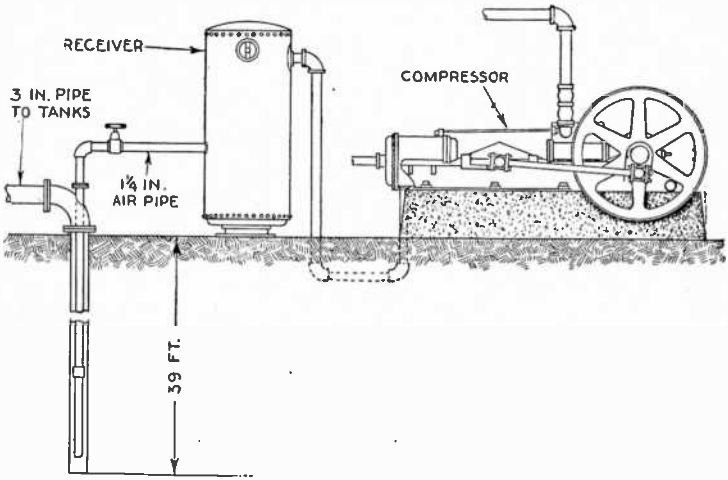


FIG. 8,926.—Pohle air lift plant showing compressor, air tank and connections.

TEST QUESTIONS

1. *Name the three sources of domestic water supply.*
2. *What are the different kinds of wells?*
3. *Name the various water supply systems.*

4. *What kind of pump is used to force the water from a shallow well?*
5. *What is a power pump?*
6. *What is the construction of a typical wind mill with wooden vanes?*
7. *How are power pumps classified?*
8. *Draw an elementary sketch of a power pump.*
9. *What is the advantage of electric motor drive?*
10. *Give numerous points relating to pumps.*
11. *Describe an automatic pneumatic system.*
12. *Describe the Pohle air lift system.*

CHAPTER 231

Air Compressors

Compressed air is *air forced into a smaller space than it originally occupied*, thus increasing its pressure.

The power available from compressed air is used in many applications as a substitute for steam or other force as in operating rock drills, shop tools and engines.

A compressor is *a machine (driven by any prime mover) which compresses air into a receiver to be used at a greater or less distance.* The system is not subject to the loss by condensation in the pipes, as is the case of carrying steam in pipes long distances.

Air stored under pressure in a reservoir can be used expansively, in an ordinary steam engine returning an equivalent amount of work that was required to compress it, less the friction.

The Compression of Air.—When the space occupied by a given volume of air is changed, both its pressure and temperature are changed in accordance with the following laws:

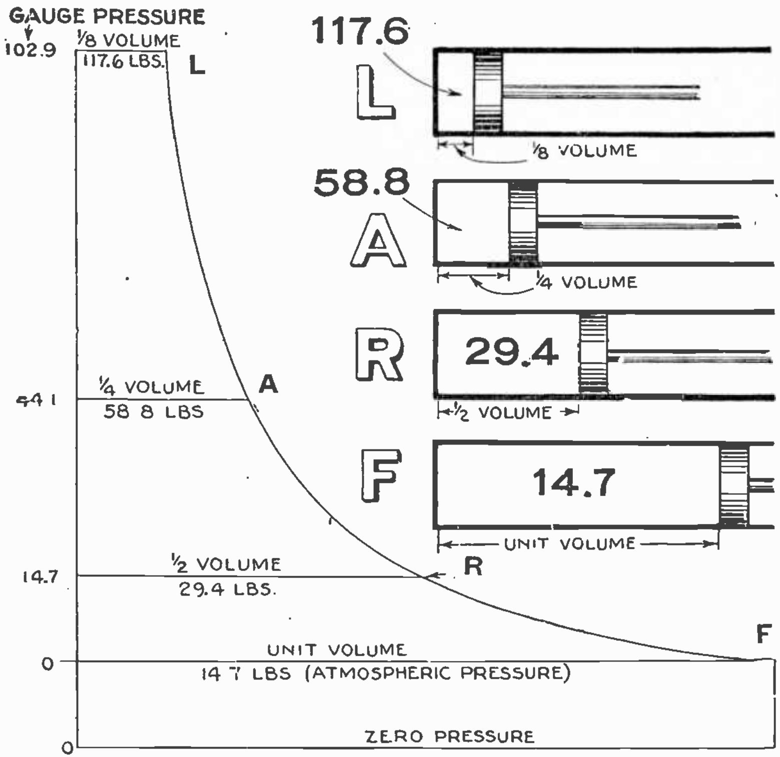
Boyle's law: *At constant temperature, the* **absolute** *pressure of a gas varies* **inversely** *as its volume.*

Charles' law: *At constant pressure, the volume of a gas is proportional to its* **absolute** *temperature.*

In the ordinary process of air compression, therefore, two elements are at work toward the production of a higher pressure:

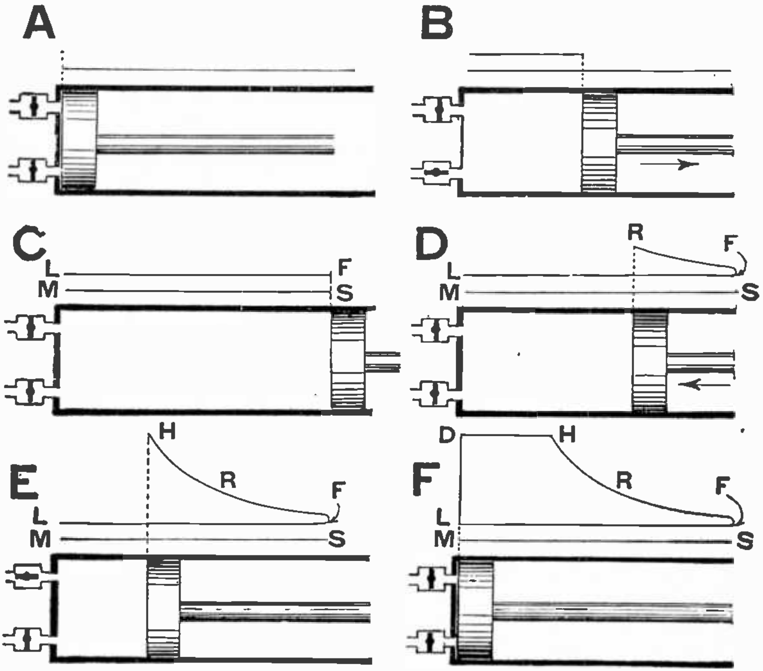
1. The reduction of volume by the advancing piston;

2. The increasing temperature due to the increasing pressure corresponding to the reduced volume.



FIGS 8,927 to 8,931.—Diagram and compression stroke progressively shown illustrating *Boyle's law*. As the piston travels from position F, to R, A, L, the pressures are 14.7, 29.4, 58.8, 117.6 lbs absolute, respectively, being *inversely proportional to the volume*. The points F, R, A, L, on the compression curve correspond to the piston positions F, R, A, L as shown.

The application of the two laws is illustrated in fig. 8,938, which shows a cylinder fitted with an air tight piston. If the cylinder be filled with air at atmospheric pressure (14.7 lbs



FIGS. 8,932 to 8,937.—Compression cycle illustrated by indicator diagrams and elementary compressor. A, beginning of intake stroke; B, intermediate position of intake stroke; C, end of intake stroke, note atmospheric intake line LF, and vacuum line MS; D, intermediate position R, of compression stroke; E, point of maximum compression, note compression curve FRH; F, end of cycle, note horizontal discharge line HD, indicating discharge into receiver at constant pressure.

per sq. in. **absolute**) represented by volume A and the piston be moved to reduce the volume, say to ⅓ A, as represented by B, then according to Boyle's law the pressure will be trebled or $=14.7 \times 3 = 44.1$ lbs. absolute, or $44.1 - 14.7 = 29.4$ **gauge** pressure. **In reality,** *however, a pressure gauge on the cylinder would at this time show a higher pressure than* **14.7 gauge** *pressure because of the* **increase in temperature** *produced in compressing the air.*

Now, in the actual work of compressing air, it should be carefully noted that *the extra work which must be expended to overcome the excess pressure due to rise of temperature* **is lost,** *because after the compressed air leaves the cylinder* **it cools,** *and the* **pres-**

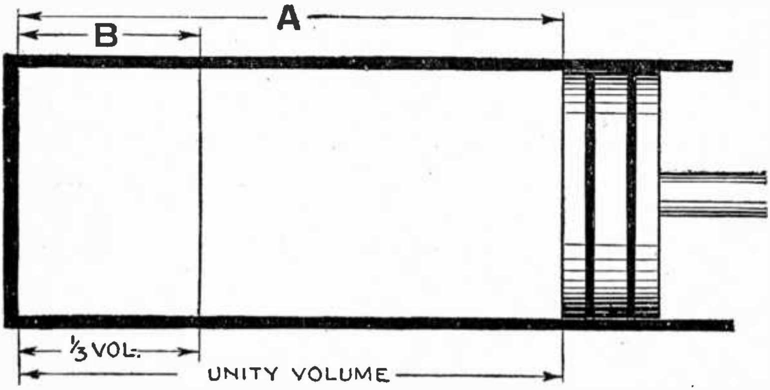


FIG. 8,938.—Elementary air compressor illustrating the phenomena of compression as stated in Boyle's and Charles' laws and explained in the accompanying text.

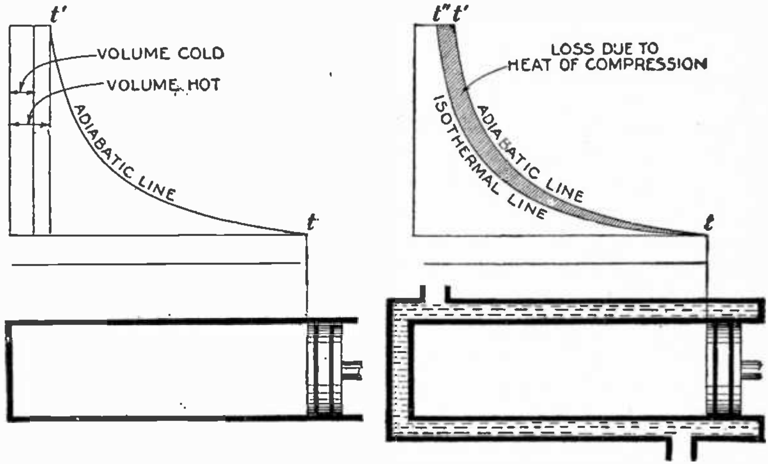
sure drops *to what it would have been if compressed at constant temperature.*

Accordingly, in the construction of air compressors, where working efficiency is considered, some means of cooling the cylinder is provided, such as projecting fins, or jackets for the circulation of cooling water.

NOTE.—***In air compressor problems*** careful distinction should be made between ***gauge pressure*** and ***absolute pressure***, the former being the pressure as indicated by a pressure gauge, as distinguished from absolute pressure which is the gauge pressure plus 14.73 lbs., the weight of the atmosphere at sea level, when the barometer reads 30 ins. or, for ordinary calculations, 14.7 lbs.

Free Air.—By definition free air is *air at ordinary atmospheric pressure and temperature.*

Heat of Air Compression.—This subject has probably received more consideration in air compressor design than any other. The principal losses in the earlier compressors were traceable to this source. Figs. 8,939 to 8,942 show why the heat of compression results in a loss.



FIGS. 8,939 to 8,942.—Diagrams and elementary compressors illustrating loss due to heat of compression. If no means be provided to carry off this heat, compression will be *adiabatic* as indicated by the curve *tt'* fig. 8,939. Assuming all the heat to be carried off by the water jacket (fig. 8,942) compression will be *isothermal* as indicated by the curve *tt''* fig. 8,940. Here both curves are shown, the shaded area representing loss. Hence in compressor construction provision is made to carry off as much of the heat of compression as possible.

It should be noted that the heat of compression, as already explained, represents work done upon the air for which there is usually no equivalent obtained, since the heat is all lost by radiation, before the air is used.

The selection of an air cylinder lubricant is, of course, governed to a considerable extent by a knowledge of the cylinder temperature it must withstand.

Knowing the air pressures, the corresponding temperatures are ascertained fairly accurately, as shown in the following table.

Cylinder Temperatures at End of Compression

Air Compressed to Lbs. Gauge	Final Temperature Single Stage Deg. F.	Final Temperature Two Stage Deg. F.
10	145	---
20	207	---
30	255	---
40	302	---
50	339	188
60	375	203
70	405	214
80	432	224
90	459	234
100	485	243
110	507	250
120	529	257
130	550	265
140	570	272
150	589	279
200	672	309
250	749	331

This table gives the final temperature in the cylinder at the end of the compression stroke, for single stage, also for two stage (or compound) compression, when the free air entering the cylinder is 60° Fahr.

Variations from these temperatures will occur in actual practice due to water jacketed air cylinders and radiation, tending to lower the temperature at the higher pressures. However, at say, 50 lbs. pressure and lower, the heat is likely to be somewhat greater than given by the table, particularly if the compressor be run at high speed and also if it be not water jacketed.

Methods of Abstracting the Heat of Compression.—Since the heat of compression results in a loss, various methods have been devised to carry off this heat so that the temperature of the air during compression will remain as near constant as possible.

The two important methods are known as:

1. Wet compression;
2. Dry compression.

In the earlier compressors, compression was accomplished in one stage or single cylinder machines, and the heat of compression was removed by

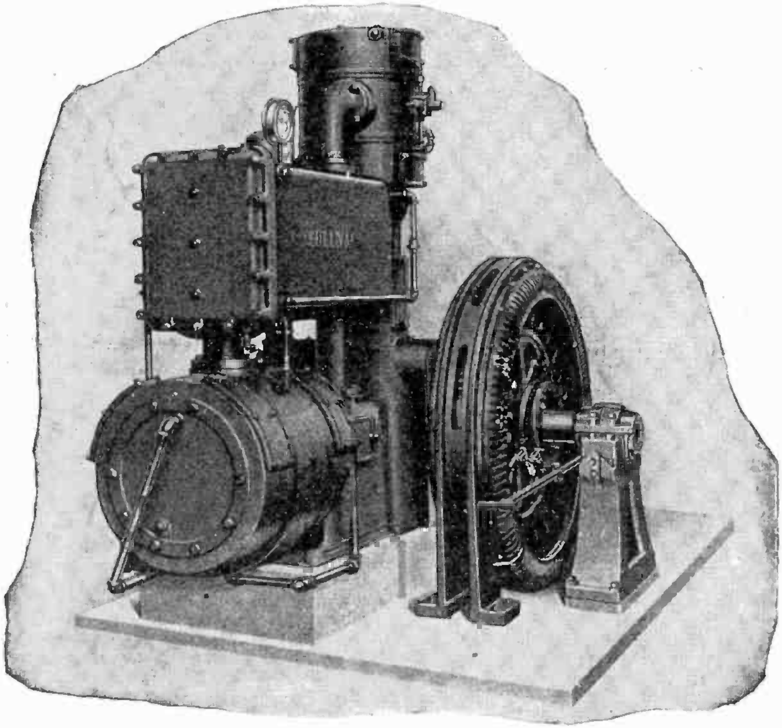
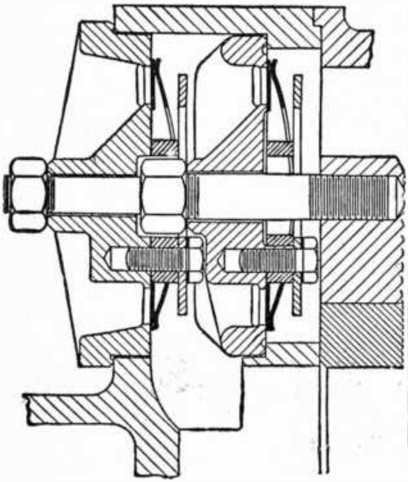


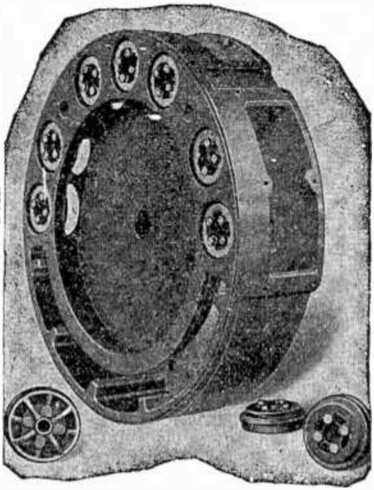
FIG. 8,943.—Sullivan angle-compound compressor direct connected to electric motor. Recent improvements in synchronous motors have made it possible to employ a simple and compact design of direct connected motor drive on angle-compound compressors. The rotor is mounted directly on the crank shaft close to the compressor frame, allowing sufficient room for getting at the bearing boxes.

injecting water into the cylinder in the form of a spray; or, in another type, the water was used as a piston for compressing.

The spray injection cylinder has now given way almost entirely in this country to the dry or jacketed cylinder.

The advantage of spray injection is higher thermal efficiency but from a commercial point of view its efficiency is not so high as with dry compression, for the water in the cylinder prevents proper lubrication, and the impurities therein attack the cylinder walls.

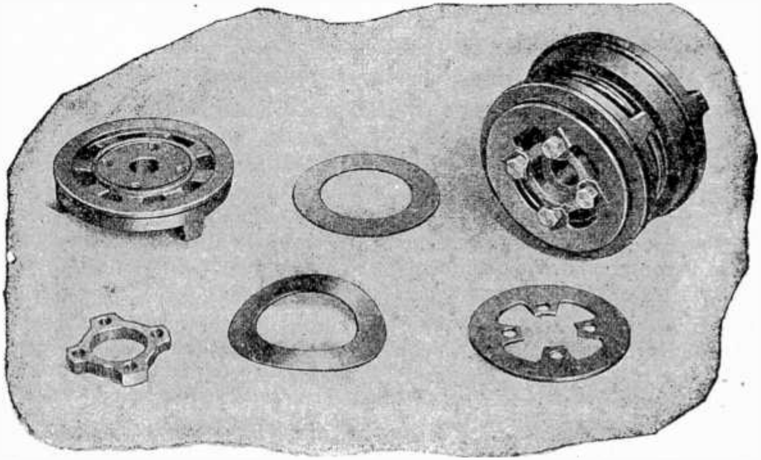




FIGS. 8,944 and 8,945.—Sullivan "wafer" valves. Fig. 8,944 valves and port arrangement for angle-compound compressors; fig. 8,945, cylinder head showing arrangement of *wafer* valves. The inlet and discharge valves are seated in pairs in tandem, one pair in each port, providing large valve area and small clearance space. *They consist of* thin flat rings resting on ground seats of the same shape. These valves are fully automatic. They are held to their seats by air pressure and are returned after opening by annular springs of the same size and material as the valves themselves. One spring is used on each inlet valve and two springs nested together on the discharge valves.

In dry compression a jacketed cylinder is provided and cold water circulated through the jacket which keeps the cylinder walls sufficiently cool so that proper lubrication is not interfered with and all other disadvantages of the wet compressor are obviated.

Single Stage and Two Stage Compressors.—In a single stage compressor the air is compressed to the desired pressure in one operation; or, in other words, the air is taken into the air cylinder at zero gauge pressure (that is, atmospheric pressure or 14.7 lbs. per sq. in.) and compressed with one stroke of the piston to the desired pressure. It is then discharged directly into the air receiver.



FIGS. 8,946 to 8,951.—Sullivan *wafer* air valves and parts. When placing these valves in the heads, be sure that the inlet valves come up to the seats; to do this make sure that the cap bolt heads on the inlet valve guards clear the ribs on the discharge valve seats; by turning the valve slightly this position can easily be found.

In a two stage compressor the desired pressure is reached in two operations, and two separate cylinders are required. The air is taken into the low pressure (large) cylinder and compressed to an intermediate pressure, whence it is passed through an intercooler to the high pressure (small) cylinder, in which the compression to the desired pressure is completed.

The principal advantage of compound compression over simple compression is the reduction of the loss due to the heat of compression.

This is due to the fact that more time is taken to compress a certain volume of air, and that this air while being compressed is brought into contact with a larger percentage of jacketed surfaces.

Other important advantages due to compounding may be enumerated as follows:

1. Cooler intake air;
2. Better lubrication;
3. Reduction of clearance losses;
4. Lower maximum strains and nearer uniform resistance.

The temperature of air leaving the intake cylinder being low, the cooling influence of the jacket is better, the cylinder walls are cooler between strokes, and the air enters the cylinder cooler than in a single stage compressor.

The lubricant for cylinders and valves is not subject to the pernicious influence of high temperatures; and the clearance losses, or losses due to dead spaces, are less in a compound compressor than in a simple compressor.

