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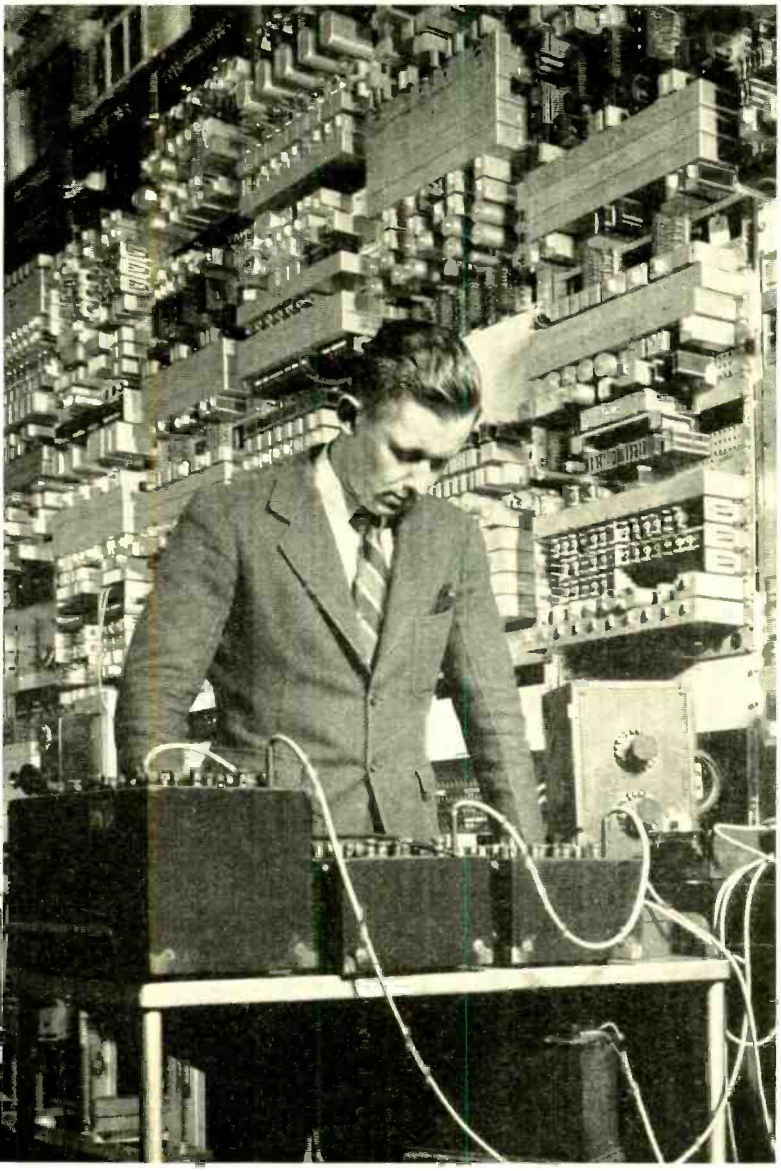

Range study of twenty-cycle ringing for toll-line circuits.

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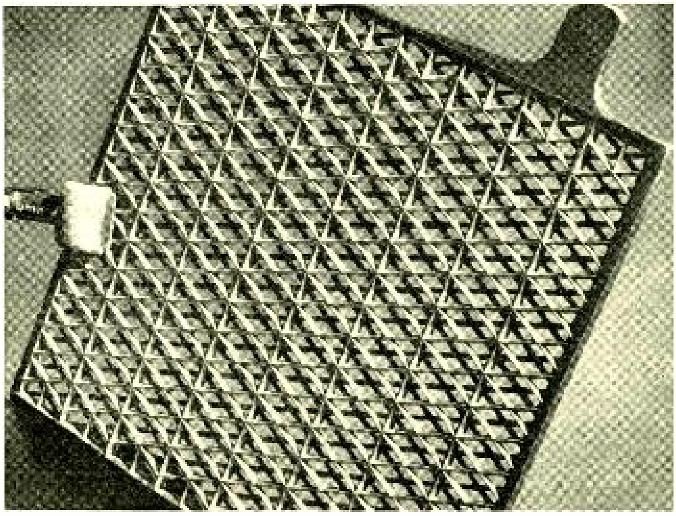

Batteries in the Telephone Plant

By H. L. MUELLER
Power Equipment Development

FROM its very first days, over sixty years ago, the telephone has used batteries for supplying current to be modulated by the speech waves. In more recent years, batteries have been employed to a much greater extent because of the steady increase in the use of relays, particularly since the adoption of dial switching, which employs relays or other electro-magnetic devices to perform practically all the switching operations. At the beginning, a variety of types of primary cells was employed to provide the necessary current, but within a comparatively few years the lead storage battery came into general use, not only because it permitted charging to replenish its energy, but because its low internal impedance gave better regulation and lessened the coupling between circuits operating in parallel from it. Since then, lead storage batteries have been used universally in telephone power plants, and although they are not manufactured by the Bell System, a great deal of research has been carried on by the Laboratories, and resulting modifications in the battery designs have been made by the manufacturers so as to provide the Bell System with batteries best suited to its needs.

The basic lead cell consists of two flat grids of strong lead alloy in the meshes of which is carried the active material: lead peroxide, PbO_2, on the positive, and spongy lead on the negative. These plates are immersed in a solution of sulphuric acid, H_2SO_4. On discharge, the active material of the positive plate is changed to lead sulphate, $PbSO_4$, and water is given off which dilutes the electrolyte. The spongy lead of the negative plate is also converted to lead sulphate. On charge, the active materials of the

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two plates are reconverted to their original form: lead peroxide on the positive plate and spongy lead on the negative plate.

A lead-antimony alloy has been used for the grids of both positive and negative plates, but the form of the plate and the manner of holding the active material have changed. The earlier positive plates were of the Manchester type, shown in Figure 1. The active material is made from corrugated strips of pure lead, rolled up into buttons as shown below the section of plate, and these buttons are forced into the holes of the grid. The corrugations on the strip permit the electrolyte to penetrate to all parts of the button, and thus provide a greater active surface. The negative plate was made up of two plates of square grid work backed with a thin sheet of perforated lead on one side. The active material, chiefly litharge, PbO, is spread into the rectangular grid spaces of each half of the plate, and the two halves are then fastened together. Such a plate is called a box negative; a section of one with a corner turned back is shown in Figure 2.