Clearance loss in an air compressor is principally a loss in capacity, and therefore affects only the intake cylinder; it increases with the terminal pressure, but since the terminal pressure of the intake or low pressure cylinder of a compound compressor is much less than the terminal pressure of a simple compressor, the volumetric efficiency of the compound compressor is greater than that of the simple compressor.

The life of a compound compressor is longer than that of a simple compressor for like duty, due to better distribution of pressures.

More heat is generated in compressing to a high pressure than a low pressure. Up to a pressure of about 60 lbs. per sq. in. it is not practical to remove this heat, and single stage compressors should be used. Above 60 lbs. a two stage compressor will not only deliver more air than a single stage compressor of equal size, but will consume less power.

NOTE.—*Air cooling.*—Hot air in the cylinder of an air compressor means a reduction in the efficiency of the machine. The trouble is that there is not sufficient time during the stroke to cool thoroughly by any available means. Water jacketing is the generally accepted practice, but it does not by any means effect thorough cooling. The air in the cylinder is so large in volume that but a fraction of its surface is brought in contact with the jacketed parts. Air is a bad conductor of heat and takes time to change its temperature. The piston while pushing the air toward the head, rapidly drives it away from the jacketed surfaces so that little or no cooling takes place.

Inter-coolers.—By definition an inter-cooler is *a species of surface condenser placed between the two stages of a compound air compressor* so that the heat of compression liberated in the first cylinder may be removed from the air as it passes to the second or high pressure compression cylinder.

The cooling surface usually consists of nests of small brass or copper tubes through which water circulates.

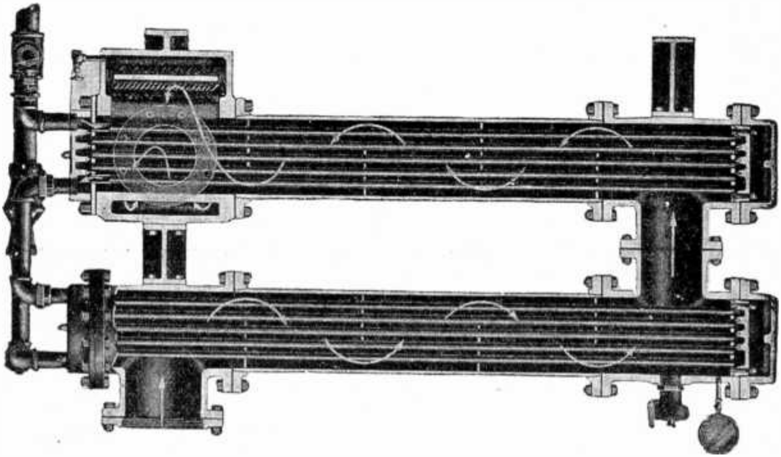


FIG. 8,952.—Ingersoll-Rand horizontal after cooler. The arrows show the course of the air or gas. The moisture separator is in the base below the right hand end of the lower tube nest.

After-coolers.—Moisture in compressed air or gas is costly and annoying. Carried into the lines in the form of vapor, it condenses when cooled and has many harmful effects. In compressed air, it washes away lubricant from the tools and machines through which it passes. It freezes in valves, ports and other openings because of the sudden expansion of the air. It hastens corrosion of all metal that it reaches and hastens the decay of rubber hose.

In the case of compressed gas for distribution, it is one of the leading causes of line and meter troubles.

Removal of moisture before the air or gas is introduced into the lines is the best method of procedure. This can be done effectually by an after-cooler which cools the air (or gas) to a point where most of the moisture and oil condense and can be removed.

This is accomplished by bringing the air (or gas) into contact with pipes through which cooling water is constantly circulated. This not only eliminates the difficulties which moisture causes at points where the air is used, but also insures more effective distribution.

The air leaves the after-cooler at a uniform and relatively low temperature, thus obviating the alternate lengthening and contraction of lines previously referred to.

With efficient after-coolers, sufficient moisture is removed to satisfy most applications of air, and no further care need be exercised.

Where the air is used for such purposes as paint spraying, enameling, food preparation, and the like, further drying of the air can be effected by passing it through special separators immediately before it is used. These remove the moisture which may condense due to further cooling of the air in pipe lines following the cooler.

Piston Displacement.—The displacement of a compressor is *the volume displaced or swept through by the piston during the compression stroke*. It is not a measure of the amount of air which the compressor will actually deliver.

Actual Air Delivered.—The amount of air actually delivered by the compressor is *always less than the piston displacement* and is the *amount of air available for useful work*. It is expressed in cu. ft. per minute of free air.

Volumetric Efficiency.—By definition, volumetric efficiency is the *ratio of the actual air delivered to the piston displacement.*

For instance, if a compressor have a displacement of 20 cu. ft. per minute and the actual air delivered be 16 cu. ft. per minute, its volumetric efficiency is $\frac{16}{20}=80\%$.

Pressure Regulators.—Because of varying and intermittent demands for compressed air, some form of pressure regulator is necessary to maintain a constant pressure in the receiver.

Various methods are employed depending on the type of compressor, drive, and other conditions.

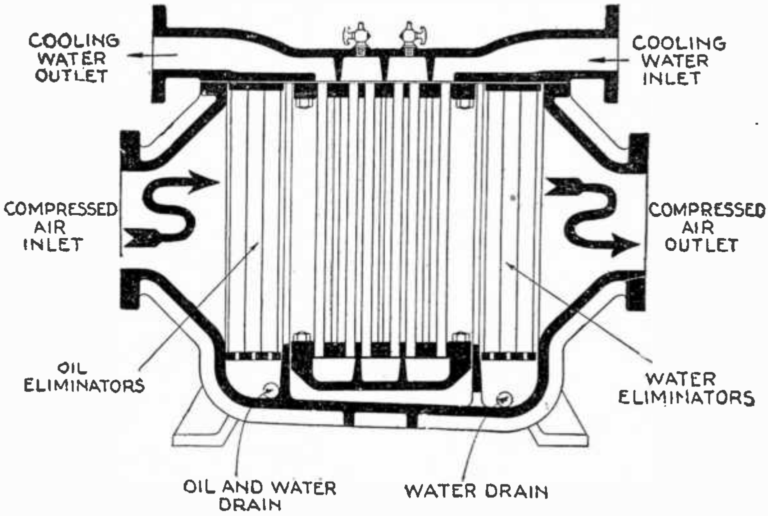
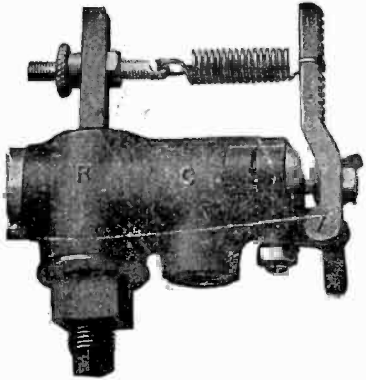
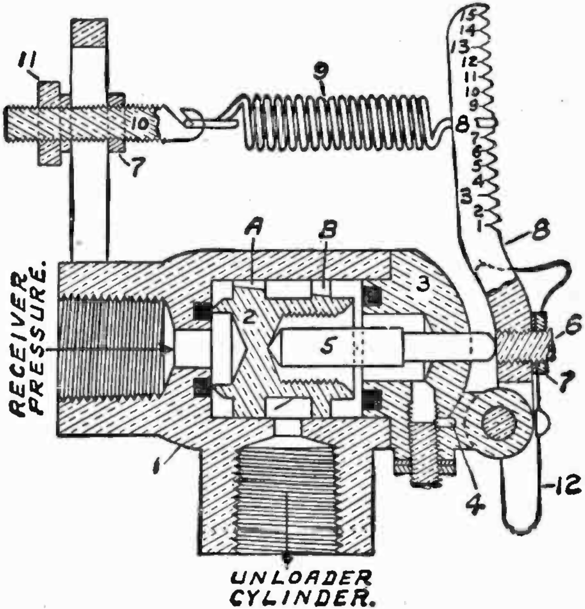


FIG. 8,953—Sullivan air or gas after cooler.

In the case of power driven machines which run at constant speed some form of "unloader" is employed which closes the inlet pipe or connects the two ends of the cylinder when the receiver pressure reaches the maximum point desired.

Duplex steam driven machines, which have a wider range of speed, may often obtain sufficient air regulation by simply varying the speed by means of a throttling or automatic governor attached to the engine.

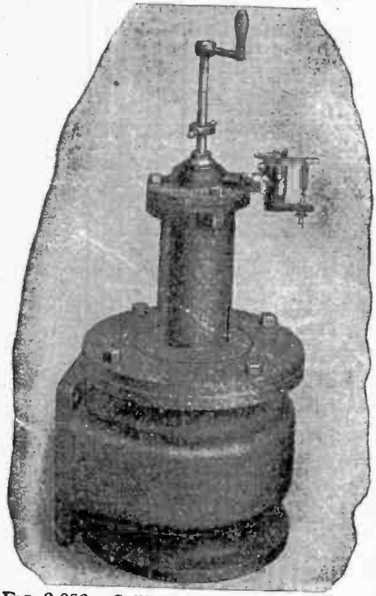




FIGS. 8,954 and 8,955.—Sullivan type R. C. pilot valve. ***The parts are:*** 1, body; 2, piston; 3, cap; 4, vent adjusting screw 5, stem; 6, adjusting screw; 7, lock nut; 8, lever with hand unloader; 9, spring; 10, spring hook; 11, adjusting nut. ***In operation,*** the pilot valve delivers receiver pressure to the unloading device at predetermined maximum receiver pressure to unload compressor and at predetermined minimum receiver pressure it shuts off receiver pressure and exhausts all pressure in unloader device to load compressor. The cycle is repeated as receiver pressure rises and falls.

When the conditions are more exacting, as in mining operations, a combined speed governor and unloader is used.

Among other methods of regulation may be mentioned the shifting of the driving belt in the case of small power machines; the starting and stopping of the motor of electrically driven compressors used in connection with air brake systems; and the varying of the clearance on the compressor as the load changes. All of these devices operate automatically through changes in the receiver pressure.



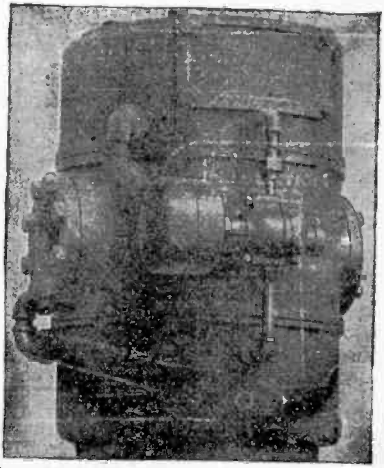


FIG. 8,956.—Sullivan unloading device with pilot valve for air intake conduit. ***It consists of*** a double beat valve, placed on the air inlet duct, and controlled by a pilot valve. The valve is set to shut off all the incoming air from the compressor when the receiver pressure rises above a predetermined point; that is, when the demand for air drops away. The compressor then runs under no load except that due to friction, compressing no air, and reducing the consumption of power to a very low factor. When the demand for air begins once more, that is, when the pressure in the receiver falls below the point at which the unloading device is set to act, the valve again opens fully, and the compressor automatically resumes its entire load until the demand for air again ceases, when the cycle of operation, just described, is repeated. The pilot valve may be adjusted to maintain any desired pressure in the air receiver.

FIG. 8,957.—Sullivan auxiliary control valve. This works independently of but co-ordinating with the unloader. ***In operation*** when the low pressure unloading valve has been on a few revolutions, and the high pressure cylinder has pumped out the inter-cooler, the auxiliary control valve on the high pressure cylinder provides that any air which may have leaked into the machine is exhausted. All chances of building up excessive heat and pressure in a closed circuit in and on crosshead pins, crank pins, guides, etc., are eliminated.

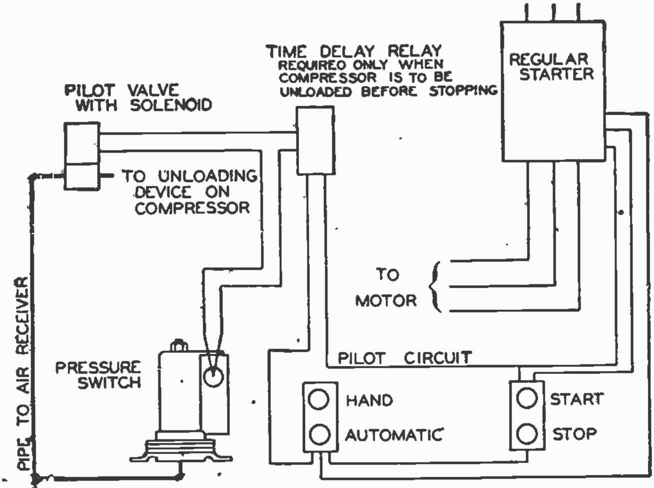


Fig. 8,958.—Sullivan diagram for automatic start and stop control of direct connected synchronous motors, when time delay relay *is used*.

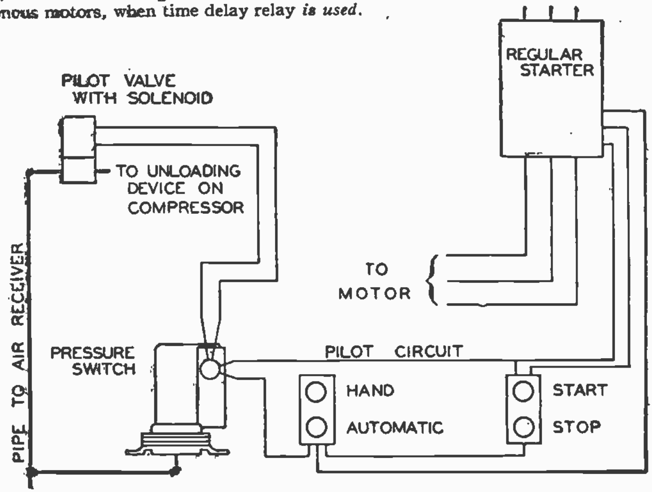


Fig. 8,959.—Sullivan diagram for automatic start and stop control of direct connected synchronous motors, when time delay relay is *not used*.

Prevailing types are shown in the accompanying illustrations.

Automatic Start and Stop Control.—As an example of this method with direct connected synchronous motor drive, two diagrams are shown, figs. 8,958 and 8,959.

In the diagram 8,959, the control consists of the regular automatic starter operated by a start and stop push button.

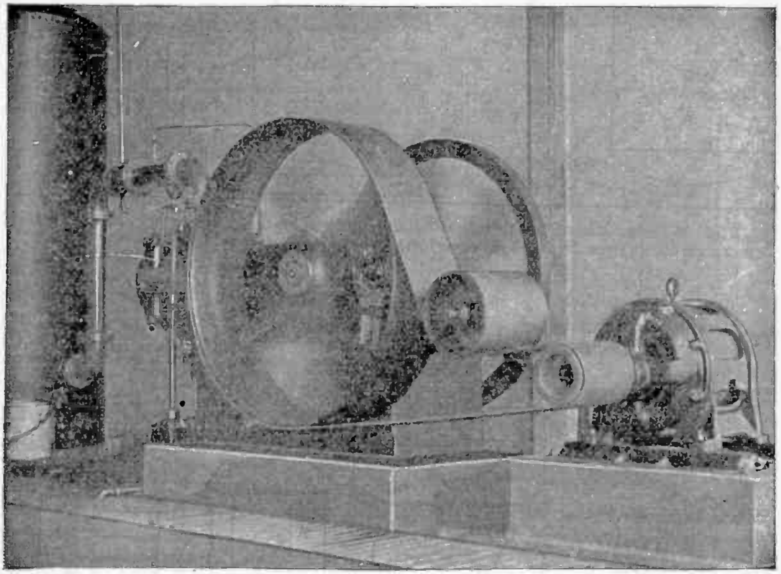


FIG. 8,960.—Sullivan close connected belt driven air compressor showing idler pulley and air filter on air inlet.

The automatic starter is an essential part of the equipment and must be substituted for the manually operated starter regularly used with slip ring induction, squirrel cage or *d.c.* motors. To this is connected, as indicated in the diagram, an electric pressure switch, a definite time delay relay and another push button, which cuts in and out at will the automatic start and stop operation. Two types of pressure switches are available.

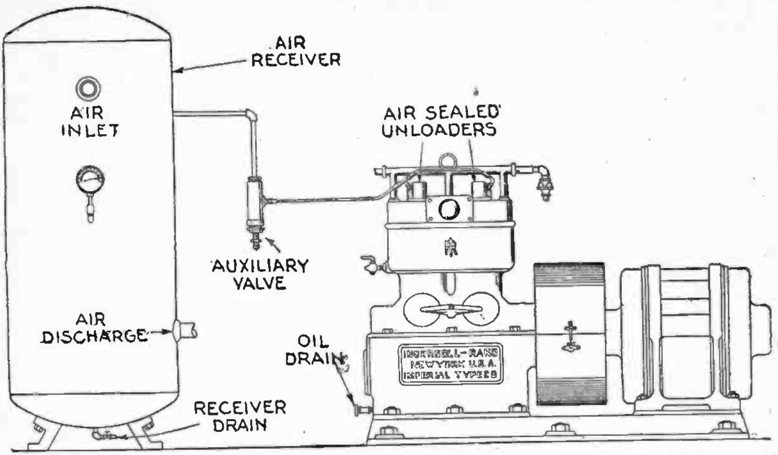


FIG. 8,961.—Piping diagram for Ingersoll-Rand stationary direct connected electric motor driven air compressor *arranged for constant speed operation.*

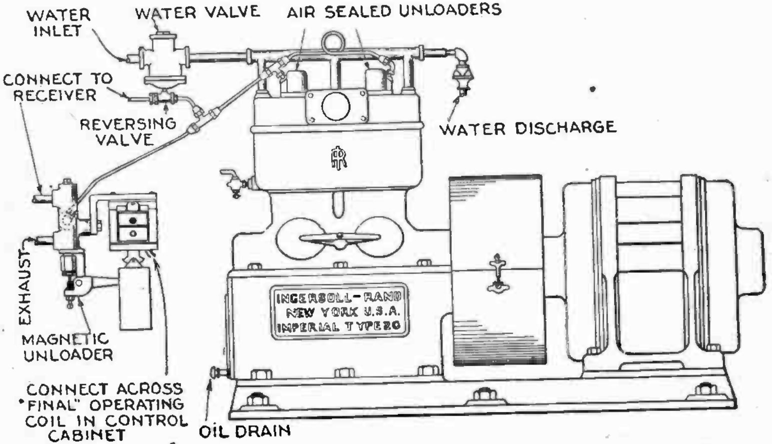


FIG. 8,962.—Piping diagram for Ingersoll-Rand stationary direct connected electric motor driven compressor arranged for *automatic start and stop control.*

The diaphragm type is operated by a diaphragm and has a differential in pressure between stopping and starting.

The gauge type is operated by a Bourdon tube and has a small differential pressure. They are interchangeable.

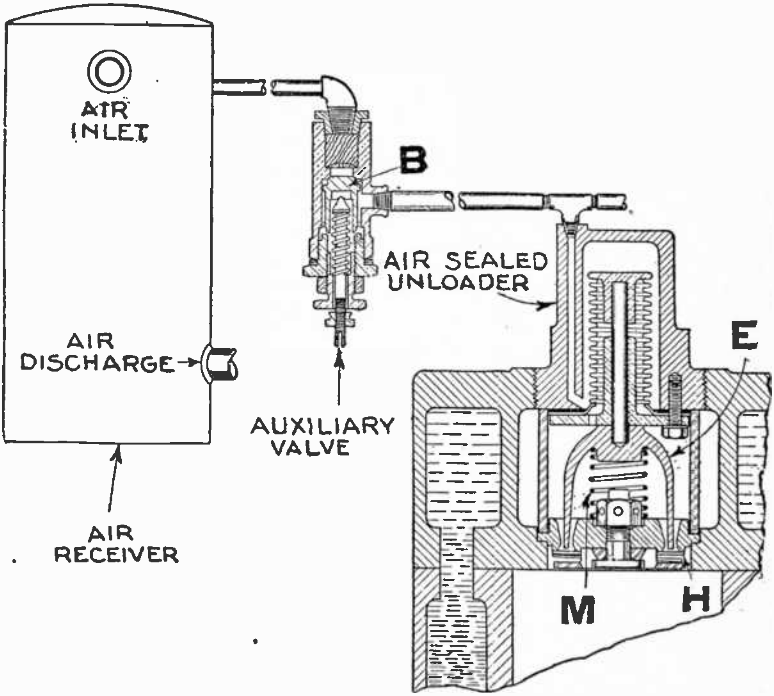


FIG. 8,963.—Ingersoll-Rand unloader for stationary direct connected electric motor driven compressor arranged for constant speed operation. See fig. 8,964 for operation.