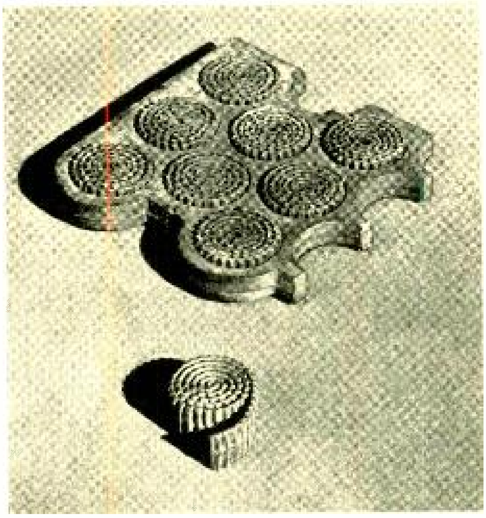

Fig. 1—Section of a Manchester positive plate with one of the lead buttons beneath it

Both positive and negative plates are put through a long electrolytic "forming" process to convert the lead buttons of the positives to lead peroxide, and the litharge of the negatives to spongy lead. After the plates are fully formed, they are assembled with thin wood separators between positive and negative plates, and this assembly is then put in a container to hold the electrolyte. The smaller sizes of cells were of the glass-jar type, while for the larger cells lead-lined wooden tanks were used as shown in Figure 3.

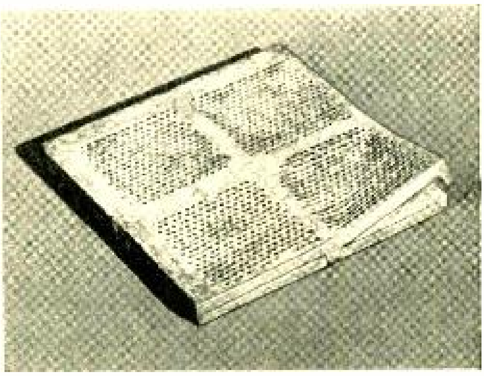

Fig. 2—Section of a box-type negative plate with one corner of facing turned back

Space is generally at a premium in a central office, and Bell System engineers are always looking for ways of securing greater capacity in smaller cells. One of the early changes in storage batteries, therefore, was the adoption of the pasted plate. Grids of this type may have narrow rectangular openings as shown in Figure 4, or diamond-shaped openings as in the illustration at the head of this article, and the active material, in the form of a paste, is filled in these openings. A combination principally of red lead, PbO_4, and litharge is used for the positive plate, and mainly litharge for the negative. These reduce to lead peroxide and spongy lead after forming, but the forming process is shorter than for Manchester positives and box negatives. At first the assembly of plates was tied together at the bottom by a rubber rod, and hung from a cover plate by the terminals. An early modification was the addition of thin slotted rubber envelopes slipped over the positive plates from each side to hold the active material in place. Wood separators were also used, but the softer condition of the active material on the positive plate needed added support to hold it in place during charge, when the evolved gases create a steady wash of electrolyte upward along the surface. These pasted plates permitted considerably larger capacity cells to be mounted in glass jars and charged at the factory.

A minor improvement made about this time was the addition of a cage containing colored pellets to give an indication of the state of charge of the battery. One pellet is white and one red, and their specific gravity is adjusted so that the white pellet sinks at approximately ⅓ discharge, and the red pellet, at ⅔ discharge. As the cell is recharged, the pellets float as the charge reaches the ⅓ and ⅔ state. These give easy indication to the maintenance force as to the approximate state of charge of the cells, and permit any pronounced irregularities to be readily seen.

During charge, and particularly toward the end of the charging period, oxygen gas is given off at the positive plate and hydrogen gas at

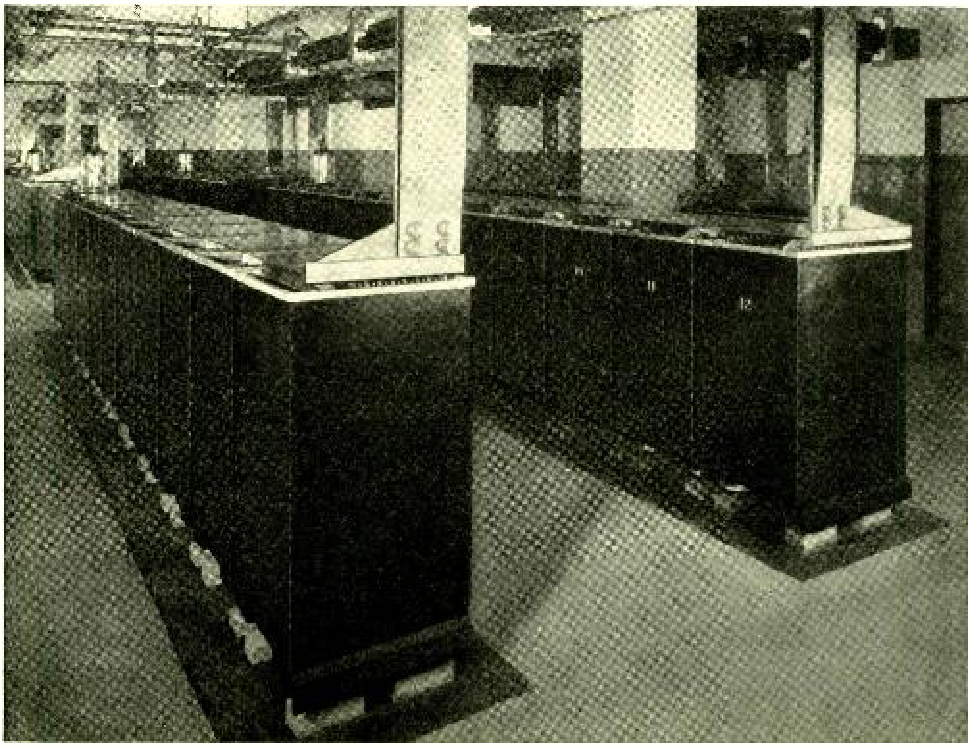

Fig. 3—An installation of lead-lined tanks, such as are used for the larger batteries

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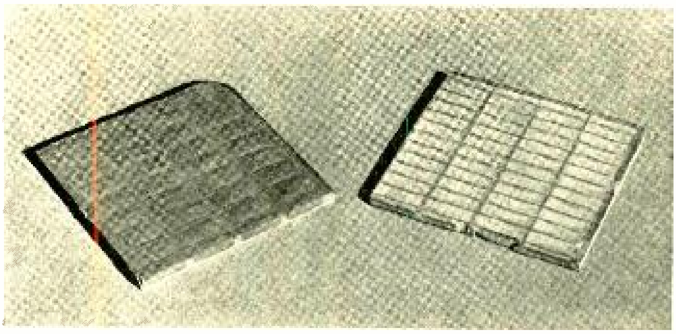

Fig. 4—Sections of negative and positive plates of the pasted type provided with narrow rectangular openings

the negative plate, and these two gases—or the hydrogen alone with the oxygen of the atmosphere—form an explosive mixture. In the open air around the cells, the quantity of hydrogen present is too small to be explosive, but with the new tightly closed glass jar it seemed worth while to take steps to avoid an explosion within a cell that might be caused by a small spark of static electricity, perhaps generated by the attendant in walking around the battery. To minimize this hazard, the combined funnel and vent plug shown in Figure 5 was developed. The lower end of this device is very close to the tops of the separators, and is therefore always immersed in the electrolyte. The gas, rising through the electrolyte, enters the space between the surface of the electrolyte and the cover, and escapes through vent holes just below a hard-rubber ring that deflects the gas outward away from the mouth of the funnel. If a spark should be formed as the attendant touches the top of the funnel to add water to the battery or measure the specific gravity of the solution, no explosion would occur because there is insufficient gas within the funnel to form an explosive mixture. Since the funnel tip is always immersed in the electrolyte and telephone batteries are grounded, the discharge is conducted to ground without a spark occurring within the cell.

Extended experience with batteries in the field indicated that better life could be secured if the group of plates could be more firmly held together. This need has been met in two ways by different manufacturers. One employs heavily reinforced outside negative plates held together by hard-rubber tie rods as shown in Figure 6. The other employs a strong moulded-glass jar, and the plates are held together by wedges between the jar and the outer negative plates. Glass jars of the blown type are not strong enough to withstand this

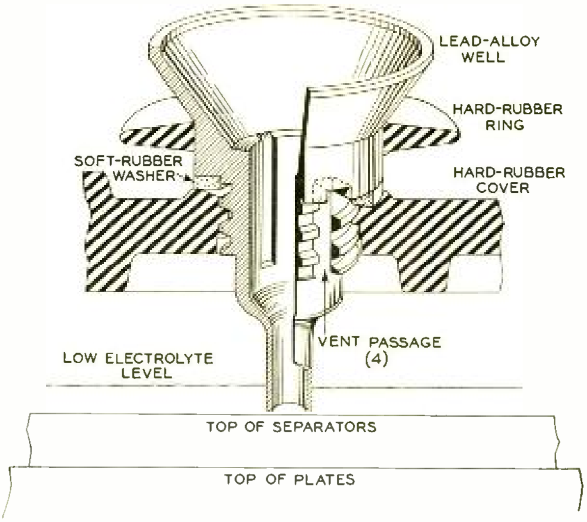

Fig. 5—Combined funnel and vent plug designed for sealed-glass storage cells

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wedging pressure, and for this reason moulded glass was used. Such a cell is shown in Figure 7.

In earlier practice, the batteries were operated on a charge and discharge basis; they were usually charged during the day, and allowed to partially discharge at night. Under these conditions the life of the battery is usually determined by the washing away of the active material from the positive plate. In more recent years, however, the practice has been to "float" the batteries. A generator, with accurately regulated voltage, is connected across the battery all the time. It directly supplies all the normal office load, and a small trickle charge into the battery to replace internal losses so as to maintain it at full charge all the time. Only in case of failure of the commercial power supply does the battery carry the load. Since it is during the periods of charging that the active material of the positive plate is washed away, "floating" operation results in a longer life for the battery. With floating, failure generally results from a gradual wasting away of the grid structure of the plate. It was obvious, therefore, that longer life could be secured by making a heavier grid structure, and a line of batteries having thick-plate grids was developed. The use of these thick-plate grids increased the life of the batteries about forty per cent. One of these thicker positive grids is shown beside a thinner one in Figure 9.

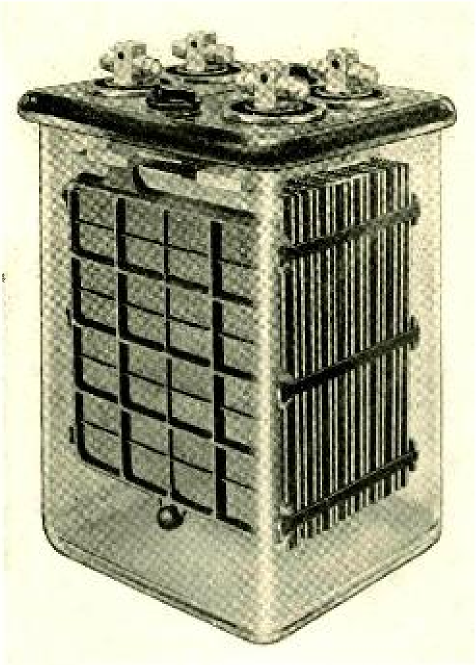

Fig. 6—One recent sealed-jar cell uses reinforced outer negative plates held together by hard-rubber tie rods

The limiting factor in the size of glass-jar batteries is the strength of the glass container. Larger batteries have used lead-lined wooden tanks, which required that the plates be assembled in the central office, and this requires a lot of additional work

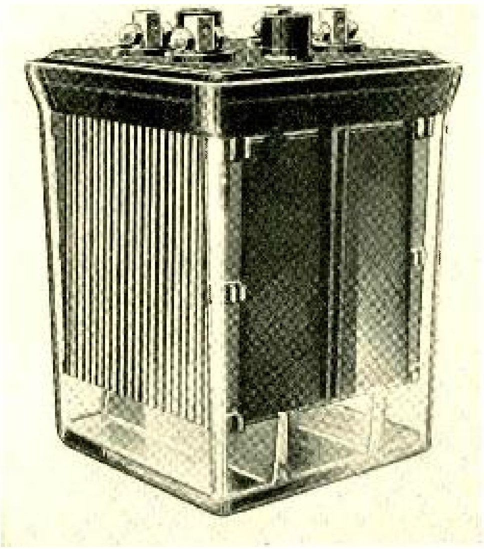

Fig. 7—Another type of cell uses reinforced outside negative plates that are wedged in a moulded-glass jar