The definite time relay provides a means for unloading the compressor before stopping or starting and is to be recommended in most cases. It is required with all short belt idler drives with multi-step control.

When the definite time relay is omitted, the wiring is as in fig. 8,959. This equipment controls the pilot valve with solenoid.

The equipment will run by hand or automatic control, depending on the position of the maintaining contact push button station used as change over switch.

When operating on hand control, that is, with the button marked *hand*, on the maintaining contact switch depressed, the motor is controlled by the regular start-stop push button. In this condition, the compressor will load and unload as governed by the setting of the unloader.

When starting, the compressor will load after the motor is up to speed and will unload simultaneously with the power being thrown off the motor when the *stop* button is depressed.

When the automatic button of the maintaining contact push button station is depressed, the regular start-stop push button station mentioned

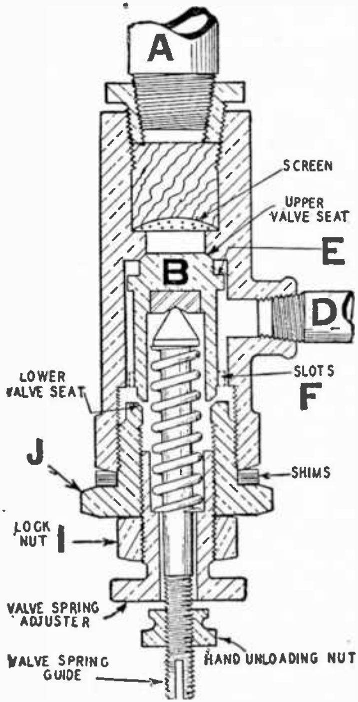


FIG. 8,964.—Enlarged view of auxiliary valve shown in fig. 8,963. ***Constant speed control:*** With the compressor operating under normal conditions, it builds up pressure in the air receiver until maximum desired pressure is reached. The auxiliary valve **B**, drops to the lower seat, opening up the passage and admitting receiver pressure to the air-sealed unloader. Receiver pressure applied to the unloader overcomes the resistance of spring **M**, and forces the plunger **E**, down, holding open the inlet valve **H**. Thus the compressor is unloaded, since no air can be compressed and discharged to the receiver. When the pressure in the air receiver has fallen approximately 10 lbs. the auxiliary valve **B**, is forced to its upper seat by the spring, closing the air passage between the receiver and unloader. This releases the pressure over the unloader bellows to atmosphere. The spring **M**, in the unloader now raises the plunger **E**, and the inlet valve is free to open and close. Thus the compressor is loaded and air is again compressed and discharged to the receiver. The normal operating pressure between unloading and reloading points is usually 90 to 100 lbs. giving a range of 10 lbs. This can be varied slightly by adjusting the auxiliary valve. ***Operation of auxiliary valve:*** Air enters the auxiliary valve from the receiver through piping **A**, passing through a strainer and screen. When the air pressure reaches say 100 lbs. this pressure acting downward on the valve **B**, overcomes the upward push of the spring, and the valve **B**, starts downward. In this position the additional surface at **E**, is momentarily exposed to receiver pressure, quickly forcing before, is removed from the control circuit and the pressure governor substituted. The equipment will then start and stop automatically, governed by the setting of the pressure governor.

A similar sequence of starting and stopping is obtained by the pressure governor control in that the compressor will load after the motor is up to speed and unload when power is cut off from the motor.

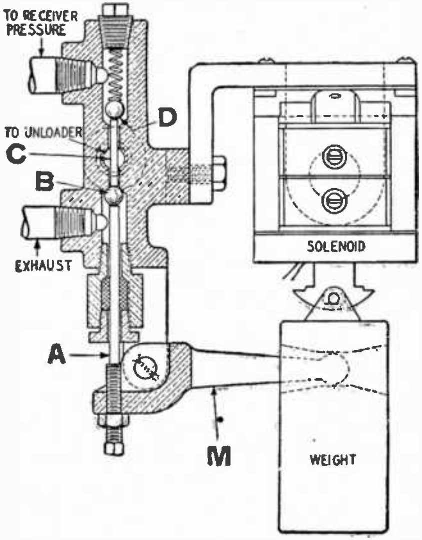


FIG. 8,965.—Magnetic unloader for Ingersoll-Rand stationary direct connected electric motor driven compressor arranged for *start and stop control*. The unloader is wired in parallel with the last step of the controller so as to load the compressor only after motor has attained full speed and full voltage conditions. When the last contact on the controller is made, electric current energizes the solenoid, which raises the weight suspended beneath it. Acting through the lever **M**, this drops the pin **A**, and unseats the ball valve **B**. There is a pin **C**, between the upper and lower ball valves of such length that when one ball is unseated the other is permitted to seat. *In shutting down*, the solenoid is de-energized and the weight

FIG. 8,964.—*Text continued.*

valve **B**, to the lower valve seat. Receiver pressure against the larger area now exerts a total force which more than makes up for the additional force exerted by the spring through being compressed. With the valve **D**, on the lower seat, pressure from the receiver passes freely out piping **D**, to the unloaders. When the receiver pressure has dropped about 10 lbs. then the force that the air is exerting downward on the valve is less than the spring is exerting upward and the valve returns to the upper seat. With the valve in the upper position there is an open passage from the unloaders to atmosphere. This passage is through piping **D**, past the slots **F**, and down the valve spring guide. With the escape of air from the unloaders to atmosphere, the compressor resumes its load.

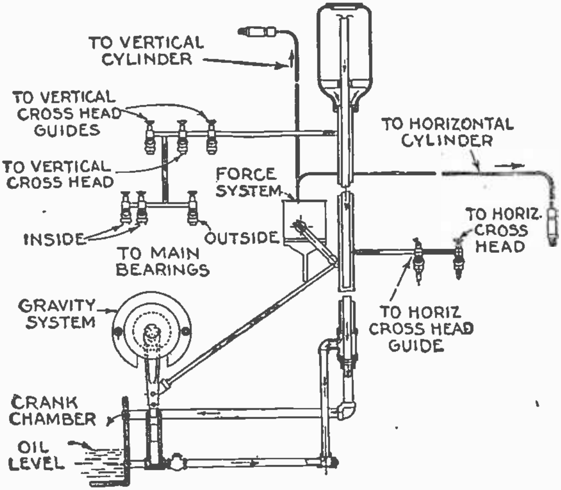


FIG. 8,966.—Sullivan oiling system for angle compound compressor *In operation* the oil pump forces the oil from the crank chamber up the standpipe, into the reservoir. From the standpipe the oil is distributed through branch pipes to the various bearings to be oiled. Adjustable sight feeds are attached at each of these points in order that the flowing stream of oil may be watched and adjusted at all times. The surplus oil is returned to the crank chamber through the overflow pipe. When the compressor stops, the oil contained in the standpipe and reservoir is prevented draining back into the crank chamber by suitable check valves, thus insuring an immediate flow of oil to the bearings when the compressor is again started.

FIG. 8,965.—*Text continued.*

drops down. This moves the pin **A**, up, holding the ball valve **B**, tight against its seat. This forces the pin **C**, up, unseating the upper ball **D**, Unseating the ball **D**. opens the passage so that the receiver pressure is admitted to the unloaders. When ball **D**, is seated this passage is closed off and ball **B**, is unseated, opening a passage from the unloaders to atmosphere. When the receiver pressure rises above that for which the pressure switch is set, the switch cuts out and the motor and compressor stop. At the time the solenoid is de-energized, the weight drops and lever **M**, pushes up on pin **A**, until the ball valve **B**, is seated. Discharge pressure is now admitted past ball **D**; going to the unloaders and acting through the bellows, it holds the inlet valves open. Thus the compressor stops in an unloaded condition. When the receiver pressure drops below that for which the pressure switch is set, the switch cuts in and the motor and compressor are started up. When the last contactor in the controller is reached the solenoid is energized, lifting up the weight and moving lever **M**, so that the pin **A**, drops down and the ball valve **B**, is unseated. Until this time the compressor has been starting up *unloaded;* that is, with the inlet valves held open. With the lower ball unseated and the upper one seated, receiver pressure is cut off and the air in the unloaders exhausts to atmosphere through the unloader, permitting the inlet valves to operate and the compressor to discharge air. Pressure in the receiver now builds up until the pressure switch cuts out again, thus completing the cycle. By hooking the solenoid in with the last step in the controller, the compressor starts up unloaded, and remains unloaded until the motor has attained full speed.

Three Stage Air Compressors.—These are used *for extra high pressure air*. Taking the Ingersoll-Rand three stage compressor as an example, the low pressure air cylinder of three stage compressors is double acting, while the intermediate and

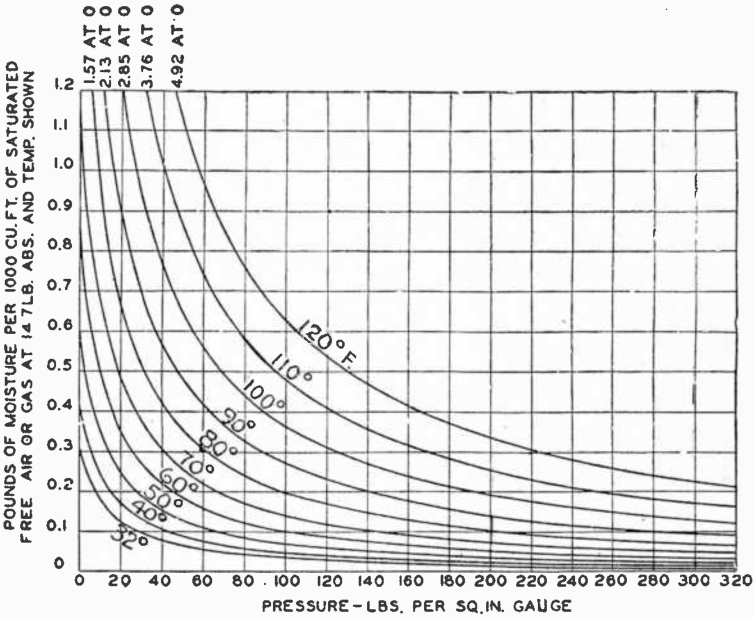


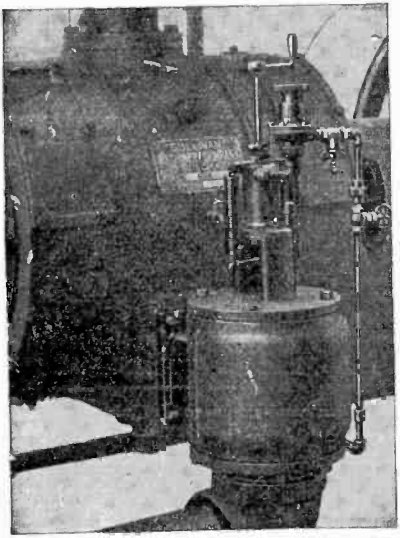
FIG. 8,967.—Curves showing moisture remaining in saturated air or gas when compressed to any pressure and cooled to temperature shown. *Example:* Saturated air at 80° at compressor intake (0 lb.) contains 1.57 lbs. of moisture per 1,000 cu. ft. Compressed to 100 lbs. and cooled to 80° with 65° water the air contains only .20 lb. per 1,000 cu. ft. or 13% of the moisture originally taken into the compressor. The rest has been condensed in the intercooler (if used) and the after cooler.

high pressure air cylinders are single acting. The low pressure cylinder is supported by a foot piece. Inlet valves are of the direct lift, poppet type, and discharge valves are of the cushioned direct lift poppet type.

All three air cylinders, as well as the steam cylinder of steam driven units, are oiled by means of a force feed lubricator having separate feeds to each cylinder.

The standard construction on three stage compressors, both belt and steam driven, also includes a cast iron box type sub-base, which extends under the entire machine.

An inter-cooler is located above and between the low pressure and intermediate air cylinders, while a second inter-cooler of coil construction is



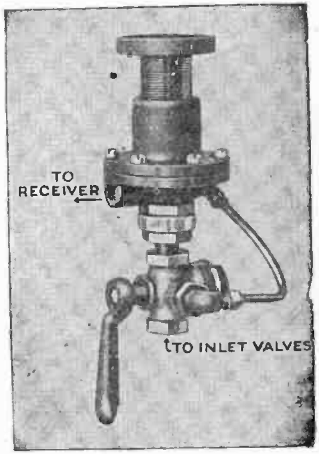


Fig. 8,968.—Sullivan unloading device with pilot valve on air intake conduit.

Fig. 8,969.—Detail of Sullivan pilot valve and piping, handle (down) in loading position (horizontal for starting).

located in the sub-base between the intermediate and high pressure air cylinders. Separators remove the condensed moisture from the air before it enters the second stage of compression.

Control Methods.—Since the power driven compressor is almost always a constant speed machine various methods of regulation are employed. Constant speed means constant piston displacement; the problem of delivering a variable volume of air with constant piston displacement, becomes one of making a portion of that displacement non-effective in the compression and delivery of air.

The following methods should be noted:

First method.—This is really one of unloading, rather than of regulating. *A pressure controlled mechanism is arranged so that when pressure exceeds normal, a communication is opened between the two sides of the compressor piston.* Usually this is accomplished by opening and holding open one or several of the discharge valves at both ends of the cylinder, the air is then simply swept back and forth from one side of the piston to the other through the open valves and the air discharge passage.

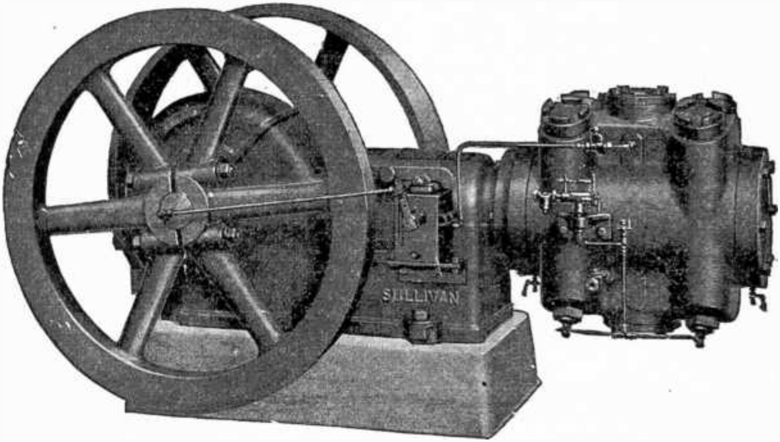
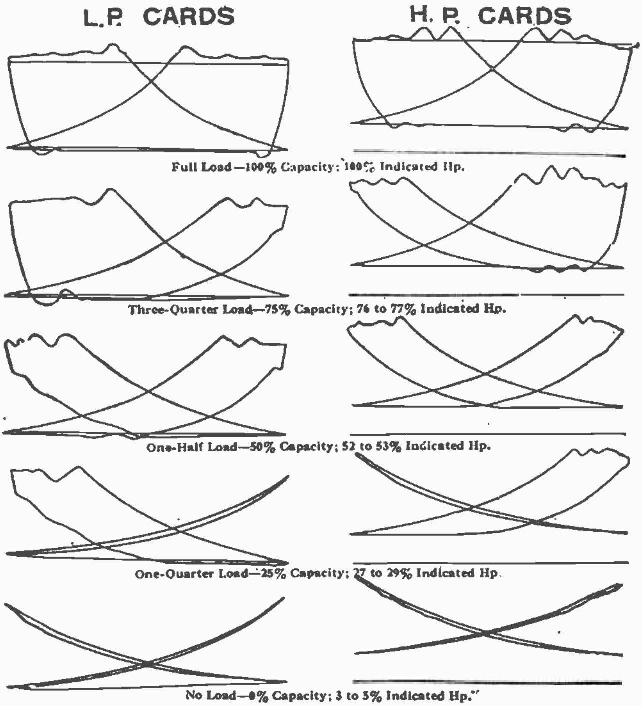


FIG. 8,970.—Sullivan straight line center crank, single stage belt driven compressor.

When normal pressure is restored, the valves are automatically closed, and compression and delivery are resumed. Evidently this is practically a total unloading of the machine for a longer or shorter period—a sudden release from load and a sudden resumption of load. Moreover, the air which is swept back and forth by the piston in its travel is air under full pressure; so that when the discharge valves suddenly close, the piston at once encounters a full cylinder of air at maximum pressure. These facts limit regulators of this class to machines of comparatively small capacity.



FIGS. 8,971 to 8,980.—Indicator cards showing operation of clearance control at five load points.

NOTE.—*Clearance control regulation for Ingersoll-Rand compressors.* This control automatically regulates the capacity of the compressor in five equal steps; namely, full, ¾, ½, ¼ and no load, keeping the power input approximately in proportion to the amount of air delivered at the compressor discharge. It further maintains a nearly uniform crank effort, not only at full load, but at all partial loads, thus eliminating the necessity for extremely heavy fly wheels required by other types of part load regulation where the crank effort is not kept uniform. Each cylinder is equipped with four clearance pockets, two at each end. With a two stage machine the volume of the clearance pockets in the high pressure cylinder bears the same relation to the volume of the low pressure clearance pockets as the cylinder ratio. On the single stage machine with two cylinders, the clearance pockets in both cylinders have the same volume. Each of these pockets is equipped with a balanced clearance valve. The regulating device which is automatically controlled from receiver pressure is built with four pilot valves, which operate in succession to control the opening and closing of the clearance pocket valves in the proper sequence. If the compressor be running at full load and rated discharge pressure and the demand for air decreases, the receiver pressure will

***Second method.**—By means of a pressure operated device, the partial or total closing of the compressor intake under reduced load is accomplished.* To avoid the dangers attendant upon such an operation acting suddenly, these devices are provided with some damping mechanism so that they are compelled to operate slowly, making the release or resumption of the load gradual.

Third method.—This is very similar to the first, ***except that here the** inlet valves, instead of the discharge valves, are held open when the machine is unloaded*, the piston thus simply drawing in and forcing out air at atmospheric pressure. It is open to the same criticism (though in somewhat less degree) as the first method, namely, undue shock and strain on release and resumption of load.

***Fourth method.**—A pressure controlled valve is here used on the compressor discharge of single stage machine, combining also the functions of a check valve to limit the escape of air from the receiver or air line.* Excessive pressure blows the discharge to atmosphere, instead of into the line. This arrangement is also used on two stage machines by placing it on the low pressure discharge to the inter-cooler. Then, when the governor valve is opened by excess pressure, the low pressure cylinder discharges to atmosphere, and the high pressure cylinder acts simply as a low pressure cylinder with intake at atmospheric pressure.

This device is more of a relief valve than an unloader, for the piston must continue to compress to a pressure which will open the discharge valves; this volume of compressed air is wasted.

***Fifth method.**—Provides auxiliary clearance spaces, or pockets, at each end of the cylinder, which are successively "cut in" as load diminishes.* The excess air is simply compressed into these clearance spaces and expanded on the back stroke. The capacity of the cylinder is reduced without any appreciable waste of power; for the energy used in compressing the clearance air is given back by its expansion.

NOTE.—*Continued.*

tend to rise until, at a predetermined point the clearance regulator functions to open the first set of clearance pockets; that is, one clearance pocket in each cylinder. In this manner approximately 25% of the air being compressed will pass into the clearance pockets, cutting the capacity of the machine to 75% of its full capacity rating. On the return stroke, the air thus trapped in the clearance pockets expands again, giving up its power to the pistons. Similarly, if the demand for air continues to decrease, the second set of pockets open, cutting the capacity of the compressor to 50%, etc., until, with all the pockets open, the machine is completely unloaded and no air is delivered to the receiver.

NOTE.—***Three things are to be avoided*** in the successful unloader or regulator for power driven machines; first, a sudden release or resumption of load, throwing heavy strains on the machine; second, undue rarefication of the intake air, resulting in a wide range of cylinder pressures and temperatures; third, the blowing off of compressed air to the atmosphere with a waste of power.

TEST QUESTIONS

1. *State Boyle's and Charles' Law.*
2. *What is the difference between absolute and gauge pressure?*
3. *What is free air?*
4. *What happens when air is compressed?*
5. *Describe two methods of removing the heat of compression.*
6. *What is the object of two stage compression?*
7. *Describe the construction of compressor valves.*
8. *What are the advantages due to compounding?*
9. *What is an inter-cooler?*
10. *What is the difference between an inter-cooler and an after-cooler?*
11. *What is the piston displacement of a compressor?*
12. *Define volumetric efficiency.*
13. *Describe the various methods employed for pressure regulation.*
14. *What is a pilot valve used for?*
15. *What is the function of a start and stop by pass?*
16. *Describe automatic stop and start control.*
17. *Describe the connections of an automatic starter.*
18. *Describe the method of constant speed control.*
19. *How does a magnetic unloader work?*
20. *What are three stage air compressors used for?*
21. *Describe the five control methods in general use.*
22. *Sketch indicator cards, illustrating clearance control.*
23. *Name three things to be avoided with unloaders.*

CHAPTER 232

X-Rays

These rays, discovered by Roentgen were called X-rays because of their unknown real nature. They are useful in locating foreign objects in the human body, dislocations, fractures, etc. The rays are also useful in dentistry, and the metal industry. In boiler construction, welded seams which are replacing riveted seams, are tested for flaws with X-rays.