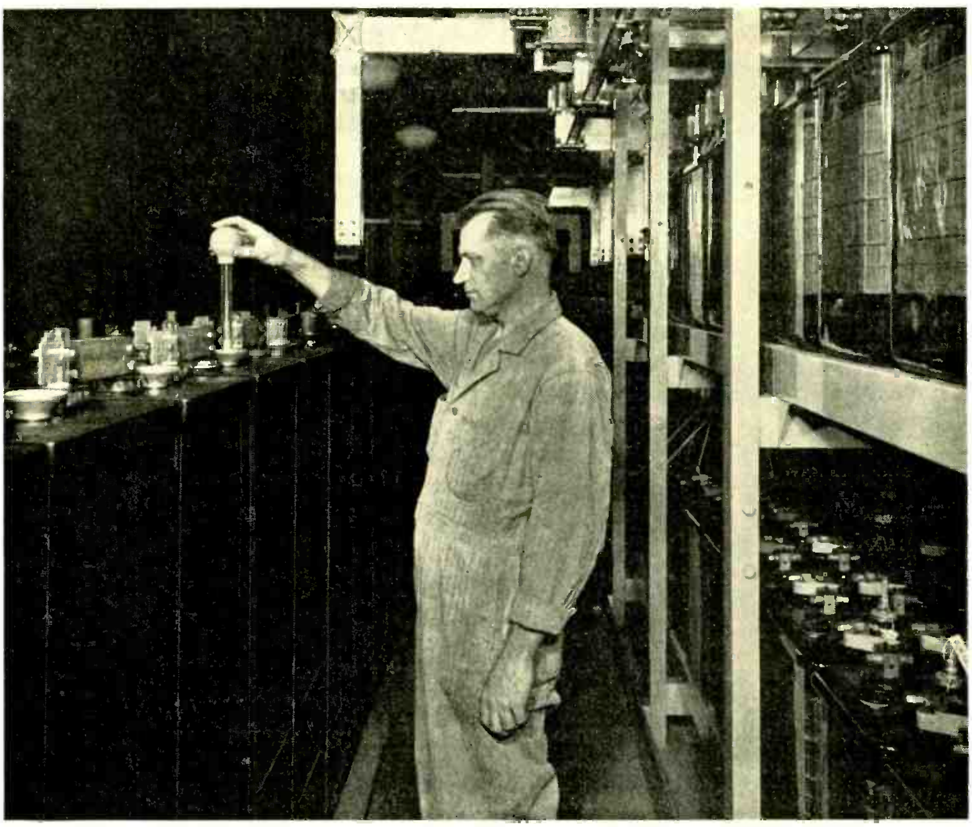

Fig. 8—An installation of new hard-rubber tanks for large-capacity plants

and charging before the battery is ready for service. A recent change that permits the use of larger capacities in factory-assembled cells is the adoption of hard-rubber tanks as shown in Figure 8. These have a sealed rubber cover and thus permit larger sizes with factory assembly. Sealed rubber jars are also being used for the smaller cells that have previously used glass jars. With rubber cells, both in the smaller and larger sizes, two methods are employed—each by a different manufacturer—to secure freedom from explosions. In one, a rubber hood is placed over the plates just above the separators, and a vent is carried from the highest, or central, part of it through the cover and up a few inches above it to carry away the gas that collects. All the gas rising from the electrolyte is gathered by this hood and conducted to the air and thus none collects between the hood and the sealed cover. Should an explosion occur, it would be only of the small amount of gas in the vent, and would result merely in a small "pop." The other method employs a perforated rubber baffle over the top of the plates, and the space between the baffle and the sealed top is filled with smooth glass crystals. A vent pipe is carried through the top of the cell to allow the gas to escape, while a filling funnel runs down through the perforated baffle to the top of the separators. The function of the glass crystals is to cool the gas, if it should

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be ignited, below the burning temperature. Both methods have been found to reduce explosions to harmless "pops."

Since these rubber cells are not transparent, they are provided with "level indicators" to indicate the height of the electrolyte. These are small floats contained in tubes running through the cover and down to the separators.

One of the promising recent developments in batteries is the lead-calcium plate, already described in the RECORD.* The antimony in the previous plates tended to leach out and thus weaken the grid structure, which has affected the life of the cells, particularly under "float" operation. Calcium is free from both of these objections, and field and laboratory tests are now being made to ascertain the performance of the lead-calcium cells under the usual "floating" operations.

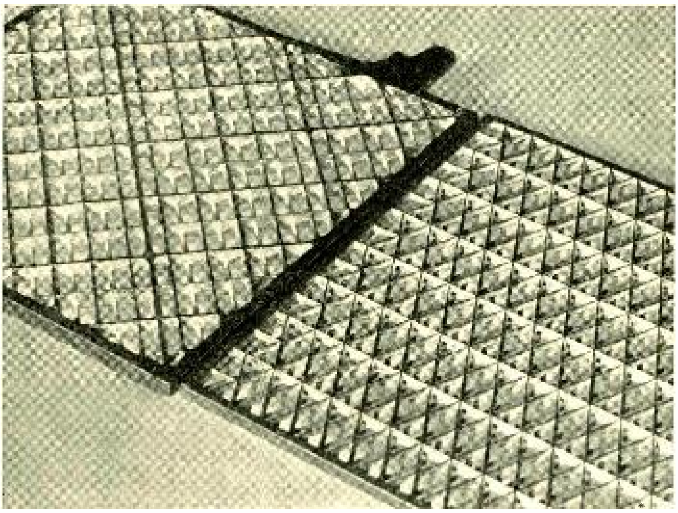

Fig. 9—The new positive grids for floating service, shown at the left, are thicker and have heavier cross-members

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*RECORD, *September*, 1937, *p.* 12.

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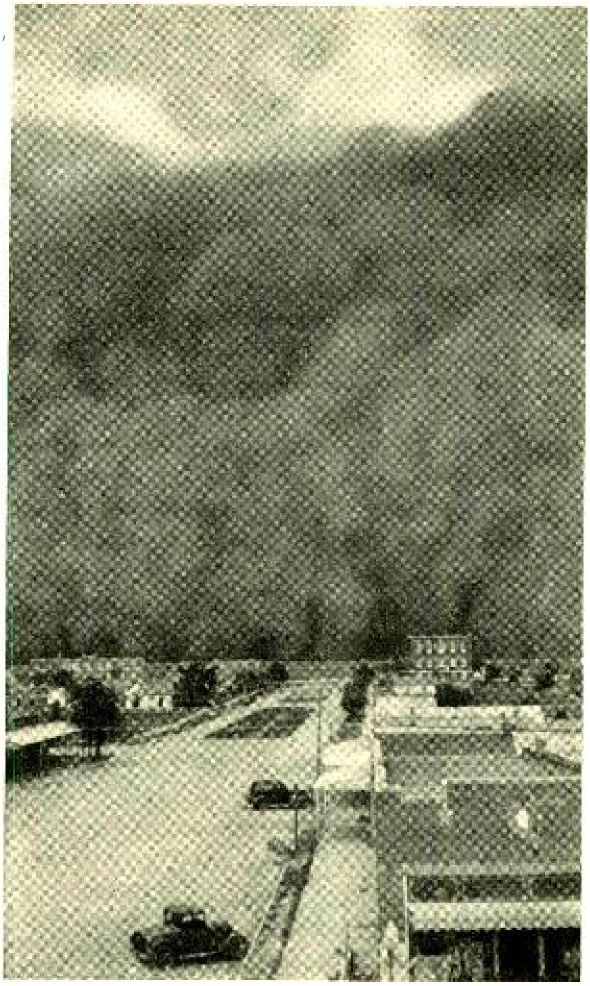
Dust-Storm Static

By M. T. DOW
Transmission Engineering



WHEN dense clouds of wind-blown dust blanket a dust bowl, electrical phenomena occur which are often of a surprising nature. Press reports in the wake of these storms have described such effects as corona on radio antenna lead-ins and fences, failure of automobile ignition systems, interference with airplane communications, flashovers on power systems at insulators and lightning arrestors, and even the electrocution of wheat in the fields. These phenomena are of direct concern also to communication companies and the possibility of their occurrence must be taken into consideration in the design of open-wire telephone circuits. If appropriate preventive measures are not provided, severe noise disturbances may be caused on important circuits during dust storms. These disturbances cover a broad frequency band and may affect both voice-frequency and carrier-frequency circuits. In regions where these storms occur frequently, "dust static" may be a more important consideration in determining maximum repeater spacings for open-wire telephone systems than the more usual atmospheric disturbances that are the result of lightning.

No theory has as yet been evolved which explains satisfactorily the mechanism responsible for "dust static." It seems evident, however, that the flying dust particles become electrically charged by friction with one another, the air, and other surface materials of the earth and it is known that their presence greatly increases the potential gradient of the atmosphere. Evidence obtained from field tests and theoretical studies indicate that the noise-producing mechanism is an electrical discharge from the

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The photograph above is reproduced through the courtesy of the Oklahoma Publishing Company.

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wites to the atmosphere which takes place as the electrified dust particles enter the region of high potential gradient immediately surrounding the line conductors.

The noise produced in telephone circuits by a dust storm is characterized by a hissing sound which builds up gradually in intensity as the severity of the storm increases. In the absence of lightning the noise eventually reaches a more or less steady level which may persist for hours. The hissing noise is accompanied by a rise in potential to ground of the line wires and the intensity of the noise correlates with the latter to some extent. Tests have shown, however, that the noise persists even though the line conductors are at ground potential. Noise has been found to be lower, by as much as 10 to 20 db, on pairs which occupy inner pin positions than on those located at the outer ends of a crossarm.

Fig. 1—Voltage recorder with which studies of dust-storm static are made. Miss E. M. Rentrop is operating the apparatus

When the effects of lightning are superimposed on those of dust static, variations in the noise and the voltage or current to ground become very rapid and erratic. Sometimes after a gradual build-up the noise increases suddenly 20 to 30 db and then gradually decreases. At other times, after a particular magnitude has been reached through gradual increases of the disturbances, a sudden drop occurs, sometimes to zero.

It is important in regions where these disturbances occur that a direct-current path be provided from line wires to ground. Without such a path the high potential set up on the conductors may cause intermittent breaking down of the line protectors and superimpose a popping noise on the relatively steady hissing sound. Under severe conditions the charges on the wires may build up rapidly enough to cause protector breakdowns at the rate of 300 times per minute. If the line protectors were removed, the potential to ground might reach surprising proportions. In one such test it built up to 15,000 volts, at which value flashover occurred across the gap between the terminal of the line and the ground bus. These high-potential discharges are not dangerous, however, because the power that is dissipated is very small.

When a direct-current path is provided as much as several milliamperes may flow continuously from the line wires to ground. Tests have shown that the magnitude of this current is more or less independent of the resistance of the drainage circuit over

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a range from 0 to 100,000 ohms, which indicates that the discharge source is of very high internal impedance.

Snow and sleet storms may also cause noise in telephone circuits which is generally similar in character to that observed during dust storms. The term "precipitation static" is used to identify both types of noise.

Field tests of the effects of precipitation static have been carried out by the Laboratories in several locations in connection with the development of the new open-wire carrier systems. A number of tests were made on the Fourth Transcontinental Line and on the lines between Trinidad and Amarillo, which traverse a region that is probably the most severely affected by storms of this type.

The field tests indicate that satisfactory drainage paths to ground, which are needed to prevent the intermittent breakdown of protectors during storms, may be provided either through special drainage apparatus or through equipment normally used for other purposes, such as ground-return alarm and control circuits, simplex telegraph or other direct-current telegraph connections.

The Laboratories studies have also yielded data from which it was possible to determine operating levels and repeater spacings for the new open-wire carrier systems that would suitably limit the effects of the hiss of precipitation static. Thus satisfactory operation of these systems has been secured during both good and stormy weather. In regions where precipitation static occurs, the repeaters must be spaced much more closely than in other parts of the country.

G. A. CAMPBELL AWARDED EDISON MEDAL

The Edison Medal for 1940 *has been awarded by the American Institute of Electrical Engineers to George Ashley Campbell, who retired from the Laboratories in* 1935, *"in recognition of his distinction as a scientist and inventor and for his outstanding original contributions to the theory and application of electric circuits and apparatus." Among the eminent engineers and scientists who have been recipients of the medal are Elihu Thomson, George Westinghouse, Alexander Graham Bell, John J. Carty, Michael I. Pupin, Robert A. Millikan, Frank B. Jewett and Bancroft Gherardi.*

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The 2B Carrier Pilot Channel

By D. M. TERRY
Transmission Development

WITH the early open-wire carrier systems, the variations in line loss that occur with changes in weather conditions were offset by manual adjustments of gain at repeater stations or terminals. Meters were employed to indicate the level of the transmitted signal at various points, and by frequent attention to them and careful coördination of the adjustment made at various points along the line, the maintenance force could hold the variation in gain to about 3.5 db either way from normal. This regulation was considerably improved and maintenance procedures simplified some years ago by the development of the 2A carrier pilot channel.* With that system, the gain corrections were made automatically, and the variation could be held to ±2 db. In connection with the development of the C5 carrier system,† a new regulating system known as the 2B carrier pilot channel was developed.

This new system, although similar in principle to the 2A, uses improved circuits and equipment, and will hold the variation in transmission to about ±1 db. Along with this improvement in performance, there has been simplification in the design that results in a marked saving in equipment and space and greatly reduced first cost and maintenance.

A pilot current of suitable frequency is transmitted between terminals in each direction. The amplitude of this pilot current as received at each repeater and at the distant terminal is used as an indication of the changes in line loss over the corresponding section of the line. When the received pilot current departs from its normal level, automatic equipment operates to add or take out local attenuation to restore the pilot current at the output of the repeater or receiving amplifier to its normal level. By this change in attenuation, the three carrier speech bands, transmitted over the same path as the pilot current, are likewise adjusted to normal levels. The frequency of the pilot current is so selected that it lies adjacent to the central channel band for each direction, as shown in Figure 1, and its normal value at the output of the repeater or receiving amplifier is 8 db above reference power of one milliwatt.

The attenuation of the open-wire line

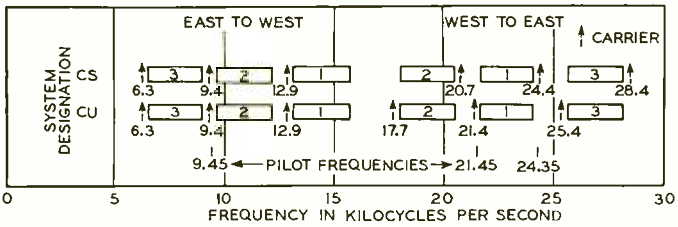

Fig. 1—Carrier and pilot positions for the two frequency allocations provided for the C5 carrier system

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*Record, *October*, 1934, *p.* 49.

†Record, *August*, 1940, *p.* 354.

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increases with frequency, and an equalizer network with a slope equal but opposite to that of the line, and in amount sufficient to equalize the maximum wet-weather attenuation of a line section, is inserted in the incoming circuit at each repeater and receiving terminal. Normally, with the line not exhibiting its maximum attenuation, local artificial line is added to build out the line attenuation to the maximum value for which equalization is designed. An overall flat loss frequency characteristic is thus obtained. Since the changes in line loss themselves increase with frequency, the attenuation correction must be graded correspondingly, as shown in Figure 2. With the earlier 2A pilot channel, regulation is obtained by inserting or removing units of artificial line in steps of about ¼ db, while with the 2B pilot channel, the regulation is smooth. The gain is changed by a motor that drives an air condenser connected as a potential divider across artificial line units. A schematic of the circuit elements is shown in Figure 3.