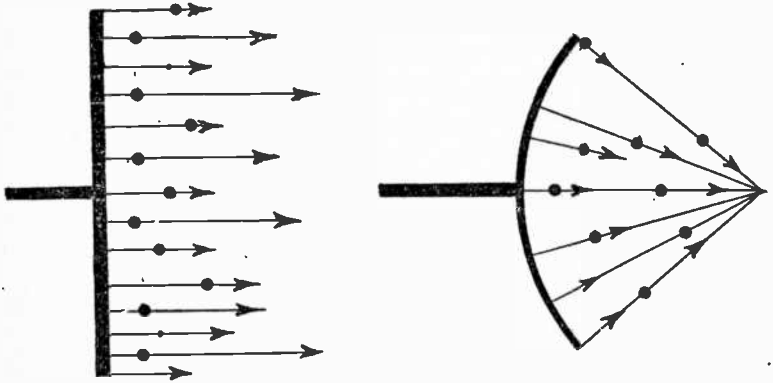
Production of X-Rays.—The apparatus necessary for the production of X-rays consists of:

1. Source of current;
2. Induction coil;
3. X-ray tube;
4. Control devices.

X-Ray Tubes.—An X-ray tube consists of a thin walled glass tube from which the air has been exhausted, and into which two electrodes or terminals have been sealed.

When a source of high voltage is passed between these electrodes, the following has been observed to take place: From the surface of the electrode to which the negative wire has been connected, minute electric particles are seen to fly off at right angles to the plane of the surface; these are cathode rays or electrons, and the electrode is called the cathode. If the cathode surface be shaped like a concave mirror, these particles will be focused at the center of the curvature. These conditions are shown in figs. 8,981 and 8,982.

Fig. 8,982 shows cathode rays coming from a circular cathode and converging to a point. When the cathode rays strike the other or positive electrode of the X-ray tube, which electrode is called the *target*, a ray is emitted from the spot struck, and if a sufficient number strike, a luminous beam appears; this has the penetrating power and these rays are the unknown or X-rays.



FIGS. 8,981 and 8,982.—Flat and circular cathode or negative terminal showing direction of the cathode rays.

In striking, it is as though a piece of metal were struck by a hammer rapidly until it became white hot and emitted light, as just described.

The quality and intensity of X-rays depends upon the voltage and current applied.

The voltage is measured by a spark gap and the current by a milli-ammeter as shown in fig. 8,984.

There are numerous types of X-ray tubes designed to meet the various conditions and requirements. These types are called:

1. Universal;
2. Radiator;
3. Radiator dental;
4. Portable radiator;
5. Oil immersed;
6. Air cooled deep therapy;
7. Water cooled deep therapy.

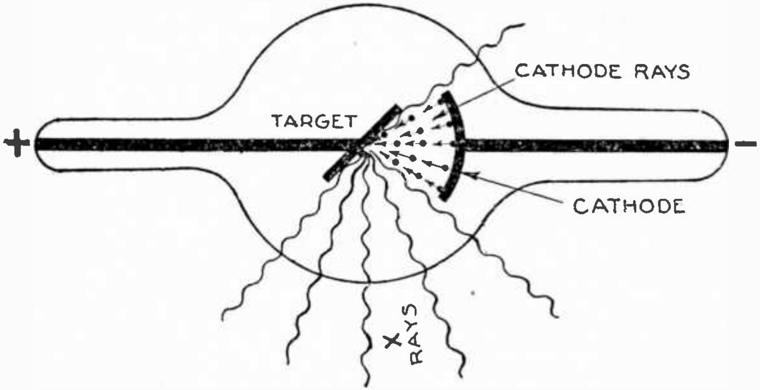


FIG. 8,983.—Diagram of an X-ray tube. *In operation,* cathode rays strike the positive terminal or target of the tube and cause rays to emanate from the target, which have the quality of penetrating objects and are known as X-rays.

In general an X-ray tube consists of *a tube exhausted to the highest degree and in which the cathode, or negative terminal may be heated by an external low voltage electrical source.*

The object of heating the cathode is to provide a means to liberate electrons or cathode rays without resulting in the intense heat to which an ordinary X-ray tube is subject, where the high voltage both liberates and drives the electrons to the target.

The cathode consists of a small spiral of tungsten wire.

This is heated to white heat by the external source, 10 to 12 volts and liberates the electrons. The high voltage then applied in the ordinary way, drives them to the target and produces the X-rays. It is possible to apply higher voltages, get greater concentration and operate for longer periods.

The various types of tubes just listed are described in the accompanying illustrations and notes.

Method of Heating the Cathode Filament.—The cathode filament may be heated by means of a storage battery or preferably from the *a.c.* supply (when available) using a small

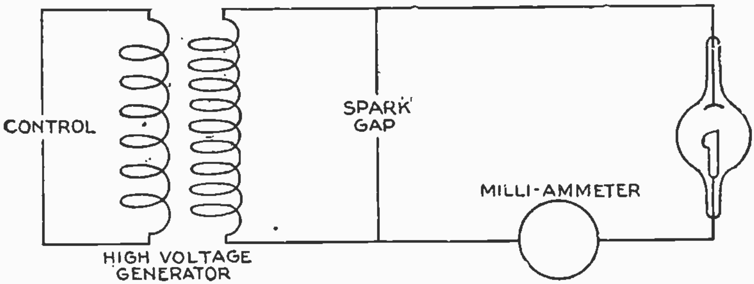


FIG. 8,984.—X-ray circuit diagram snowing primary and secondary winding of induction coil, spark gap for measuring voltage and milli-ammeter.

step down insulation transformer. The battery is universally applicable. The transformer may be used wherever there is *a.c.* available, either from the supply mains or from a synchronous converter. The filament current transformer is not to be recommended for radiographic work where there is much line drop or fluctuation in the current supply.

This transformer should have a low tension output of 10 to 12 volts and not over 5 amperes. It should be capable of finely graduated control by means of either a resistance or variable inductance device.

As the low tension side of this transformer will be brought to the full voltage of the tube, it is important that it be thoroughly insulated from the high tension side, the ground and the patient.

The filament should never be subjected to more than 5 amperes.

The best technique demands the use of an ammeter in the filament circuit in order that settings may be properly made. If the supply voltage be fluctuating, a stabilizer can be used to maintain a constant high tension through the tube.

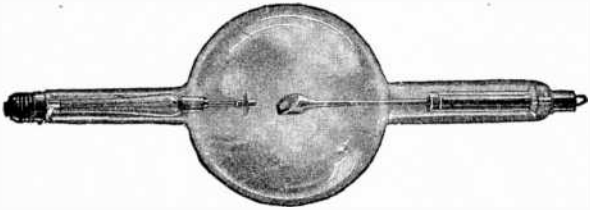


Fig. 8,985.—Coolidge ***universal type*** tube. ***Adapted*** for all classes of X-ray work, radiographic, fluoroscopic and therapeutic, but should be used only on rectified current and at voltages not exceeding 140 ***kv***. maximum.

Fig. 8,986.—Coolidge ***radiator type*** tube. The physical characteristics of the radiator tube are, in general, the same as those of the universal tube. There is this important difference, however, that the radiator tube may be used to rectify its own current and may therefore be operated directly from the terminals of a high tension transformer without the interposition of any auxiliary rectifying device. It will operate equally well on rectified current, but has the same definite limitations in both cases. ***Designed solely*** for diagnostic purposes and should never be used for therapy. On account of the small diameter of the bulb and certain characteristics increasing the danger of puncture, the radiator type tubes should not be used at voltages higher than 84 ***kv***. maximum on either rectified or non-rectified current. 84 ***kv***. is approximately a 5 in. gap between points.

NOTE.—When a tube is operated self-rectifying, that is, with one-half of the complete wave suppressed, the used or loaded half wave has a lower peak than the unused or inverse half This difference between the inverse and useful peak voltages will vary with the different transformers and with different loads on the same transformer. While it is theoretically possible to calculate this difference, the most practical method is to determine it experimentally.

It is very important that the whole filament circuit from the filament transformer to the tube be made with good joints and contacts and with large conductors, since the voltage is only 10 to 12, and the current may be as high as 5 amperes.

Poor or variable contacts in the filament circuit may frequently be the cause of damaged tubes or failure to get good results.

Cooling X-Ray Tubes with Water.—In perfecting the high power therapeutic X-ray tube, it became necessary to develop a system which would maintain the cathode of the tube at

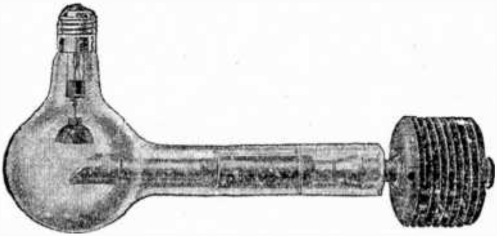


FIG. 8,987.—Coolidge *radiator dental type* tube. *Adapted* particularly for dental work and is used on only those types of apparatus which are specially designed for operating this tube. It is intended for making radiographs of the teeth and jaw only and not for general radiographic work. This tube is similar to the standard radiator tube in characteristics and construction except that the cathode is mounted in the side of the bulb at right angles to the anode arm. The advantages claimed for this type are: 1, the useful X-rays are emitted in line with the axis of the anode arm, thereby making it easy to manipulate the tube to the best advantage; 2, the cathode circuit is grounded so there is only one high tension wire and this is always connected to the radiator which is farthest from the patient being radiographed; 3, the focal spot to film distance is reduced to the minimum, thereby reducing the time of exposure.

NOTE.—*Portable radiator type tube.*—This tube is similar to the other radiator tubes but is smaller and is made of lead glass in order to provide protection against the X-rays and to be simple and light for portable work. The useful X-rays come through a thin lime glass window in the side of the bulb and practically all of the rest of the radiation is absorbed in the lead glass.

NOTE.—*Oil immersed dental type tube.* This tube is made of lead glass with a thin lime glass window similar to the portable tube. It has a special small anode with a copper stem extending out into the oil for cooling purposes and a very small cathode and is so designed as to be enclosed, with the transformer, in oil in a very small container which is mounted on an adjustable bracket for dental work.

proper temperature and be safe in operation both for patient and the tube.

The water cooled tube is so constructed that water, properly cooled. can be circulated within the reverse side of the anode and by conduction, transfer the heat to a point outside the walls.

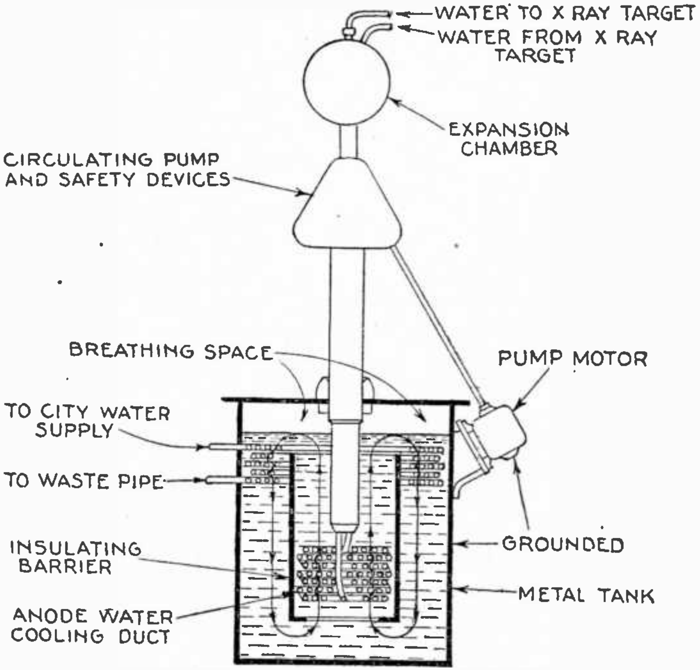


FIG. 8,988.—Acme-International water-oil-water cooling system. The anode water cooling ducts are shown at the bottom and the ducts connected to the city water supply, at the top. The top is filled with a high grade transformer oil. Between the two water circulating systems is an insulating barrier which directs the flow of the oil. The anode water ducts being at the bottom of the tank, they heat the oil and the oil rises along the lines indicated by the arrows. This hot oil rising to the top is replaced by cool oil that flows down past the city water ducts and is cooled thereby; thus forming a circulating medium between the two water systems. The motor is connected by an insulated shaft to a small pump in the housing and the terminals carried through insulated bushings.

It is essential that the cooling system be such that the water passing through the tube and thereby charged with high tension current be safely conducted and disposed of; this prevents the use of direct connection to the city water mains as the high voltage would make it dangerous wherever the water might be conducted.

A method in use provides a reservoir of chemically pure water from which water can be drawn and passed through the tube, cool the anode and return. This reservoir has to be properly insulated and must be safe.

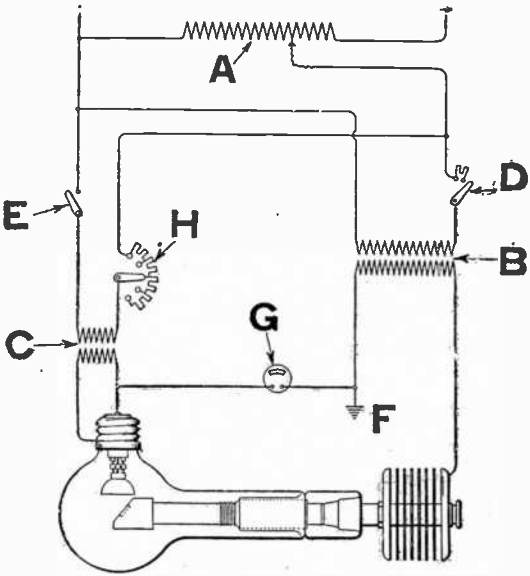


FIG. 8,989.—Coolidge wiring diagram of radiator, dental type tube circuit. *The parts are* A, auto transformer, 100 to 120 volts; B, X-ray transformer; C, filament transformer; D, X-ray switch with resistance; E, filament switch; F, ground connection; G, milli-ammeter; H, filament control.

Proper cooling of the reservoir keeps the water at the proper temperature. The apparatus is contained as shown in fig. 8,988 in a small grounded metallic tank.

Method of Tube Operation.—The widely different technique of various operators and the marked difference in equipment make it difficult to give, in this limited space, detailed suggestions that will be universally applicable.

On account of the tube characteristics, the voltage and current may be controlled independently of each other, making it possible to get practically any settings desired if the apparatus have sufficient range and flexibility.

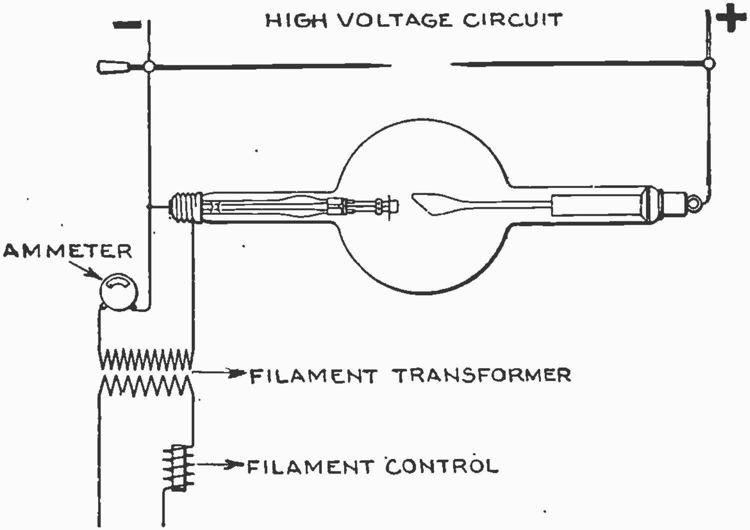


FIG. 8,990.—Coolidge wiring diagram of cathode circuit showing filament heating circuit where a transformer is used, and where control is obtained by the use of a variable inductance device placed in series with the primary coils of the filament transformer.

In order to save time, each outfit should be calibrated, making it possible to duplicate any given condition and thus avoid the necessity of wasting time and material in attempting to find the settings that will give satisfactory results for different parts of the body and different sizes of the individual.

By calibration is meant making readings on a volt meter connected across the transformer primary at the same time that the voltage across the tube is determined by means of a sphere gap. These readings, together with the auto-transformer settings and such other data as may be desired, should be recorded on a chart for ready reference as a guide for all X-ray work.

To measure the voltage across the tube with any degree of accuracy, a reliable sphere gap must be used in making a calibration or in checking up the tube voltage later.

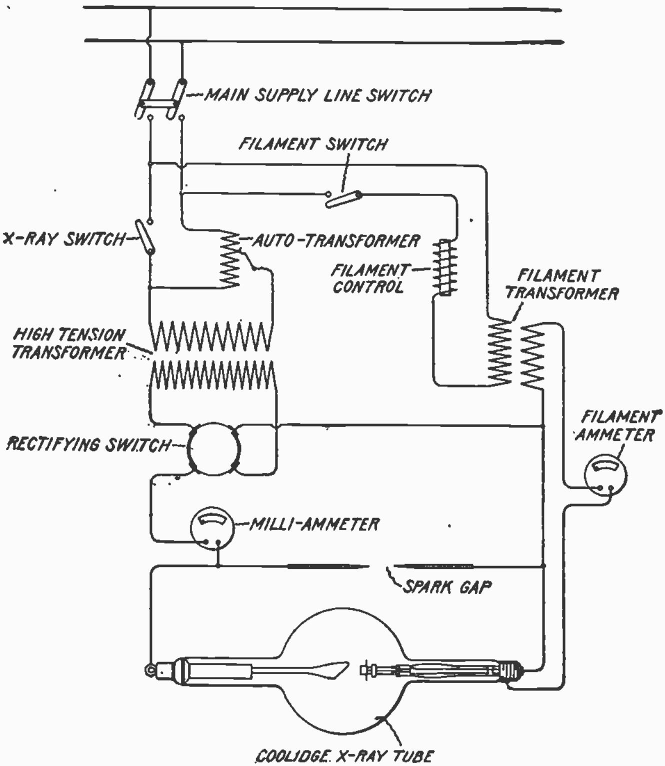


FIG. 8,991.—Coolidge wiring diagram of universal type tube on rectified current.

Because of its inaccuracy, the old time point spark gap should never be used.

To properly determine the useful kilo-voltage across a tube operating under self rectifying conditions, it is necessary to include in the circuit a Kenotron, which will serve as a check valve, cutting off the inverse and permitting only the useful to reach the gap. The drop across the Kenotron will be so small that it can be neglected in measurements of this character.

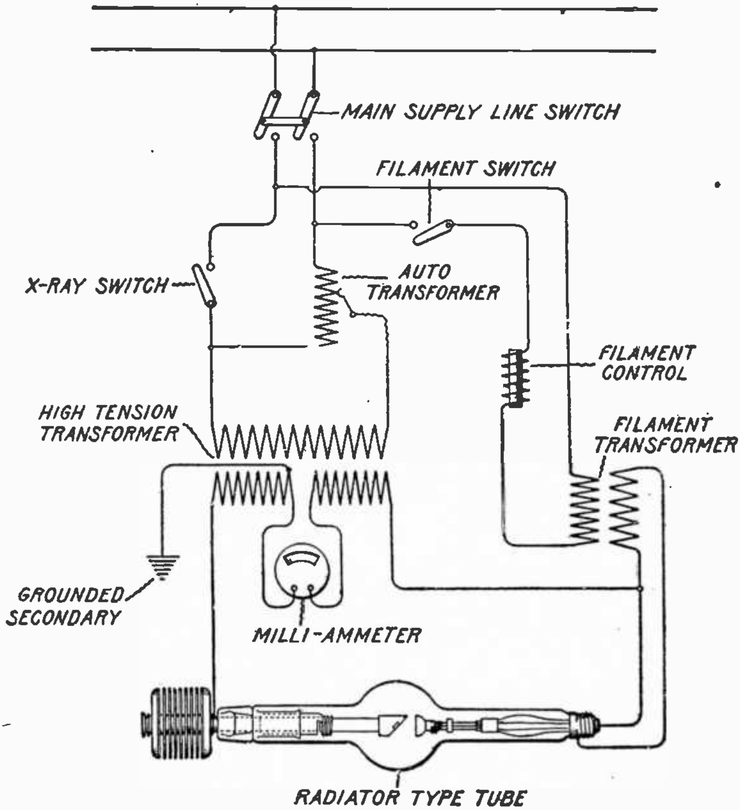


FIG. 8.992.—Coolidge wiring diagram of radiator type tube on unrectified current.