The pilot current, along with the speech sideband currents, enters the artificial line units at the left of the figure after passing through the equalizer. The actual attenuation afforded by these artificial line units is determined by the position of the rotor of the regulating condenser, which interleaves successively with four stator sections. These stator sections bridge across the four line units as shown. The condenser operates as a smoothly changing potential divider. The voltage thus tapped from the artificial line units is made effective by being impressed across the high-impedance input of the regulating amplifier, which is arranged with a stabilizing feedback circuit. The output of this one-tube buffer amplifier is supplied to the line amplifier, if at a repeater, or to the receiving amplifier, if at a terminal. It is at the output of this second or main amplifier that the pilot current is tapped off to control the regulation. The amount of line current taken is kept very small by using a bridging circuit of very high impedance. The pilot current is then filtered

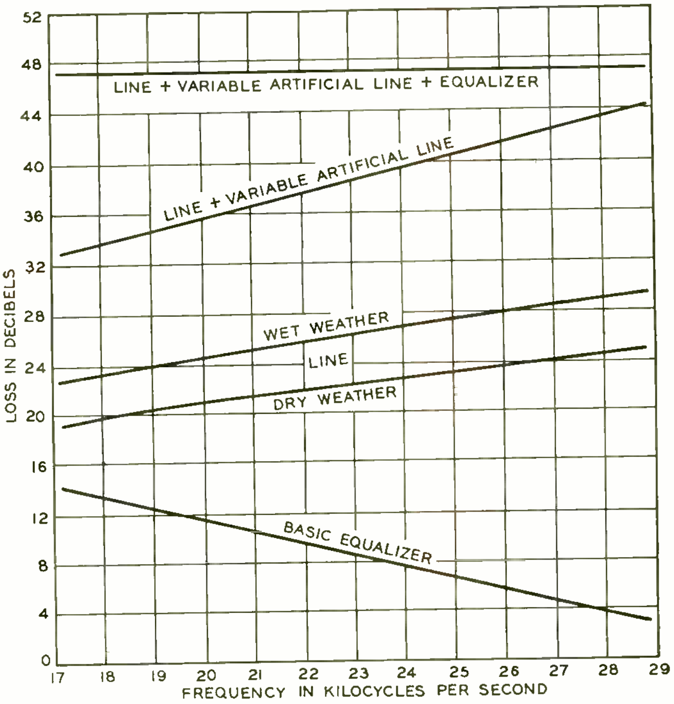

Fig. 2—Frequency-loss diagram for upper frequency band of the C5 carrier system indicating function of equalizer and artificial line in making attenuation corrections

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out through a narrow-band filter, and rectified by a copper oxide varistor. The resulting direct current flows through the armatures of two "Sensitrol" relays. The upper relay initiates regulation through contacts when the pilot current departs from normal by ±0.5 db. The lower relay is used for alarm and suspension of regulation by effecting contacts when the pilot current suddenly falls from its normal value by 5 db, or more, or suddenly increases by 3 db, or more, from the normal level.

When the pilot current changes by 0.5 db in either direction, the upper relay operates relay A or B depending upon the direction of current change. These relays effect contacts which drive the regulating motor in the proper direction to return the pilot current to its normal level. A reduction gearing is employed between the motor and the regulating condenser so that the attenuation correction will not take place too fast. A maximum of approximately 32 db of regulation is provided. The change in regulation, however, is effected through successive operating periods of the motor until the pilot current is restored to the normal operating region. These periods are timed by the slow-operate pulse relay which is operated from the A or B relay.

This pulse relay is one of three slow-action mercury relays. When the relay is energized, a mercury column is displaced by a solenoid-operated plunger, and contact is produced when the mercury reaches a certain height, but its rise is delayed by the slow release of trapped gas through a ceramic orifice. The closing of the contact of the pulse relay operates restoring mechanisms on the Sensitrol relays, which pull the pointers off contact to central positions. This releases the A or B relay previously operated, which in turn releases the

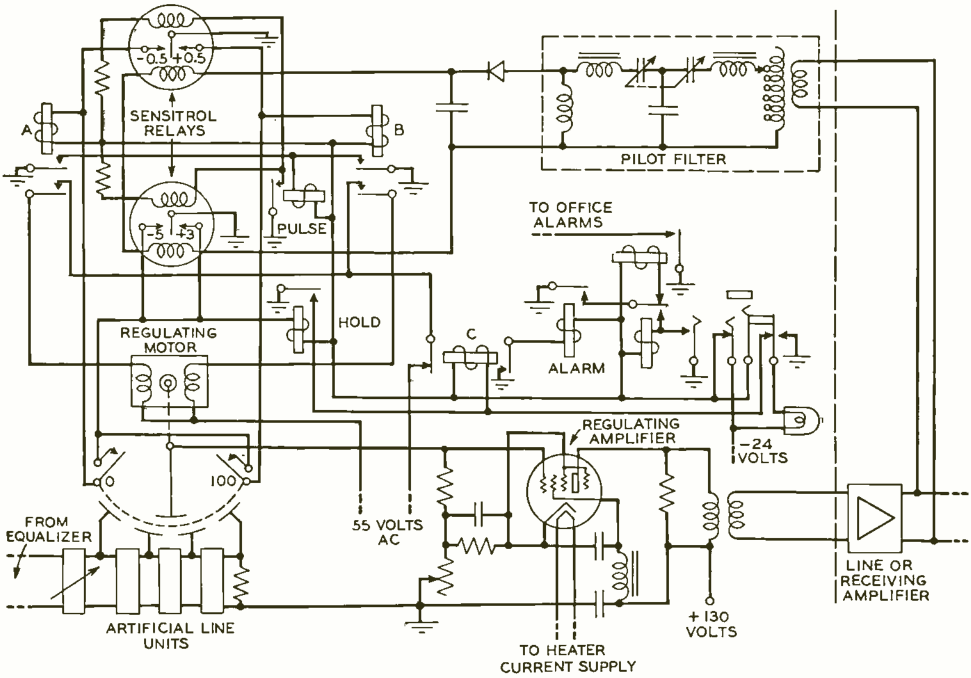

Fig. 3—Simplified schematic of regulating circuit

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pulse relay. The restoring mechanism of the Sensitrol relays is then released, allowing the pointers to re-contact or take up any new position. Pulsing will continue until sufficient gain correction has been made.