Capacity of Tubes.—The capacity of a tube refers to the amount of energy that a tube will safely carry and not to the voltage alone that it will stand. Energy may be considered as the product of the voltage across the tube (*r.m.s.* value) multiplied by the milli-amperage.

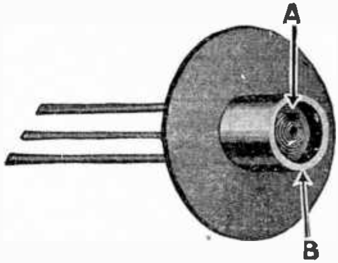


FIG. 8,993.—Cathode of Coolidge universal and therapy type tubes. ***It consists of*** a flat or slightly cone shaped spiral of tungsten wire **A**, mounted inside but close to the end of a metal tube **B**, to which it is electrically connected. The tungsten spiral or filament is heated from an external electrical circuit and becomes the source of cathode rays or electrons. The focusing depends largely on the shape of the spiral and its position in the metal tube.

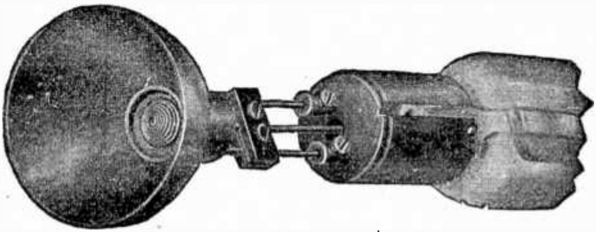


FIG. 8,994.—Cathode of Coolidge radiator type tube. The filament in the radiator type is similar to that in the universal type but, to assist in the focusing, a hemispherical metal cup is attached. By means of this construction a small focal spot with a relatively uniform distribution of energy is secured

The voltage across the tube is recorded and referred to as maximum or peak volts and the only practical accurate method of measuring it is by means of a reliable sphere gap.

When it is desired to determine the energy input into the tube by multiplying the voltage by the milli-amperage the peak voltage must first be converted into its *r.m.s.* value by dividing it by 1.41.

The allowable energy input is determined principally by:

1. Target material;

2. Area of the focal spot;

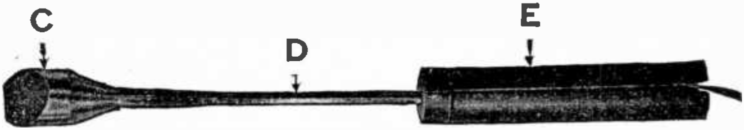


FIG. 8,995.—Anode of Coolidge universal and therapy (air cooled) type tubes. *It consists of* a solid piece of wrought tungsten C, attached to a wrought molybdenum stem D, which is in turn attached to a split metal tube E, for support in the glass bulb. Under certain normal operating conditions the anode may be run white hot without damage and the heat will be radiated through the vacuum and glass as rapidly as it is developed, after a certain temperature has been reached. The focal spots of some tubes will be seriously damaged if run this way; this is further explained under "Capacity of Tubes" on page 5,642.

FIG. 8,996.—Anode of Coolidge radiator type tube. *It consists of* a tungsten button, on to which has been cast, in a vacuum, a specially purified copper head which is then electrically welded to a long copper rod which extends out through the glass of the anode arm to a copper radiator. The important difference between the radiator type anode and the universal type is that the former conducts the greatest part of the heat imparted to it out to the radiator where it is dissipated into the air, making it possible to keep the focal spot and anode relatively cool as compared with the universal type anode.

3. Time during which energy is applied;

4. Temperature of the target at the beginning of the exposure;

5. Speed of dissipation of heat from the focal spot and tube.

The metal at the focal spot is wrought tungsten, which has a melting point of about 3,300° C.

Energy must never be applied in quantities sufficient to raise the focal spot to that temperature or the tube will be damaged. Approximately 99.8% of the energy applied to the focal spot is converted into heat, which means that the danger point may be reached in only a few seconds if much energy be used.

When the focal spot becomes brightly incandescent it is an indication of danger, and the current should be turned off immediately.

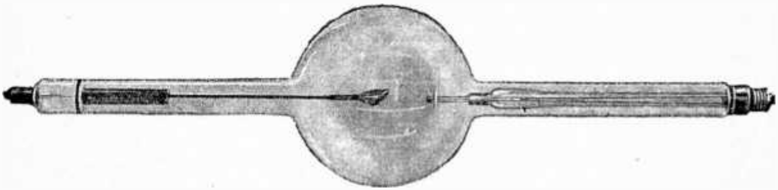


FIG. 8,997.—Coolidge ***air cooled deep therapy type tube.*** This tube is similar to the universal tube, but is larger and is designed to operate on rectified current at a voltage not exceeding 200 *kv.* maximum at 5 milli-amperes and 8 milli-amperes continuously un er proper cooling conditions.

In order that users may have a better idea of the limitations of tubes figures in the table page 5,645 are given, and it should be understood that these are the extreme safe limits when starting with cold targets. When targets are hot the limits are very much reduced.

For exposures or periods of operation longer than given in the table, there must be a time of rest to allow the heat to be conducted away from the target before continuing to operate the tube.

For instance, when a radiator tube is hot a safe maximum limit at 30 *m.a.* is 5 seconds on and 40 seconds off, unless longer periods to cool off are allowed.

Capacity of Tubes

Kind of Tube	Approx. Diam. Focal Spot	M. A.	K. V. Max.	Approx. Inches, Point Gap	Time
Therapy Water Cooled...	1″	30	200	....	Contin's.
Therapy Air Cooled.....	15/32″	5	200	14″	Contin's.
Therapy Air Cooled with Blower...............	15/32″	8	200	14″	Contin's.
Universal:					
Broad Focus..........	15/32″	5 80	140 100	10″ 6″	Contin's. 5 sec.
Medium Focus........	23/64″	50	100	6″	5 sec.
Fine Focus...........	9/32″	25 100	100 100	6″ 6″	10 sec. 1/10 sec.
Radiator:					
100 M. A.............	5/16″	100 350	84 50	5″ 2½″	8 sec. 1/10 sec
30 M. A.............	13/64″	30	84	5″	20 sec.
10 M. A.............	⅛″	10	84	5″	30 sec.
Dental, Right Angle.....	⅛″	10	56	3″	60 sec.

In the cases where 1/10 second is given as the maximum time limit, a reliable time switch must be used and the current determined by some other means than by the milli-ammeter; for if the current be left on long enough to get a dependable reading on the milli-ammeter, the tube will be damaged. This difficulty is entirely overcome by the use of a *stabilizer*, which makes it unnecessary to test the tube out to determine how much current is being used.

The 100 *m.a.* technique should not be attempted without proper preparation and a thorough understanding of the conditions, or the tube may be ruined.

Because of its greater heat capacity, it takes, with a given energy input, much longer to heat the radiator type of target

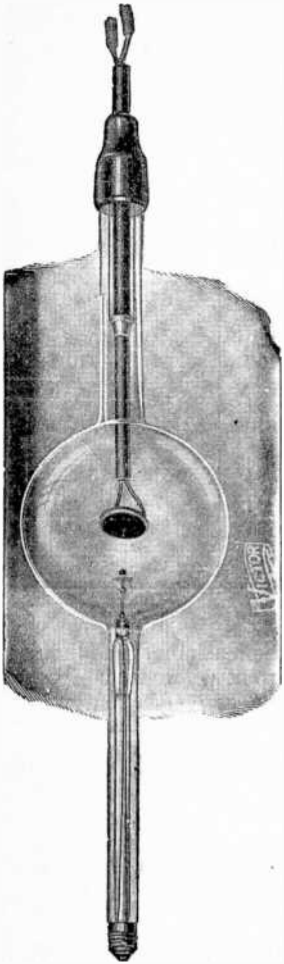


FIG. 8,998.—Coolidge *water cooled deep therapy type tube.* Except for the anode construction and mounting, this tube is very similar in appearance to the air cooled treatment tube and has similar characteristics. The anode is constructed to provide for the circulation of water immediately behind the focal spot to remove the heat as rapidly as it is generated, thereby making it possible to use much greater energy than heretofore.

to a given temperature than it does the solid tungsten target, but the latter may be heated to a much higher temperature than is permissible with copper on account of the great difference in melting points.

For radiographic work the important fact is that between exposures the radiator type target cools comparatively rapidly owing to the large stem and radiator. This condition makes it possible to apply for short periods a greater amount of energy to a given focal area than with the universal type tube.

There is, however, one very decided limitation that has not been sufficiently recognized by many users, namely, that it is very easy to apply energy much more rapidly than the heat can be conducted away through the copper and the danger point may be reached after only a few seconds of operation. This is particularly true in the case of 30 *m.a.* radiator type tubes, when the current is above 10 *m.a.*

Frequent exposures of but slightly more than 10 *m.a.* may in a short time cause a slight but progressive melting around the target, eventually greatly reducing the life of the tube.

When a radiator tube is operated without a mechanical rectifier the inverse voltage across the tube is always higher than the useful voltage, which means that the voltage representing the penetration of the X-rays cannot be measured by means of a spark gap unless a kenotron be used.

FIG. 8,999.—General Electric Victor hand timing switch for timing the exposure of radiographs. *In operation* the dial is set to the point on the scale indicating the desired number of seconds for the exposure, and upon pressing the button on the side of the handle, this time interval is automatically measured.

If high current be used on a small line or if much resistance be in the line circuit, the inverse voltage will be greatly increased, thus increasing the danger of puncturing the tube.

Focal Spot Pictures.—In case there be occasion to determine the size of the focal spot of a tube it may be done easily by making pinhole radiographs as follows:

Take a piece of sheet lead 1/16 or 1/8 of an inch thick and the size of the diaphragm or filter usually used in a tube stand. Make a conical depression in the center with a machinist's center punch or other suitable tool.

With a knife remove the small prominence produced in this way on the back of the lead sheet, and then with a pin or small drill open the hole to the desired size, about .02 in. in diameter.

If the hole be too large the focal spot picture will lack sharpness, and if it be too small the time of exposure will be needlessly long. Put the lead sheet and tube in place in the tube holder and lay the film on the table below.

The size of the focal spot picture may be varied by changing the distance. If it is to be the natural size the distance from the film to the pinhole should be equal to that from the pinhole to the focal spot.

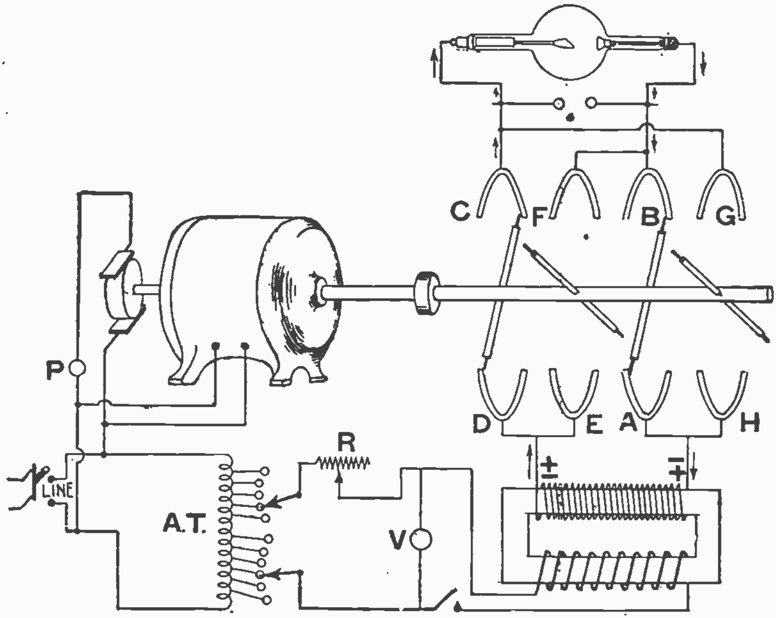


FIG. 9,000.—Snook rectifying switch and connections. *In construction*, the four cross arms are mounted on an insulating shaft and revolved by a synchronous motor especially designed for the purpose, and so constructed that it turns the shaft one-half revolution per cycle. Collecting shoes of opposite polarity are amply insulated with glass barriers, thus reducing the space occupied by the rectifier to a minimum. On the lower side of the switch two adjacent shoes **D** and **E**, are connected to one high tension terminal of the transformer; the other two adjacent shoes **A** and **H**, are connected to the other high tension terminal of the transformer. On the upper side of the switch, the two outside shoes **C** and **G**, are connected together and thence to one side of the tube, and the two inside shoes **F** and **B**, to the other side of the tube. At the instant depicted when the left hand terminal of the transformer is positive and the right hand terminal is negative the cross arms will be in such a position that connection is made between shoes **C** to **D**, and **B** to **A**, and the connection between shoes **F** to **D**, and **G** to **H**, is broken. At this instant the current may be said to flow from the left hand or positive terminal through shoes **D** and **C**, to the anode of the tube, thence through the tube, and back through the shoes **B** and **A**, to the right hand high tension terminal. One-half cycle later the polarity of the high tension transformer will have reversed so that the left hand side is negative and the right hand side is positive. During this time the rectifying switch will have turned one-quarter of a revolution so that the connection between shoes **C** and **D**, and between shoes **B** and **A**, is broken, and a connection established between shoes **F** and **E**, and shoes **G** and **H**. Now the current flows from the right hand or positive terminal of the transformer through **H** to **G**, and thence to the anode of the tube, then through the tube and back to the left hand or negative terminal of the transformer through **F** and **E**. Thus, regardless of the polarity of the high tension transformer the current will always flow through the tube in the same direction.

Tube Troubles and Their Detection.—The largest proportion of tube troubles is due to abuse or carelessness in operating tubes.

Among the troubles may be listed the following:

Puncturing.—This is due to excessively high voltage or surges, accumulation of dust, accumulation of moisture, reverse polarity, poor insulation, poor filament circuit, poor line on synchronous motor causing reverse polarity, and overloading.

Overloading.—This results in damaged target, damaged bulb, gassy tube and burned out filament.

Cracking of the glass.—Due to sudden chill when hot, excessive mechanical strains and excessive overloading.

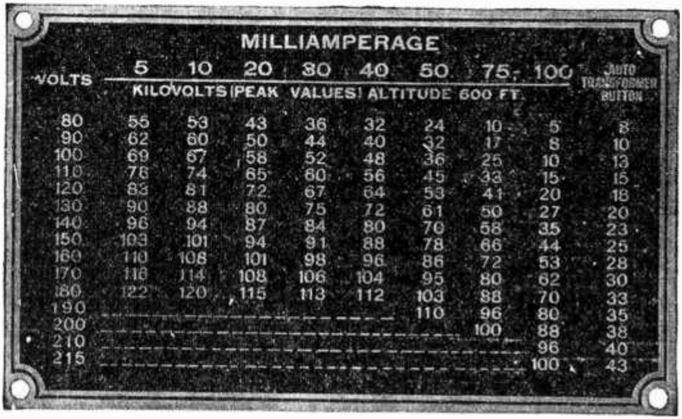
Points Relating to Tubes.—1. When excessively high energy inputs are employed or the current is on too long continuously, the tungsten at the focal spot melts, volatilizes and is deposited in a thin film over the active hemisphere of the tube, giving a mirror-like appearance. This film of tungsten exerts no appreciable filtering effect upon the X-rays, but it does disturb the electrical conditions within the tube and makes the tube much more subject to puncture and otherwise greatly reduces the life of the tube.

2. Glass is readily discolored by the action of the X-rays and different glasses discolor differently, depending upon the constituents of the glass itself. Some glass used for bulbs contains some manganese, which is responsible for the amethyst color of the glass, but this in no way affects the satisfactory operation of the tube. Some glass becomes a greenish color because of other constituents. The lead glass used in protective bowls colors brown when used for any length of time.

3. When tubes are new the glass may be slightly amethyst in color, and the target usually has a frosted area in the center of the face, due to the tube being operated up to a point that is just within the maximum limits of the tube during the exhaustion and testing processes. The frosted area is due to a crystallization of the tungsten at the high temperature and the size of it is not always an indication of the true size of the focal spot.

4. When a tube has become gassy it will not work steadily, and may show fluorescence of the glass and flashes of color in the bulb similar to small cloud effects. When a condition of this kind exists, it is not safe to operate the tube, as further damage may result, involving more expensive repairs. Such a tube should be returned to the factory for repairs. Fluorescence in the anode arm only, does not indicate anything wrong.

5. A punctured tube may at first behave like a gassy tube, but the green fluorescence of the glass which appears first will give way to a pink glow within the tube which changes in extent and intensity as air enters the bulb.



VOLTS	MILLIAMPERAGE 5	10	20	30	40	50	75	100	AUTO TRANSFORMER BUTTON
	KILOVOLTS (PEAK VALUES) ALTITUDE 600 FT.								
80	55	53	43	36	32	24	10	5	8
90	62	60	50	44	40	32	17	8	10
100	69	67	58	52	48	36	25	10	13
110	76	74	65	60	56	45	33	15	15
120	83	81	72	67	64	53	41	20	18
130	90	88	80	75	72	61	50	27	20
140	96	94	87	84	80	70	58	35	23
150	103	101	94	91	88	78	66	44	25
160	110	108	101	98	96	86	72	53	28
170	116	114	108	106	104	95	80	62	30
180	122	120	115	113	112	103	88	70	33
190						110	96	80	35
200							100	88	38
210								96	40
215								100	43

FIG. 9,001.—General Electric Victor milli-ammeter chart as on 220 volt *a.c.* outfits. It makes possible a complete calibration of the machine over its entire range, so that a reading of the pre-reading volt meter indicates the number of kilovolts obtained under any given auto-transformer setting and milli-amperage, replacing spark gap in diagnostic work.

If the filament be left on while much air enters the bulb, it will burn out quickly because hot tungsten oxidizes very rapidly in air, forming a white or bluish vapor or powder deposit on the metal parts. If the anode be bright hot when a puncture or crack occur, the whole inner surface of the bulb may be covered with white or brightly colored oxides of tungsten.

Deep Therapy Tubes.—In operating therapy tubes, both air and water cooled, much more care is necessary than with diagnostic tubes on account of the fact that they are run continuously for long periods of time at much higher voltages, and in the case of the air cooled tube, at almost the maximum limits of the glass and tungsten. A simple comparison of the energy input and time of active operation of the treatment and diagnostic tubes will help to illustrate the severe service expected from treatment tubes.

All treatment tubes are carefully seasoned, and if properly operated should give good service from the beginning.

Treatment tubes should always be started slowly and heated up gradually to avoid undue strains in the glass.

In starting a cold air cooled tube it should be run at about 150 to 175 *k.v.* and 5 *m.a.* for a few minutes before increasing the voltage to 200 *k.v.*

If a tube be forced too much or overheated there is danger of gas being liberated from the electrodes or glass, which will seriously interfere with proper operation of the tube.

The presence of gas is indicated by green fluoresence of the glass or a bluish cloud-like appearance in the bulb and when this occurs it is a sign of danger, and the tube should not be forced. Some green fluorescence in the anode stem only, is of no significance and may be disregarded. If only a small quantity of gas be present, it will often disappear if the tube be run at moderate voltage and gradually worked up, but if this do not help, it may be advisable to set the tube aside for a few days to allow the gas to be absorbed by the glass and electrodes.

If a tube has been abused to the extent that there is always considerable evidence of gas present, it may be best to return the tube to the factory rather than run the risk of puncturing it by trying to force it while in a gassy condition.

Minute quantities of gas in a tube, insufficient to cause fluorescence of the glass, may change the sound and appearance of the sparking on the rectifying switch.

They may also cause the milli-ammeter to operate erratically, and the circuit breaker to open occasionally.

There are other causes for unsteady operation of a tube which should always be carefully investigated before condemning the tube.

Some of these causes are:

1. Bad line conditions;

2. Fluctuating voltage or surges;

3. Insufficient spacing or insulation in the high tension system, allowing leakage and setting up an unbalanced condition.

The anode of the water cooled tube is intended to be operated cold and there should never be any visible heat at the focal spot. Do not confuse the light from the filament as heat on the anode. To properly cool the anode of the water cooled tube requires a continuous flow of 8 pints of water per minute. There is great danger of ruining the tube if it be operated without sufficient water.

Protection Against X-Ray Burns.—Lead being extremely opaque it is used as a shield for the X-rays and diagnostic rooms are lined with it. Leaded glass is used to cover the tubes and apertures provided for the admittance of the rays and for concentration on the object. The leaded glass is usually in the form of a bowl with two slots on which the tube rests. Another form is a lead glass shield which is clamped over the tube.