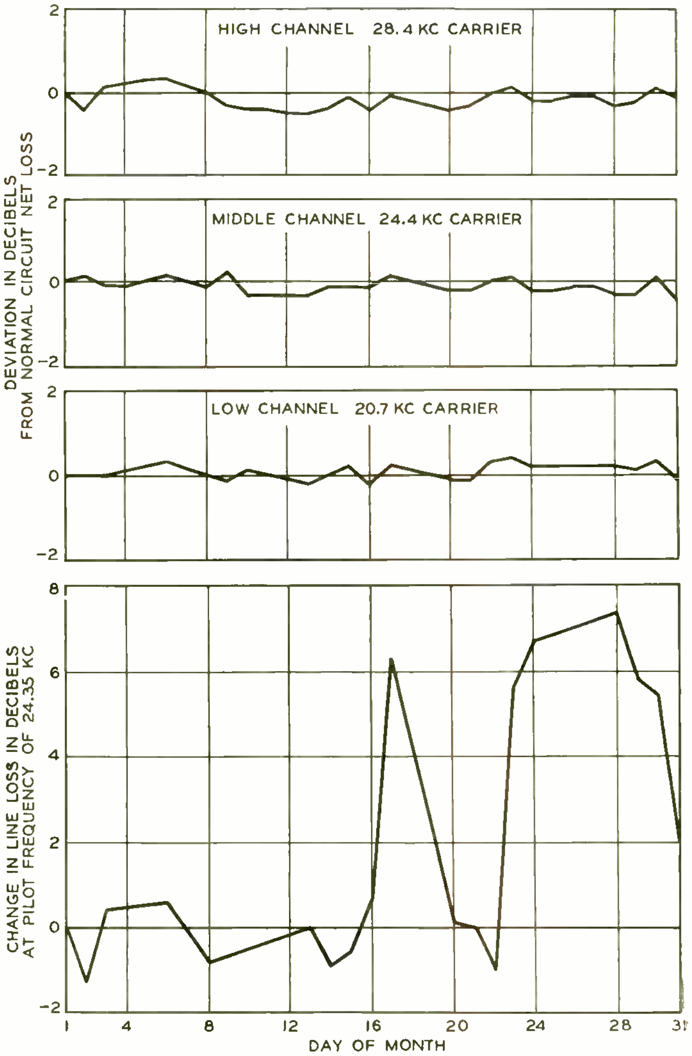

Fig. 4—Regulation maintained for a one-month period by the 2B pilot channel over a system with one repeater

One of the desirable features of the Sensitrol relay is the provision of more than the usual contact pressure for relays operating on such small current. This added pressure is secured by small permanent magnets at the stationary contacts, which exert a pulling force on an iron armature attached to the bottom of the pointer when the pointer comes within ⅛ inch of contact. Operation of the restoring mechanism is thus necessary to lift the pointer off contact.

When a sudden large change in energy occurs, the lower Sensitrol relay operates. This relay is used for alarm purposes, and its contacts, when made, operate the "HOLD" mercury delay relay. This latter relay is arranged to operate fast but to give a slow release so that under the alarm-pulsing conditions continuous contact is provided to hold relay c operated. Relay c opens the a-c circuit of the motor, stopping further regulation, and also energizes the alarm delay relay. A continuous energization of this latter relay for approximately 25 seconds is necessary before its contact takes place, when it brings in an audible alarm. This delay is incorporated to prevent momentary changes in line levels, even though of large magnitude, from bringing in an alarm. The principal purpose of this alarm is to call attention to open-line circuits. Additional alarms are provided on the regulating condenser to call attention if an end position is reached, since it

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would stop further regulation in that particular direction. All alarms are automatically self-restoring.

The regulation provided by the 2B carrier pilot channel over a typical system with one repeater is shown in Figure 4. Although wide changes of temperature and weather may take place, the overall transmission will, in general, be maintained with a variation in transmission of less than 1 db. In addition to providing better regulation than the 2A pilot channel, the 2B pilot channel requires considerably less space, a seven-inch panel instead of nearly a full bay for the 2A. This has already been pointed out in the RECORD for May, 1939, pages 288 and 289, where photographs were given of both the pilot channels.

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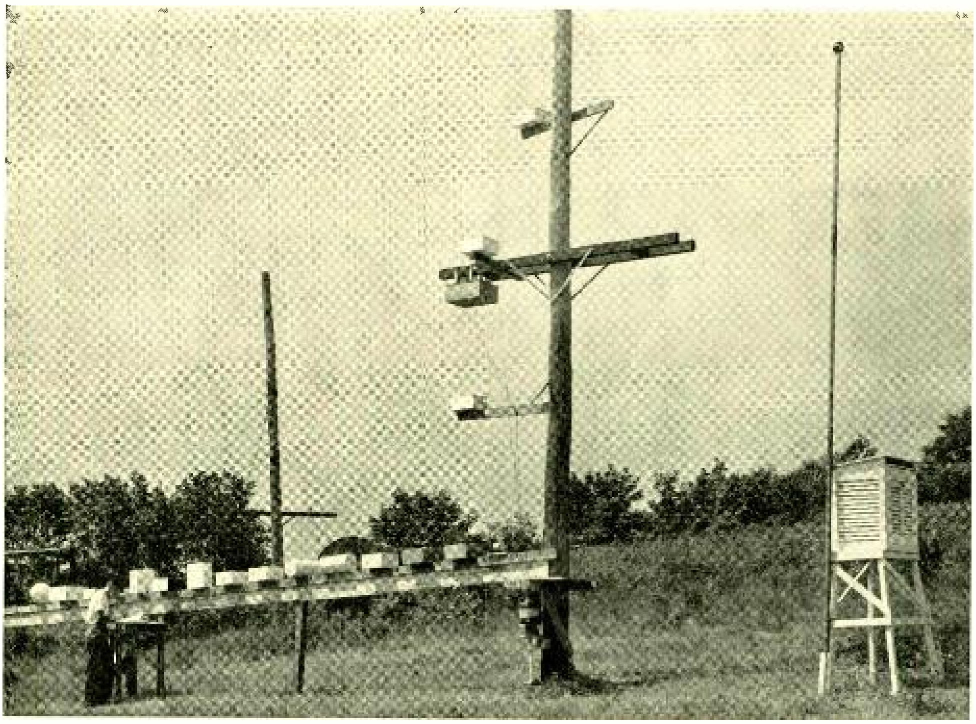

To determine how hot apparatus may become out of doors, this array of steel boxes has been set up at the Chesterfield laboratory. The effect of the shape of the boxes, various orientations relative to the sun, paints of different colors and insulation inside the boxes are being tested. Temperatures are measured with thermocouples which are located in the boxes. The slotted box at the right is a shelter in which the air temperature is measured. An anemometer at the top of the pole determines the wind velocity. G. E. Hadley is making the measurements

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Earth Resistivity Measurements

By G. WASCHECK
Systems Development

Although the earth is a poor conductor of electricity, its extent is so great that it adds comparatively little resistance to direct-current circuits with earth-return such as telegraph circuits, provided they have good ground connections. In alternating-current circuits which have earth-return, however, the earth's resistivity and the varying magnetic fields which accompany alternating currents change the distribution of the return currents in the earth. This affects the self-impedance of the circuits, and particularly their coupling with neighboring ground-return circuits. Many communication problems are concerned with the currents or voltages in circuits which have the conductors of a metallic communication circuit in parallel on one side and the earth-return on the other. Such circuits are called "longitudinal circuits."*

The resistivity of the earth varies with location from about 1 to over 10,000 meter-ohms,† and hence it must be measured in the immediate region of interest for precise calculations involving this quantity. Values may be determined either by direct or alternating current. With the direct-current method, which is often employed because it is simple, a potential is applied to a pair of ground elec-

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*Record, *September*, 1939, *p.* 2.