Fluorescing Screens.—Examination of objects, such as the bones of the hand, foreign bodies in the system, etc., are made with the aid of a *fluorescing screen* or *fluoroscope*, as shown in fig. 9,002.

If a hand, for instance, be placed between the screen and the tube, the X-rays will pass through the fleshy parts and impinging on the screen will cause it to fluoresce, but, being intercepted by the bones, will not affect the screen, thus leaving thereon a shadow picture of the bones as shown in fig. 9,003. It is immaterial whether the screen be placed in the holder box with the crystal coated, or opposite side turned to the eye aperture.

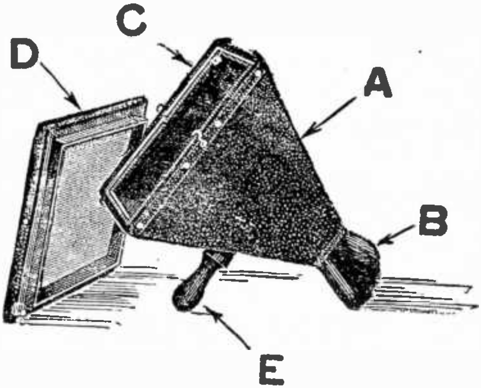


FIG. 9,002.—Fluoroscope. *It consists of* a light tight box **A**, provided with an aperture for the eyes at **B**, and an opening **C**, at the opposite end for the fluorescing screen **D**. The latter consists of a piece of paper or cardboard coated with platinum-barium cyanide crystals, which fluoresce under the action of X-rays. When such a screen is held against the face by means of the handle, and the aperture **B**, pressed tightly around the eyes so as to exclude all outside light, and the screen placed near an active X-ray tube, the former will fluoresce with a greenish yellow light.

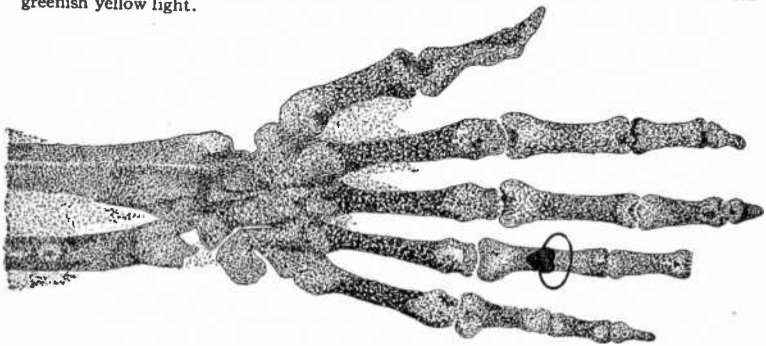


FIG. 9,003.—X-ray fluorescent shadow of the bones of the hand and wrist.

The intensity of the illumination produced by the fluorescence on the screen rapidly diminishes with the distance of the screen from the tube, therefore, in order to obtain a maximum illumination and consequently a sharply defined shadow, the screen should be held close as possible to the source of X-ray, and the hand close to the screen.

Radiographs.—A radiograph is *a picture taken upon a photographic plate by means of X-rays.*

In taking a radiograph replace the fluorescent screen of the fluoroscope by a suitable photographic plate, give it the proper exposure and develop as in photography.

The length of exposure will depend upon the character of the object radiographed, the quality of the X-ray tube, and the current strength employed.

TEST QUESTIONS

1. *What apparatus is necessary to produce X-rays?*
2. *Describe an X-ray tube.*
3. *Give method of heating the cathode filament.*
4. *What is a radiator type tube?*
5. *Describe the method of tube operation.*
6. *What is the capacity of a tube?*
7. *What are focal spot pictures?*
8. *Describe some tube troubles.*
9. *Give a few points relating to tubes.*
10. *Describe a deep therapy tube.*
11. *What precaution is taken against X-ray burns?*
12. *Describe a fluorescing screen.*

CHAPTER 233

Electro-Therapeutics

By definition, electro-therapeutics is *the treatment of disease by electricity*. Electricity is of special importance in the treatment of maladies. The high frequency currents in various modulations are used for heating, cutting, preparation of surfaces, examinations, etc.

Kinds of Currents Employed.—The various kinds of electric current for therapeutic uses are:

1. Direct;
2. Alternating.
    - *a*. Low frequency.
    - *b*. High frequency.
3. Low voltage;
4. High voltage;
5. Various combinations.

The special apparatus or physical therapeutic unit for the production of the numerous currents used is not the result of a few months seclusion of engineers in experimental pursuit of something "new" but represents the embodiment of accumulated thought, medical, electrical and mechanical, over a period of years.

Currents for Low Voltage Technique.—To illustrate the many kinds of current used, the following resumé of the *modalities* obtained from the McIntosh polysine generator is given. The apparatus delivers three distinct types of modalities:

1. Galvanic currents;
2. Sinusoidal currents;
3. Oscillatory currents.

The galvanic group, comprising Nos. 1, 2, 3, 4, 5, 6 and 7, constituting currents either with a definite polarity, such as Nos. 1 to 5; or currents which are derived from galvanic currents, such as Nos. 6 and 7, and which possess certain ionizing properties and produce a negative wave of considerable duration.

All of these currents produce a pronounced skin effect.

Currents of the alternating group, which comprise the rapid sinuoisdal, No. 16; the interrupted sinusoidal No. 13; rapid sinuoisdal wave No. 14, and the rapid sinusoidal wave sustained peak No. 15; all of which are obtained from the basic current, the rapid sinusoidal and none of which possesses any polar effect, although the negative impulse is 1-120th of a second in duration and produces a certain amount of skin effect.

These two groups of modalities have been supplied with older types of polysine generators and many clinicians have found distinct fields of use for certain types of these waves.

The group of modalities from Nos. 8 to 12 are obtained from the McIntosh penetrator and have different physiological effects from that obtained with any of the older type modalities.

The oscillatory current as delivered by this polysine is a current in which the polarity reverses suddenly and the positive and negative impulses have a duration of only 1-1,360th of a second each, with an equal interval of rest between each impulse. This short duration at which the current is of a negative value, eliminates all irritation which is caused by this pole.

The sudden rise and fall in voltage and the rapid reversal of the current produces the most powerful and deeply penetrating effects.

In extensive clinical applications, the oscillatory wave currents have proven the most desirable by the patients, and to be the most efficient in results.

1

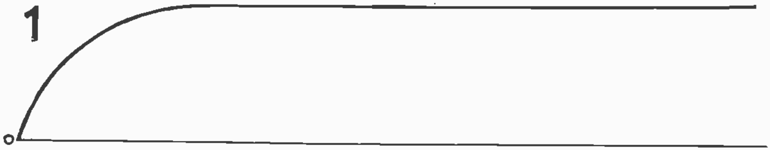


FIG. 9,004.—Galvanic current. It is obtained from a copper-oxide rectifier which changes the *a.c.* to *d.c.* The galvanic current then passes to a choke coil and condenser, known as the filter circuit, where all ripples or pulsations are removed or filtered out.

2

FIG. 9,005.—Interrupted galvanic. The motor and transformer switches must both be snapped on to obtain this modality, as well as the remainder, except Nos. 5 and 16. A special commutator affords a make and break in the current flow, which by means of a regulator may be timed for the proper duration.

The oscillatory wave current can be used whenever the rapid sinusoidal wave currents are indicated.

In the sections following are given the various modalities as produced with the McIntosh polysine generator, their uses, etc.

Galvanic Current.—This is a smooth and even current of the form shown in fig. 9,004. On account of its polar effects, the galvanic current is indicated in ionization, electrolysis, etc. The positive pole is acid, vaso-constrictor, sedative and hardens tissue. The negative pole is alkaline, vasodilator, irritating and softens tissue. In ionization, a simple rule to use is to consider what part of the solution it is desired to drive into the tissues, and put it on the pole corresponding to its own polarity.

Some authorities consider the galvanic to be the most useful current in physical therapy. It is also of great benefit in testing for nerve and muscle degeneration and in the successful treatment of same.

3

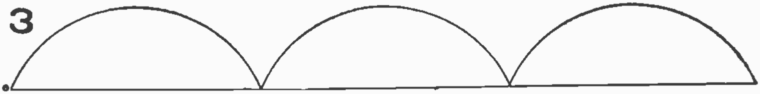


Fig. 9,006.—Galvanic wave. Five to forty-five pulsations per minute are available. The wave frequency regulator and the pilot light indicate the exact number of pulsations.

4

Fig. 9,007.—Galvanic wave sustained peak. 5 to 45 pulsations per minute. This galvanic current resembles No. 3, except that after the current leaves the zero line, it rises somewhat more abruptly to a peak. The current is maintained at the maximum for almost one-half phase and decreases to zero as abruptly as it rose from zero. Somewhat similar to the interrupted galvanic, except that it does not rise to the peak so abruptly and again there is no rest period between the waves.

Interrupted Galvanic.—Nearly all clinicians employ this current for testing for the reaction of degeneration, for if the muscle fail to respond, it means that a final diagnosis can be made. Its form is shown in fig. 9,005.

Galvanic Wave.—This current is of real value in treating various types of paralysis. This wave has practically the same sensation as the galvanic sinusoidal, but maintains its polarity or chemical properties. It is also of great value in treating adhesions with hard and indurated scars. See fig. 9,006.

Galvanic Wave Sustained Peak.—Its greatest value lies in intestinal atony with muscular degeneration. A very good wave current with full polarity effect. See fig. 9,007.

Combined Galvanic and Sinusoidal.—Many gynecologists employ this particular modality to great advantage in female G.U. pathology, for short seances, to avoid fatigue. Many uses will be found by the practicing physician, in view of its massage and chemical action. See fig. 9,008.

Super-Imposed Wave.—This current affords deep abdominal and pelvic contractions and hence is indicated in visceral or pelvic ptosis. Excellent results may be obtained by applying the current at the 7th and

5

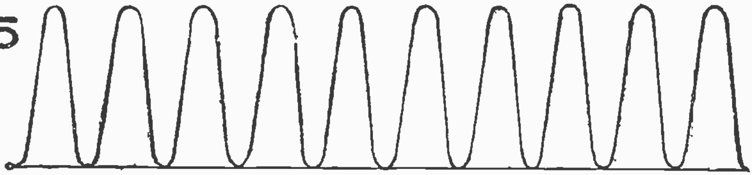


FIG. 9,008.—Combined galvanic and sinusoidal. This combines two valuable currents and gives the polarity effect of galvanism with the tonic effect of the rapid sinusoidal current.

6

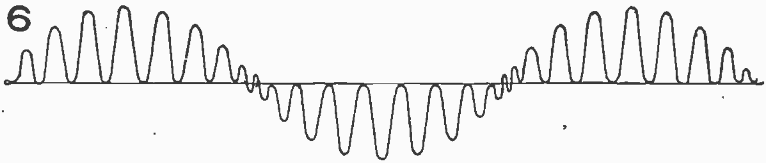


FIG. 9,009.—Super-imposed wave. 10 to 90 pulsations per minute. *It consists of* a compound wave formed by super-imposing a rapid sinusoidal on the galvanic current and retaining the valuable therapeutic properties of both.

8th dorsal vertebrae. Many clinicians precede this current with diathermy to aid in breaking up and absorbing deep adhesions. This modality is also valuable in treating flat foot, with one pad under each arch and each pad connected to one binding post of the polysine. See fig. 9,009.

Galvanic Sinusoidal.—Neiswanger recommends this for treating paralyzed muscles and terms it "practically a perfect imitation of the natural contractions that build muscular strength. It has a marked effect upon cellular metabolism and in building up secretory function, as for example: a prostate with poor secretion."

This modality was formerly widely used for the treatment of many gastro-intestinal conditions, but owing to the duration of the negative impulse, it produces considerable skin sensation, consequently it is being rapidly displaced by No. 8, pulsating galvanic sinusoidal, in which sensory effect to the skin is practically eliminated. C. F. Voyles in "Archives of Physical Therapy" recommends this modality as a mechanical exercise for atony of the colon and states that for stronger effect the rapid sinusoidal wave or super imposed wave may be substituted. He states that cases have been reported in which this treatment corrected incompetency of the ileo-cecal valve. See fig. 9,010.

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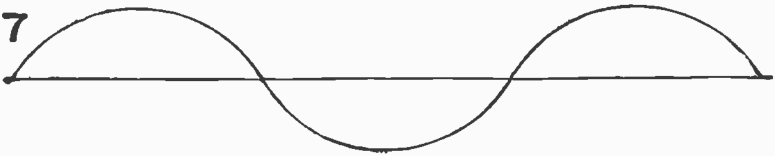

FIG. 9,010.—Galvanic sinusoidal. 10 to 90 pulsations per minute. This was formerly called the slow sinusoidal. It is an alternating galvanic current with slight polar effects and acts favorably on unstriated muscular tissues.

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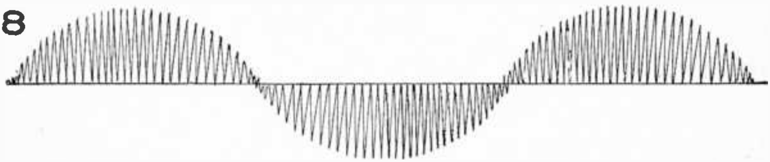

FIG. 9,011.—Pulsating galvanic sinusoidal. In this modality only one-half of each oscillation produced by the penetrator is employed, consequently the frequency of the voltage change is only one-half as great as with modality No. 9 (oscillatory wave); and the intensity of the impressed voltage is changed 170 times per second, while the peak voltage is on for only 1-1,360th of a second, with a rest period of 3-1,360ths of a second.

Pulsating Galvanic Sinusoidal.—The rapid pulsation of this current eliminates all possibility of irritation by chemical action on the skin, still causing greater nerve stimulation, so deeper penetration and greater action of muscle and various organs may be obtained with less current, each pulsation acting as a sudden interruption of the galvanic current.

The pulsating galvanic sinusoidal retains the characteristics of the slow change or reversal of polarity and will cause a contraction and then a distention at each reversal, this being controlled by wave controller to normal rate of contraction or muscular action of part of body being treated.

The pulsating galvanic sinusoidal is especially indicated in intestinal stasis, constipation and splanchnoptosis, as well as other conditions where deep massage is indicated. This current is rapidly replacing the galvanic sinusoidal and super-imposed wave currents. See fig. 9,011.

Oscillatory Wave.—Superimposing upon the oscillatory current a slow wave motion, the basic current is not altered, but the current pulsations can be synchronized to conform with the natural movement of the organs with the most energetic effects and a minimum or no irritation. This modality is now being employed for practically every condition for which No. 14 rapid sinusoidal wave has heretofore been used. See fig. 9,012.

FIG. 9,012.—Oscillatory wave. In this modality the polarity reverses 680 times per second. Every reversal is accompanied by a rest period of the same duration as that of current closure. In other words, the current is in a positive direction for 1-1,360th of a second; zero for 1-1,360th of a second; in a negative direction for 1-1,360th of a second and zero again for 1-1,360th of a second, when the same cycle of events begins again. This short duration, during which time the current is in a negative direction, reduces the usual irritation which is caused by this pole.

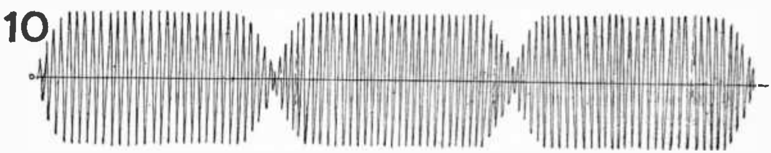

FIG. 9,013.—Oscillatory wave sustained peak. The curve shows the general form of the wave.

Oscillatory Wave Sustained Peak.—This form of wave gives a longer, stronger pull than either 6, 8, or 9 and is to be used after the case has made considerable progress and the muscles have attained more nearly their normal tone and contractibility. See fig. 9,013.

Interrupted Oscillatory Wave.—This type of current gives the same intense nerve stimulation as No. 2 (interrupted galvanic), without its sudden shock and skin irritation; therefore it is frequently of very definite use for starting a new case when pronounced stimulation and severe muscle contractions are not desired. See fig. 9,014.

Waveless Oscillatory Current.—Plank recommends that this modality be used at the end of each treatment for nerve stimulation, as it is waveless and gives a mild cell massage along the course of the nerve, thus increasing its blood-supply and nütrition. See fig. 9,015.

Interrupted Rapid Sinusoidal.—Neiswanger recommends it in nerve degeneration. Waggoner states, "If we split the rapid sinusoidal current

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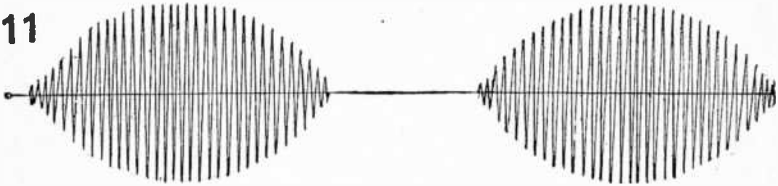

FIG. 9,014.—Interrupted oscillatory wave. This form of wave has the same frequency and duration of impulse as No. 9 (oscillatory wave), and will likewise be found to be free from skin effect.

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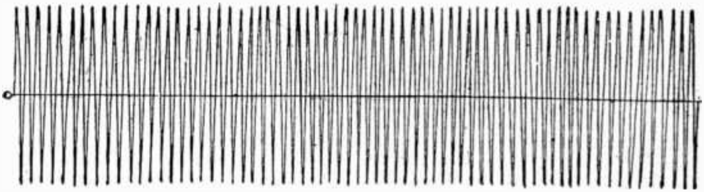

FIG. 9,015.—Waveless oscillatory current. This modality is somewhat comparable to No. 16 (rapid sinusoidal), excepting that it does not follow the sine wave form and its frequency is higher, while the duration of each impulse is the same as with No. 9 (oscillatory wave).

into segments with an interrupter, we have one of the finest currents for regeneration of nerve function." Eberhart writes: "It is a true tonic to the nerves and it is the best form of sinusoidal current we have for regenerating impaired nerve function." This current can be used in alternation with No. 12, after a few treatments, as it gives a much deeper cell massage, not only of nerve cells, but of muscle cells as well.

C. F. Voyles in "Archives of Physical Therapy" referring to splanchnic insufficiency states: "Such patients usually have ptosis. The blood pressure is usually low but is higher with the patient lying down. On rising the blood pressure falls and the pulse rate increases. Vertigo and air hunger are some of its symptoms.

Physical therapy is indicated and especially the interrupted rapid sinusoidal current. The abdominal muscles are contracted at the rate of 16 to 17 times per minute." See fig. 9,016.

Rapid Sinusoidal Wave.—It has been much used in breaking up adhesions and in the regeneration of impaired nerve function. Eberhart likens the "surge" to a string that cannot be broken by a steady pull, but is easily broken by a sudden jerk.

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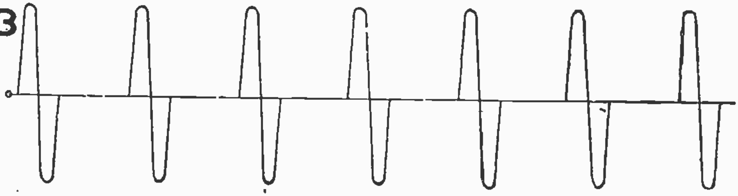

FIG. 9,016.—Interrupted rapid sinusoidal. 10 to 90 interruptions per minute. This current gives the same number of alternations as No. 16, but mechanical means are provided to interrupt the flow at definite time intervals. The period of rest prevents undue fatigue.

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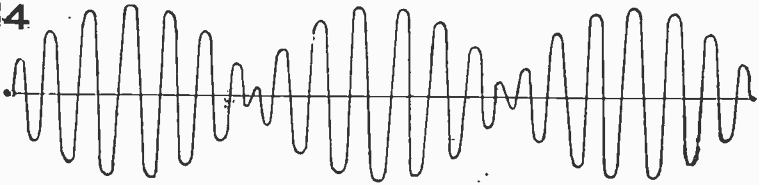


FIG. 9,017.—Rapid sinusoidal wave. This was formerly called the surging sinusoidal current. It is produced by sending the rapid sinusoidal through the rotor, which forms and controls the surge.

He first employs diathermy and follows with this current. However, on account of the skin sensation accompanying the application of this form of wave, clinicians are rapidly displacing it with the No. 9 (oscillatory wave) which possesses all of the virtues and none of the drawbacks of this type of current. See fig. 9,017.

Rapid Sinusoidal Wave Sustained Peak.—This current will satisfy the physician's need for a very strong push and pull effect, without polarity, for the combined tonic effect on nerves and muscles.

In cases of intestinal stasis and where prolapsed colon exists and a more powerful stimulant is required to stir up the sluggish musculature into action, this current can be relied upon. However, much better results may be obtained by employing No. 10 (oscillatory wave sustained peak), which embodies all of the good principles of this form of wave, with many additional refinements. See fig. 9,018.

Rapid Sinusoidal.—It may be safely used in hydrotherapy. In view of the fact that the direction of the current is constantly reversing polarity no chemical effects are obtained, but it is widely used for massage and promoting muscular tone. It acts favorably, due to its exercising effect, in removing the sequelæ of fibrositis, but for this purpose it should be given at a point just below that necessary to produce contractibility. Neiswanger prefers it in the treatment of peripheral nerve atonicity.

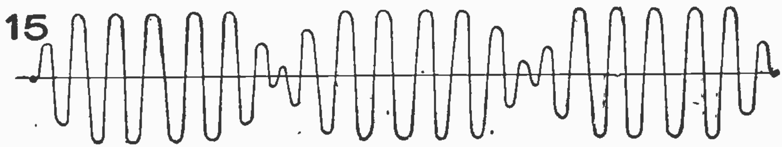


FIG. 9,018.—Rapid sinusoidal wave sustained peak. This current is the same as No. 14 (rapid sinusoidal wave), except the sustained peak effect.

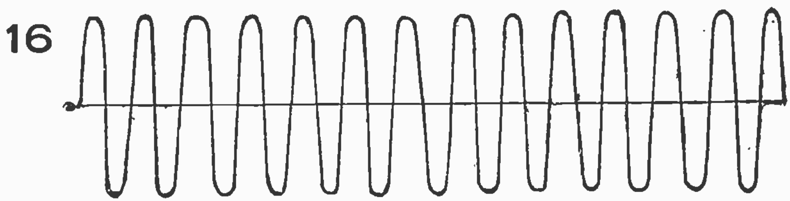


FIG. 9,019.—Rapid sinusoidal. 3,600 cycles per minute. This current is obtained from the ungrounded secondary of the transformer and hence is earth free.

Waggoner uses it for massaging adhesions and deposits. Mild treatments stimulate, but heavy dosages will produce sedation through inhibition. See fig. 9,019.

Caution. It is of the utmost importance when using Kantbern pads that these electrodes be thoroughly saturated with a sodium chloride or sodium bicarbonate solution before starting treatment.

Reasons for Oscillatory Wave Currents.—The effect produced by an electric current in stimulating the nerve of a living animal or producing an involuntary contraction of a muscle, was carefully studied by Professor Emil DuBois Reymond of

Berlin, as early as 1844. Professor DuBois Reymond found that these effects depended upon the following:

1. The strength of the current which was employed; and that the effects occur only when the current is turned on and when it is turned off, or when the electrodes first touch the nerve and when they are separated from it. Subsequent investigations further proved that in case of the human nerves only moderate currents would produce these effects; strong currents produced Tetanus.

2. The effects were dependent upon the rapidity with which the current used reached its maximum value; that is, the rapidity of change of current density.

3. The effects were dependent upon the sudden reversal of the polarity of the current used and that the more sudden the reversal took place, the more energetic would be the effect.

FIG. 9,020.—McIntosh new polysine generator. All polysine currents may be regulated to the finest gradations, for the physical and chemical properties of galvanism, the neuromuscular stimulating properties of wave currents or any modification of these.

Simple closures and completions of the circuit produced only a minimum effect.

The Term Pole in Medicine.—The term positive pole is applied to the circuit which leads from the current course to the receiver and the term negative pole is applied to the circuit which leads from the receiver to the current source. In medicine, the electrode where the current enters the patient is the positive pole and where the current leaves the patient is the negative pole.

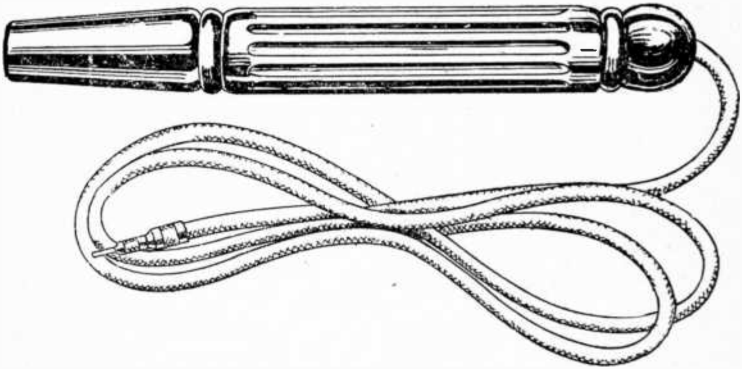


Fig. 9,021.—McIntosh high frequency handle made specially for use with the gallois, mercury vapor, quartz high frequency electrodes on the Tesla current, can also be utilized with the ordinary glass vacuum or non-vacuum electrodes.

Irritation Caused by Prolonged Negative Impulse.—The sinusoidal current, although free of polar effects, will according to Pflueger, cause irritability at the negative pole and in order to overcome the irritability, it follows that the reversals of polarity must take place according to Prof. Emil DuBois Reymond's findings and that the current is reversed not only suddenly, but the reversals must also take place a larger number of times in a given period.

The larger the number of reversals per minute, the shorter the time of irritability. This fact is fully demonstrated by the diathermy currents, where the reversal of polarity takes place many thousands or even millions of times per second.

Slowly Reversing Currents Cause Irritation.—In the well known *a.c.* which is supplied for domestic use, a reversal of polarity takes place. In the United States the 60 cycle current has become standard and it is probably for this reason that this type of current has been extensively employed in medicine under the term, "rapid sinusoidal current."

A 60 cycle current reverses in polarity 7,200 times per minute, this being fairly rapid. It has been found, however, to cause considerable irritation when used for therapeutic purposes.

Oscillatory Currents Explained.—In the oscillatory current as produced by modern wave generators, the polarity of the current reverses 40,800 times per minute. The current delivered by a wave generator whose frequency is 180 cycles, however, reverses in polarity only 21,600 times per minute.

Comparing these figures, it is found that the oscillatory current reverses its polarity 19,200 times more per minute than the 180 cycle rapid sinusoidal current, which shows an increase of over 50%, and not only that, the reversals of polarity take place 40,800 times per minute. The reversals are made suddenly.

In the construction of the McIntosh frequency converter, or penetrator, as it is called, a neutral contact point is provided between every active contact point; thus in one complete reversal of the current, which occupies a space of time of 1-340th of a second, there is a positive value of a duration of 1-1,360th of a second; a neutral point occupying a similar period of time; a negative value of the same duration and a neutral point of a similar extent.

Short Negative Impulse Reduces Irritation.—Reducing the time during which the current is negative, also reduces the time during which irritation may take place; and, therefore, the users of the oscillatory current report that this type of current produces the desired effect without irritation.

This type of current was considered the most efficient current by some of the pioneer investigators of the action of electric currents in therapeutics. The apparatus for the production of the oscillatory current was, however, a stumbling block and was only made possible by the combined effort of the modern electrical and mechanical engineers.

FIG. 9,022.—Erb's electrode. To be used with the faradic or rapid sinusoidal current to small muscles such as the eye, etc., and for testing for reaction of degeneration.

FIG. 9,023.—Dr. Sharpe's single copper nasal electrode for the treatment of catarrh with the positive pole of the galvanic current.

FIG. 9,024.—Copper tongue plate electrode, insulated, for the treatment of indolent ulcers and skin erosions by the application of the positive galvanic current, producing copper ionization.

Medical Diathermy.—The production of inductive heat within the body by means of a diathermy apparatus is now a generally accepted and highly useful physio-therapeutic agent.

To produce this effect, an apparatus is employed which produces high frequency oscillations, transforming the ordinary lighting current. The passing of such oscillations through the human tissue produces inductive heat.

This ability to generate heat or warmth within the tissues without shock in a definite measurable quantity, to any superficial area and to any required temperature makes diathermy technique of special importance and value to the progressive physician and surgeon.

Surgical Diathermy.—This is the process of applying heat in sufficient quantities at a concentrated point to cut or perform operations, bloodless operations, for the heat coagulates the tissues or blood.

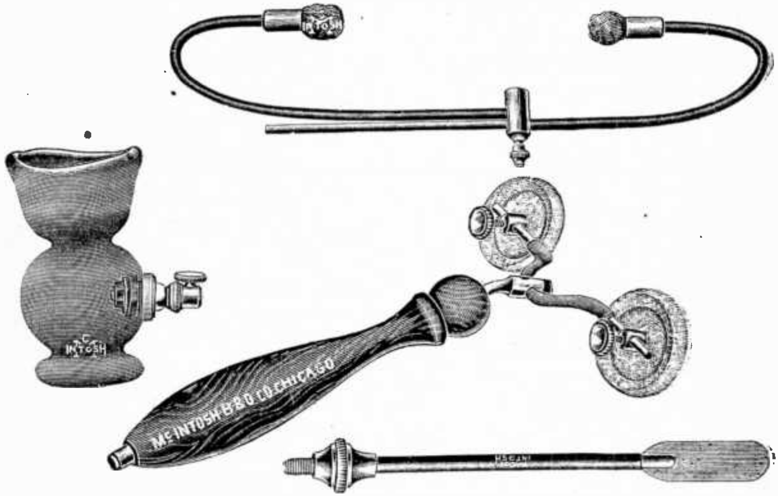


FIG. 9,025.—Ear electrode, double, insulated, with sponge tips. For use with the positive galvanic current for congestion and pain or with rapid or surging sinusoidal current for deafness.

FIG. 9,026.—Eye cup electrode. To be filled with cotton and the necessary medicated solution as conductor of the positive galvanic current for treatment of congestion.

FIG. 9,027.—Eye electrode, double sponge, with handle. For the application of the faradic or rapid sinusoidal current in treatment of atony of the muscles of the eye or for treatment with positive galvanic current for congestion.

FIG. 9,028.—Eye electrode, copper, small. For the treatment of trachoma with the positive galvanic current producing copper ionization.

NOTE.—*De Kraft* in his studies of the physical effects of diathermy on the body says that "congestion" wherever present, is relieved because of the marked activity of the internal circulation. Anemia of the splanchnic area ensues. Visceral congestion is relieved. The liver, the intestines and other organs within the abdominal cavity are made to disgorge the stagnant pools of blood which bathe their structure. When the action of the diathermic current has subsided and the blood stream returns again to its normal channels, freshly oxygenated arterial blood enters in great abundance into the previously anemic and (before the heating) venously congested areas. The parts are placed in a better state of defense against the invasion of toxins and bacterial colonies.

This differs from electric cautery where the needle or knife is heated and cuts by virtue of its heat, in that the needle or knife merely conveys current which heats the tissue and lays it open, at the same time sealing the blood channels.

It is important in all cases, that the operation of the electrical apparatus be thoroughly understood and directions closely followed.

Electrodes.—Good contact is very important, the metal must have a lesser resistance than the skin and must be so shaped that it will cover entirely and well the part desired to be covered. Block tin is used extensively as it can be cut and shaped to the curvature desired. A poor contact will cause sparking between the electrodes and skin and burn or injure the skin.

Vacuum and Non-Vacuum Glass Electrodes.—For surface treatments with the Tesla current, either vacuum or non-vacuum glass electrodes are used.

A vacuum glass electrode is really a modified condenser, in that the vacuum within the electrode acts as a plate or conductor of the current. and the glass as the dielectric. When brought in contact, patient's body surface acts as an additional plate.

A non-vacuum glass electrode is just as its name implies, instead of a vacuum being created, the inner side of the electrode is coated with a metallic substance, this substance acting as the plate and the glass as the dielectric.

The general action of vacuum or non-vacuum glass electrodes, when applied to body surfaces, is to produce heat with its sedative effect, when in actual contact with the skin and when a mild current is used.

Electro-Cautery.—By definition, electro-cautery is *cutting by a hot knife or electrode heated by electricity;* the current and therefore the temperature can be maintained as long as desired. This heating is done by a current being forced through a resistance wire sharpened to cut. The wire, the same as the filament in a lamp, is heated white hot. Fig. 9,029 illustrates the electro-cautery method of cutting.

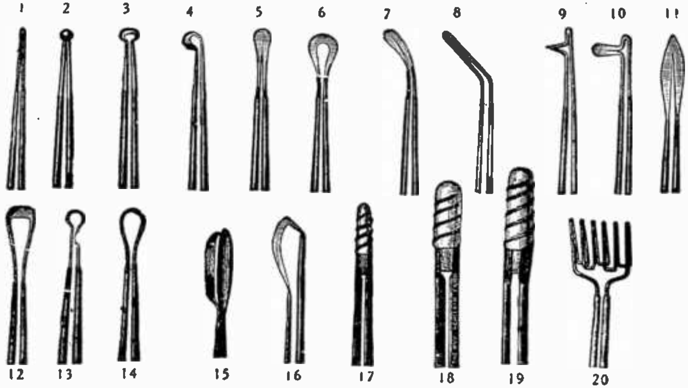
Electric Driven Saw for Bone Cutting.—Saws driven by electric motors are used for amputations; the speed of the saws

FIG. 9,029.—Kny-Scheerer electro-sector or electric cautery knife. The electro-sector, in the ordinary sense of the word, does not cut, but through an electrode, when the current is applied, it separates the tissue as readily as the sharpest scalpel with little or no resistance to the passage of the electrode. The seared surfaces of tissue present a thin layer of dehydration or electro-coagulation which sears the capillaries and prevents bleeding. The illustration shows an incision made with the electro-sector and the procedure of haemostasis without suture. This is accomplished by placing the operating tip securely against the forceps which coagulates the blood.

reducing physical shock and reducing the length of time required to be under the anesthetic.

The apparatus consists of a high speed motor. to which cutting edges can be attached.

Ultra Violet Therapy.—Formerly it was thought various cures were due to the heat rays of the sun. Later it was established that the principal curative factor in the treatment of rickets and surgical tuberculosis was essentially the ultra violet energy contained in the sunlight.



FIGS. 9,030 to 9,049.—Kny-Scheerer cautery burners showing the numerous types.

Many authorities claim that for the best results it is necessary to use both ultra violet and infra-red energy.

The rays of short wave length are known as ultra-violet. The rays of very long wave length are called infra-red.

The sun is composed of 57% infra-red rays, which are invisible to the eye, 42% of visible rays and 1 or 2% ultra-violet which are also invisible. The mercury quartz lamp yields 21% infra-red, 50% visible and 29% ultra-violet rays.

NOTE.—*Thermo-therapy.* The high degree of heat which hyperaemic treatment apparatus produces, results in an exceedingly active circulation in the parts treated, which brings about a reduction of pain and the disappearance of exudates, adhesions, stiffness, soreness, etc. Further, the growth of bacteria is stopped or retarded and effusions are absorbed and dissolved through increased circulation. This method of treatment has proven of therapeutic value in lumbago, sciatica, brachial and trigeminal neuralgia, varices and their sequalae, inflammation of the uterus, chronic exudates, thrombosis and diabetic and arterio sclerotic conditions of the lower extermities. With the apparatus now available treatments may be given to the hand, forearm, arm, shoulder, knee, foot, the entire leg, the back of the abdomen. It formerly was necessary to have a number of apparatus to administer in such a wide range of treatments.

Reports are indicative that infra-red used preceding ultra-violet irradiation, works out advantageously. The better results obtained are ascribed to the ability of the infra-red energy in increasing the amount of blood brought under the influence of the ultra-violet rays. Their effects in turn are thought to be carried to the deeper parts of the tissue, throughout the general circulation.

Divisions of Light Energy.—The spectrum of light or radiant energy received from the sun is divided into three general bands:

1. Invisible infra-red band;
2. Luminous band;
3. Ultra-violet band.

Ultra-Violet—The ultra-violet band begins at the end of the violet portion of the visible region, and is the so-called chemical band of radiant energy. It ends almost abruptly.

This region is associated with and capable of producing and inciting chemical reactions in a substance when the rays are absorbed. Its action is thought to be that of a catalyzer. It may be thought of relatively as dominantly chemical in action. Because of its power to excite chemic reaction, it has been called actinic.

White Light and Infra-Red.—The luminous or visible spectrum known as white light and employed extensively in clinical practice is now being rapidly replaced by the use of infra-red radiation.

The invisible infra-red region is to the left of the visible band which as Steinmetz says, "Carries to the earth all the heat and energy effects of the sun."

In this region are found the rays which are capable of producing and inducing heat in a substance when they are absorbed. It is true that infra-red rays represent a source of energy that may be converted into heat by absorption in a substance; although substances absorbing both infra-red and luminous rays may undergo a definite photo-chemical change, as recent studies infer that it seems certain that photo-chemical reactions can proceed in the infra-red region.

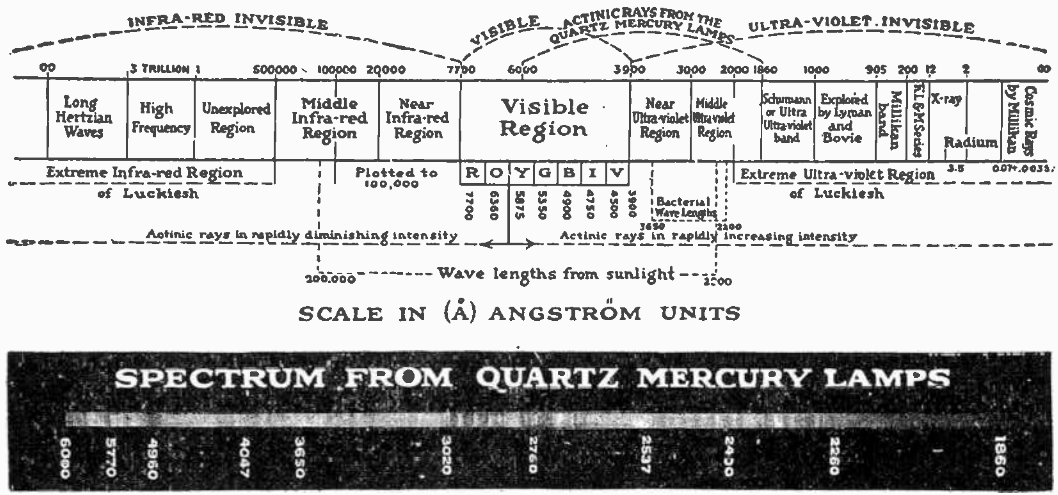


FIG. 9,050.—Diagrammatic spectrum analysis. The visible band of the spectrum is composed of the seven colors of the rainbow. The infra-red band of the spectrum is divided into three regions, near, middle and extreme. The extreme band extends over into the present well known radio or wireless waves which have been definitely demonstrated by Nichols and others, to be nothing more than light waves of great length, but not known to be part of the solar energy reaching the earth. The visible spectrum extends from about 3,600 A.U. to 8,000; and the infra-red spectrum extends from about 8,000 to the wave lengths discovered by Hertz and named after him. In the solar spectrum infra-red rays have been demonstrated up to and including 180,000 A.U. The ultra-violet spectrum extends from about 3,600 A.U. to 1,000 A.U. in artificial sources. In sunlight the ultra-violet spectrum ends almost abruptly at 2,900 A.U. Perhaps for this reason, shorter rays in artificial sources of radiation are termed abiotic, while the band simulating the solar spectrum is called biologic. The short rays exert a superficial destruction of the tissue, not penetrating deeply, in comparison to the stimulating effect of the longer relatively more penetrating biologic rays.

FIG. 9,051.—Mercury vapor in quartz. When an electric contact is made and current is passed through a quartz container retaining mercury in a vacuum, the mercury vaporizes forming a central stream of luminescence from which a supply of ultra-violet energy is emitted, richer than that contained in sunlight or in any other known source. The generative processes within the quartz envelope are accompanied with the evolution of much heat. By controlling the voltage with the rheostat on the ultra-violet generator, one is enabled to step up or step down the intensity of the energy, so that in the clinic the physiologic effects of the biologic or the abiotic wave lengths may be utilized.

Wave Length and Physiologic Antagonism.— One of the peculiarities of radiant light energy is that the longer wave lengths appear to be the physiologic antagonists of the shorter wave lengths.

It would seem that one could well represent solar radiation as a scale beam, one end being represented by ultra-violet radiation, the other end by infra-red radiation, and employing the visible spectrum as a fulcrum.

This is further demonstrated by the fact that if a certain phosphorescent body, such as Balmain's paint, be exposed for a few seconds to ultra-violet radiation, a beautiful and prolonged phosphorescence results.

Immediately upon subjecting the phosphorescent material to infra-red rays, the phosphorescence increases markedly for a fraction of a second and is then extinguished almost instantaneously.

In therapeutics the longer wave lengths are employed to correct pathology caused by the shorter wave lengths,

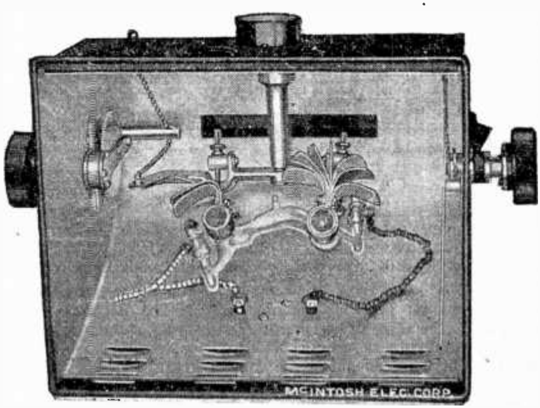


FIG. 9,052.—Hanovia burner of McIntosh alpine sun lamp.

as for instance, the treatment of radio-dermatitis by ultra-violet or infra-red irradiations.

Biologic Phosphorescence as a Guide to Treatment.—The sunburn or erythema produced by ultra-violet irradiation of the skin is thought of as a biologic phosphorescence; representing a mirrored reflection of internal reactions taking place.

Incidentally the frequency for the applications of ultra-violet energy is guided by the length of time an erythema lasts. When the erythema disappears the physiological actions induced by exposure to the energy are spent. The patient is then due for another treatment. In other words, the initial reaction is maintained.

Photo Chemical Reactions.—The term actinic rays has been erroneously bestowed on ultra-violet radiation. It is erroneous because actinic means having the power to excite chemic reactions, such as causing certain silver salts to darken. By using specially prepared silver emulsions it has been possible to photograph far over into the infra-red region.

All illuminants are more or less actinic. As the wave lengths become shorter their power to excite chemic reactions becomes greater and more pronounced and consequently more markedly apparent. Probably this is why ultra-violet radiation is sometimes termed actinic rays.

NOTE.—***Light wave length units.***—Light energy travels in wave form. There are three units used in the measurement of light wave lengths:

Unit	Symbol	Millimeters
Angstrom	A. U.	One ten millionth
Millimicron	Mu or uu	One millionth
Micron	u	One thousandth.

To convert millimicrons into Angstrom units multiply by 10; Angstrom units into millimicrons divide by 10. If a dime, which is about a millimeter in thickness, be divided equally into ten million parts, one part would approximate the size of an Angstrom unit. For brevity and simplicity the Angstrom unit is most generally used. The Greek letter Lambda (λ) is used to represent wave lengths, thus λ 2,900 represents 2,900 Angstrom units.

NOTE.—***The spectrum.*** Sir Isaac Newton placed a triangular glass in the sunlight, streaming through a small hole in a curtain, and saw the display usually known as the rainbow to which he gave the name of spectrum. Upon close examination, it was found to be chiefly composed of seven colors, namely, red, orange, yellow, green, blue, indigo and violet. In experimenting further, he found that he could place in these seven colors another prism and thus reconstruct and recondense the seven spectral bands into what is known as white light or the visible spectrum. This was certain proof that the radiant energy of the sun could be analyzed and broken up into definite bands.

Ultra-Violet a Stimulant.—Ultra-violet radiation bestows a rich coat of tan to the sun bather and pigments the patient receiving ultra-violet treatments. Dormant chemical processes in the body undergo a degree of stimulation following ultra-violet irradiation. One may mention the increased assimilation and fixation of calcium in the blood serum. Pigmentation of the skin is a photo-chemical reaction or photo-adaptation.

TEST QUESTIONS

1. *Define the term electro-therapeutics.*
2. *What kinds of current are used?*
3. *Name the current for low voltage technique.*
4. *Give the various modalities produced with generators.*
5. *State reasons for oscillatory wave currents.*
6. *Describe the term "pole in medicine."*
7. *What is the effect of prolonged negative impulse?*
8. *Do slowly reversing currents cause irritation?*
9. *Explain oscillatory currents.*
10. *What is the effect of short negative impulses?*
11. *What is medical diathermy?*
12. *Define surgical diathermy.*
13. *What are electrodes?*
14. *Describe vacuum and non-vacuum electrodes.*
15. *Define electro cautery.*
16. *How is bone cutting done?*

17. *Describe ultra-violet therapy.*
18. *What are the divisions of light energy?*
19. *Where does the ultra-violet band begin?*
20. *Describe white light and infra-red.*
21. *What is the effect of wave length?*
22. *What is the significance of biologic phosphorescence?*
23. *Describe photo-chemical reactions.*

CHAPTER 234

Resuscitation

General Points to be Observed.—The following suggestions should be carefully noted:

1. **Take Care of the Patient.**—An unconscious person becomes cold very rapidly, and chilling means a further strain on a vitality already weakened.

Experience has shown that the cold to which the victims of gassing, electric shock, or drowning are often carelessly exposed, is probably the most important cause of pneumonia, and this disease is the most dangerous after effect of all these accidents.

As far as possible keep the patient covered and warm both during and after resuscitation. Use hot pads, hot water bottles, hot bricks, radiant heaters or other similar means, but remember that an unconscious man has no way of telling when he is being burned. Do not permit the patient to exert himself. If it should be necessary to move him, keep him lying down.

2. **Medicines and Medical Help.**—Never give an unconscious man anything to drink. It may choke him. Medical science knows no drug which of itself will start the breathing in a patient whose breathing has ceased.

There is great danger of prematurely ceasing resuscitation. Breathing has been re-established after eight hours of resuscitation in cases of electric shock and of gas asphyxiation. Therefore, the ordinary and general tests for death should not be accepted, and any doctor should make several very careful examinations and be sure that specific evidence, such as the onset of rigor mortis, is present before the patient is pronounced dead and resuscitation is stopped.

Considering the widespread use of electricity for light, power, heat and many other purposes, it is almost surprising how few cases occur of serious electric shock from coming in contact with live wires.

However, when a case does occur, it often finds the witnesses as helpless as the victim because they don't know how to help him. Prompt help he needs and it can be easily given. Power plant engineers should be familiar with the subject because electricity is being used more and more in their plants.

In this chapter is given instructions for resuscitation from:

1. Electric shock;
2. Gas poisoning;
3. Drowning.

1. Prone Pressure Method for Resuscitation

Recommended by

National Electric Light Association

Follow These Instructions Even if Victim Appear Dead

I. Free the Victim from the Circuit Immediately

1. Quickly release the victim from the current, being very careful to avoid receiving a shock.

Use any dry insulator (rubber gloves, clothing, wood, rope, etc.) to move either the victim or the conductor. Beware of using metal or any moist material. If both of the victim's hands be grasping live conductors endeavor to free them one at a time. If necessary shut off current.

Begin at once to get the subject to breathe (resuscitation), for a moment of delay is serious. Use "Prone Pressure Method" for four (4) hours if necessary, or until a doctor has advised that rigor mortis has set in.

2. Open the nearest switch, if that be the quickest way to break the circuit.

3. If necessary to cut a live wire, use an ax or a hatchet with a dry wooden handle, turning your face away to protect it from electrical flash.

II. Attend Instantly to Victim's Breathing

1. As soon as the victim is clear of the live conductor, quickly feel with your finger in his mouth and throat and remove any foreign body (tobacco, false teeth, etc.).

If the mouth be tight shut, pay no attention to the above-mentioned instructions until later, but immediately begin resuscitation. The patient will breathe through his nose and after resuscitation has been carried on a short time, the jaws will probably relax, and any foreign substance in the mouth can then be removed. Do not stop to loosen the patient's clothing; ***every moment of delay is serious.***

2. Lay the patient on his belly, one arm extended directly overhead, the other arm bent at elbow and with the face resting

NOTE.—***Observe the Following Precautions:*** *a.* The victim's loose clothing, if dry, may be used to pull him away; do not touch the soles or heels of his shoes while he remains in contact—the nails are dangerous. If this be impossible, use rubber gloves, a dry coat, a dry rope, a dry stick or board, or any other ***dry insulator*** to move either the victim or the conductor, so as to break the electrical contact. *b.* If the bare skin of the victim must be touched by your hands, be sure to cover them with rubber gloves, mackintosh, rubber sheeting or dry cloth; or stand on a dry board or on some other dry insulating surface. If possible, use only *one* hand. If the man receive a shock while on a pole, first see that his belt is secure around the pole, if possible above cross arm so victim will not fall, then break the current. Pass a hand line under his arms, preferably through his body belt, securely knot it, and pass the end of the line over the first cross arm above the victim. If you be alone, pass the line once around this cross arm. If you be not alone, drop the line to those at the base of the pole. As soon as the rope is taut, free the victim's safety belt and spurs and descend the pole, guiding the victim. When the victim is about three feet from the ground, lower rapidly so that the victim's feet hit the ground hard.

on hand or forearm so that the nose and mouth are free for breathing, as in fig. 9,053.

3. Kneel, straddling the patient's hips, with the knees just below the patient's hip bones or opening of pants pockets.

Place the palms of the hands on the small of the back with fingers resting on the ribs, the little finger just touching the lowest rib, the thumb alongside of the fingers, the tips of the fingers just out of sight as in fig. 9,053.

4. With arms held straight, swing forward slowly so that the weight of your body is gradually brought to bear upon the subject, as in fig. 9.054.

FIG. 9,053.—Resuscitation from electrical shock by Prone pressure method. ***First Position.***

This operation, which should take from two to three seconds, *must not be violent*—internal organs may be injured. The lower part of the chest and also the abdomen are thus compressed, and air is forced out of the lungs, the diaphragm is kept in natural motion, other organs are massaged and the circulation of the blood accelerated.

5. Now *immediately* swing backward so as to completely remove the pressure, thus returning to the position shown in fig. 9,055.

Through their elasticity, the chest walls expand, and the pressure being removed the diaphragm descends, and the lungs are thus supplied with fresh air.

6. After two seconds swing forward again.

Thus repeat deliberately twelve to fifteen times a minute the double movement of compression and release—a complete respiration in four or five seconds. If a watch or a clock be not visible, follow the natural rate of your own deep breathing, the proper rate may be determined by counting—swinging forward with each expiration and backward with each inspiration.

7. As soon as this artificial respiration has been started and while it is being continued, an assistant should loosen any tight

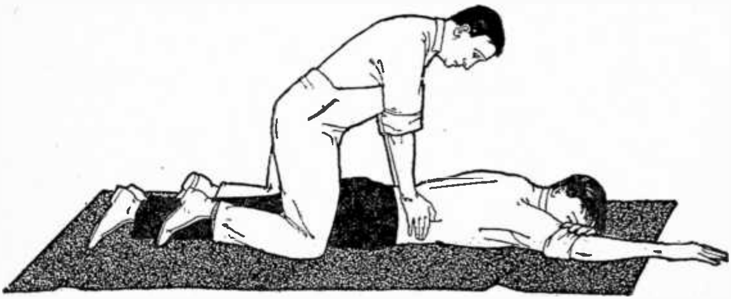


FIG. 9,054.—Resuscitation from electrical shock by Prone pressure method. *Second position.*

clothing about the patient's neck, chest or waist. (*Keep the patient warm.*)

Place ammonia near the nose, determining safe distance by first trying how near it may be held to your own. Then the assistant should hit the patient's shoe heels about twenty times with a stick, and repeat this operation about every five minutes, until breathing commences. Do not give any liquids whatever by mouth until the patient is fully conscious

8. Continue artificial respiration without interruption (if necessary for four hours) until natural breathing is restored.

Cases are on record of success after three and one-half hours of effort. The ordinary tests for death are not conclusive in cases of electric shock and doctors must be so advised by *you*, if necessary.

9. When the patient revives, he should be kept prone (lying down)—and not allowed to get up or be raised under any consideration unless on the advice of a doctor.

If the doctor has not arrived by the time the patient has revived, he should be given some stimulant, such as one teaspoonful of aromatic spirits of ammonia in a small glass of water, or a drink of hot ginger tea or coffee. The patient should then have any other injuries attended to and be kept warm, being placed in the most comfortable position.

FIG. 9,055.—Resuscitation from electrical shock by Prone pressure method. *Third position.*

10. Resuscitation should be carried on at the nearest possible point to where the patient received his injuries.

He should not be moved from this point until he is breathing normally of his own volition, and then moved only in a lying position. Should it be necessary, due to extreme weather conditions, etc., to move the patient before he is breathing normally, he should be kept in a prone position and placed upon a hard surface (door or shutter) or on the floor of a conveyance, resuscitation being carried on during the time that he is being moved.

11. A brief return of spontaneous respiration is not a certain indication for terminating the treatment.

Not infrequently, the patient, after a temporary recovery of respiration, stops breathing again. The patient must be watched, and if normal breathing stops, artificial respiration should be resumed at once.

III.—Send for a Doctor

If other persons be present when an accident occurs, send one of them for a doctor without a moment's delay.

If alone with the patient, do not neglect the immediate and continued resuscitation of the patient for at least one hour before calling a doctor to assist in further resuscitation efforts. A published up-to-date list of doctors posted by the company is recommended.

IV.—First Care of Burns

When natural respiration has been restored, burns, if serious, should be immediately attended to while waiting for the doctor to arrive.

A raw or blistered surface should be protected from the air. If clothing stick, do not peel it off—cut around it. The adherent cloth, or a dressing of cotton or other soft material applied to the burned surface, should be saturated with picric acid (.5 per cent). If this be not at hand, use a solution of baking soda (one teaspoonful to a pint of water), or the wound may be coated with a paste of flour and water, or it may be protected with vaseline, carron oil, olive oil, castor oil or machine oil, if clean. Cover the dressing with cotton gauze, lint, clean waste, clean handkerchief, or other soft cloth, held tightly in place by a bandage. The same coverings should be lightly bandaged over a dry, charred burn, but without wetting the burned region or applying oil to it. Do not open blisters.

2. Gas Poisoning and the Inhalation Treatment

1. What Carbon Monoxide Does

The reason that automobile exhaust gas, the gases from coal heating furnaces, the smoke from fires, producer gas, coke oven gas, blast furnace gas, carburetted water gas, coal gas and other manufactured gases are poisonous if actually breathed is that they all contain carbon monoxide.

When carbon monoxide is breathed it combines with the blood. The more carbon monoxide there is in the blood, the less oxygen the blood will hold.

The gas victim becomes asphyxiated just as if he were being gradually choked to death. As low as one-tenth of 1% of carbon monoxide, or even less, in the air will kill a man in time; 1% will kill in a few minutes.

If the patient do not die in the gas, but is removed to fresh air, the carbon monoxide leaves the blood in a few hours. The quicker it is breathed out of the blood, the better are the chances of recovery.

If the asphyxiation has not been too long or severe, and the first aid treatment has been prompt and correct, the patient will recover completely.

2. Protect Yourself

Do not breathe gas yourself even for a short time. If it do not overcome you, it will cut down your strength. If you have to go into gas to get a man out, remember that nobody is immune. Protect yourself.

A handkerchief tied about the nose and mouth is not a gas mask; many have died in the belief that it is. It does not stop carbon monoxide; it simply filters off the irritating fumes in smoke, but carbon monoxide itself does not irritate the throat and has no smell. It gives no warning. It often paralyzes the legs first, and so suddenly that the man even though conscious may fall down, and cannot walk or crawl.

If you must go into gas or smoke wear a mask equipped with an air hose, or an oxygen breathing apparatus.

3. Get the Man out of Gas

When a man is overcome by gas, the first thing to do is to get him into fresh air quickly.

Fresh air does not mean out of doors in cold weather. Many men have walked from a warm room containing gas to collapse in the cold outside air. Take the patient to a room free from gas and comfortably warm.

Be quick, but do not be unnecessarily rough. Remember you are dealing with a human being.

If the patient be not breathing or be breathing weakly, start artificial respiration at once and have someone else telephone the utility company for an inhalator to be used in conjunction with artificial respiration.

4. The use of Inhalation to drive Carbon Monoxide out of the Blood

In gas poisoning oxygen used properly helps to drive the carbon monoxide from the blood.

Sometimes the patients do not breathe well after they are brought out of the gas. In fact, some stop breathing entirely. Even those who breathe normally often cannot get the gas out of their blood fast enough to prevent their being very sick or even dying afterwards.

Pure oxygen does not stimulate the breathing.

For this reason it is recommended that a mixture of about 5% of carbon dioxide and 95% oxygen be used. The carbon dioxide content causes the patient to breathe much more deeply, and thus allows the oxygen to drive the carbon monoxide out of the blood very rapidly. The carbon dioxide also keeps the breathing from stopping. It starts breathing more quickly in those on whom it may be necessary to do artificial respiration.

It is useless to try to give an inhalation with a tank and funnel or any such makeshift. An approved inhalator, with its oxygen carbon dioxide tank and close fitting mask must be used.

It should be distinctly understood that the inhalator is an aid to resuscitation and does not take the place of the Prone Pressure Method. The two may be used simultaneously until the patient breathes without assistance after which the inhalation may be continued if necessary.

5. General Directions for giving the Inhalation Treatment

Without interrupting the rhythm of respiration, an assistant should put the mask over the patient's nose and mouth.

The lower part should go well down on the chin. Press down firmly over the nose. Try to prevent leaks.

As soon as the mask is properly applied, adjust the apparatus to give the patient an ample supply of the oxygen carbon dioxide mixture. In any case continue the inhalation for at least twenty minutes.

In severe cases the inhalation should be prolonged. In using the inhalation treatment, the patient should be kept in the prone position, and when treatment is prolonged a better chance for recovery is given if the head is six or eight inches lower than the feet. This position promotes the flow of blood to the heart.

6. Drowning

In a case of drowning favorable for resuscitation, breathing has ceased, but the heart beat and the circulation of the blood continue. Start artificial respiration at once. The pressure you must exert is the best means of forcing water out of the lungs and breathing passages.

If, during artificial respiration, the body can be placed on a door or other flat surface, so that the head and chest are 6 to 8 ins. lower then the feet, drainage of water from the air passages will be assisted and the circulation of the blood improved. Pay particular attention to maintaining warmth. The wet body chills rapidly.

Electric Shock

The Action of the Electric Current

In electric shock the current may pass through the breathing center at the base of the brain and cause this center to stop sending out the nervous impulses which act upon the muscles responsible for breathing. As a consequence, breathing stops abruptly.

If the shock has not been severe, after a time the breathing center recovers and resumes the vitally necessary duty of sending impulses to the muscles of breathing. In such cases the immediate use of the prone pressure method substitutes this artificial breathing for the natural respiration of the patient. As has been pointed out, the current may so paralyze the breathing center as to require 8 hrs. for recovery, and the prone method must be used unceasingly through this entire time.

Victims of electric shock of this sort are unconscious, but in them the heart and blood circulation continue. Their treatment demands artificial respiration with the greatest possible promptness. The method for giving this and the general points for the care of such patients have been given. In some cases the electric current affects the heart. Under these circumstances the heart suddenly ceases to pump blood. Many cases of electric shock escape this heart effect, and even an experienced examiner requires time to assure himself it has occurred. Consequently, it is the duty of those first reaching the shocked person to give artificial respiration by the prone method at once and to continue until natural breathing is restored or until the onset of rigor mortis.

FIG. 9,056.—Nature of high tension electricity.

TEST QUESTIONS

1. *What are the general points to be observed?*
2. *Describe in full prone pressure method of resuscitation.*
3. *What precautions should be observed?*
4. *What does carbon monoxide do?*
5. *What precautions should be taken in the presence of carbon monoxide?*
6. *How is carbon monoxide driven out of the blood?*
7. *Give general directions for giving the inhalation treatment.*
8. *What should be done in the case of drowning?*
9. *What precautions should be taken in the case of drowning?*
10. *What is the action of the electric current on the human body?*
11. *What happens if the shock has not been severe?*
12. *Are victims of electric shock rendered unconscious?*

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2

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3

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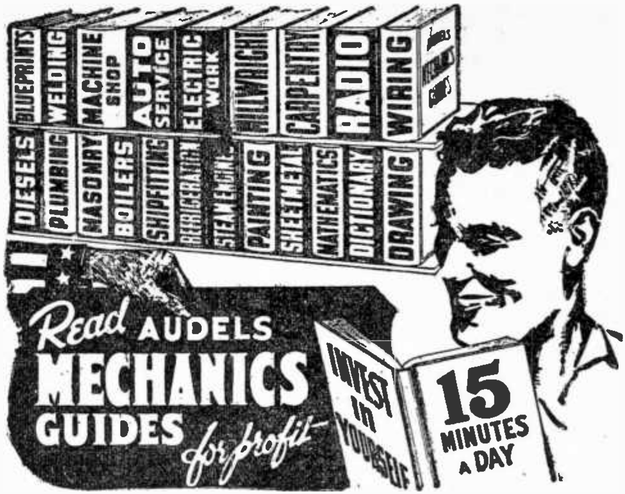

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