†The resistivity in meter-ohms is the resistance between opposite faces of a cube one meter on a side.

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trodes to form a primary circuit and the potential between two other points is measured for a given current in the primary. Periodically reversing the current reduces polarization at the ground electrodes and stray voltage effects. This measurement is equivalent to determining the mutual resistance between the two circuits. From it and the geometrical arrangement of the electrodes, the value of the earth resistivity, if uniform, may be determined by a simple formula. In using the direct-current method, care must be taken to avoid buried conductors, such as iron pipes and lead cables, since these affect the measurements.

If the earth were homogeneous, one measurement would determine its resistivity for all circuits and at any alternating-current frequency, but the earth structure varies greatly and it is necessary to determine possible variations of resistivity with depth as well as variations at different locations on the surface. To detect variations with depth, successive measurements of mutual resistance are made between electrodes which are moved progressively farther apart in a straight line from a fixed midpoint. The outer two electrodes are usually taken as the current or primary electrodes and the inner ones as po-

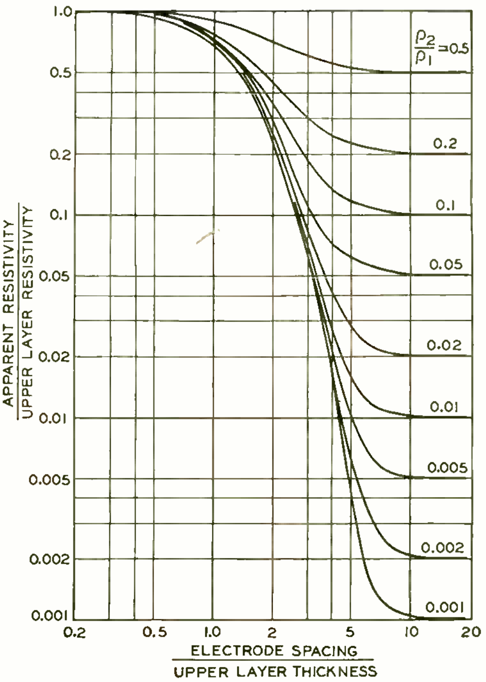

Fig. 2—The thickness of the earth layer at the surface is computed by comparing a curve of the measured resistivity for different spacings with a family of theoretical curves, for different resistivity ratios of the upper and lower layer, plotted against the ratio of the spacing to the thickness of the upper layer. The upper-layer resistivity equals the apparent resistivity for close electrode spacings. The curves are for values of the ratio, ρ_2/ρ_1, of the lower layer to the upper layer resistivity which are less than unity

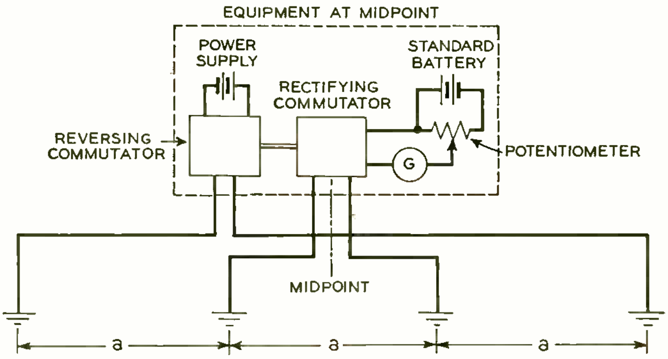

Fig. 1—Earth resistivity measurements are made by determining the drop of potential between two grounded electrodes in the path of earth currents established between two other grounded electrodes which are from a few feet to half a mile or more apart. The apparatus for making these measurements is placed at the mid-point of the circuit

tential or secondary probes, although the reverse order would give the same results. The generating and measuring apparatus is placed at the midpoint with wires extending to the separate electrodes in a symmetrical manner, as shown in Figure 1. The spacing between ground electrodes is progressively increased, at a geometric rate, from a few feet to half a mile or more depending on the resistivity trend. The depth to which information regarding earth structure and resistivity is obtained for given spacings varies with the absolute values of the different resistivities and the order in which they are encountered.

The measurements may be made with sensitive direct-current meters on which direct and reversed readings are taken to eliminate effects from stray direct current and galvanic potentials. To produce frequent and automatic reversals of current, a test set, shown on page 185, was designed. It includes a primary source of power, a reversing commutator for the primary circuit, a similar rectifying commutator, which rotates on the same shaft, for the secondary circuit, and a potentiometer with standard battery and galvanometer to detect null balances. Direct current from several heavy-duty batteries or a gas engine-driven generator is used. The rectifying commutator is usually set so that the potential contacts are closed after the current contacts to avoid transient effects. A double-pole, double-throw switch permits measurement of either the potential drop across a shunt in series with the primary circuit or the voltage in the secondary circuit. The rectifying commutator delivers a unidirectional pulsating voltage to the galvanometer circuit. This voltage is opposed by the potential from the standard battery across a voltage divider with a calibrated dial. A sensitive galvanometer, which is connected in the circuit synchronously with the pulsating voltage, detects balance when no current appears in this circuit. Both the shunt drop and the secondary voltage are determined by a potentiometric null balance and since the two are balanced against the same standard battery, the mutual resistance is equal to the ratio of the two dial readings multiplied by the shunt resistance, which is made equal to unity for convenience. When excessive stray direct voltages are encountered they may be blocked out by a condenser placed in series with the secondary circuit. This does not

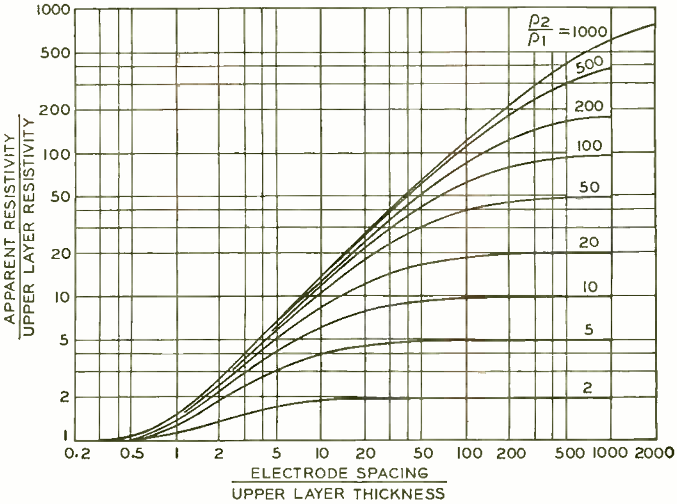

Fig. 3—A family of curves similar to those of Figure 2 but for values of the ratio, ρ_2/ρ_1, of the lower layer to the upper layer resistivity which are greater than unity

interfere with measurement of the desired voltage since the latter is periodically reversed, thus causing a transient charging current to flow at each reversal. A uni-directional current comes from the rectifying commutator until balance is secured.

The resistivities calculated from experimental data often show a transition from one value to another as the spacing between current and potential electrodes is increased from initially small values. This characteristic, especially when duplicated at neighboring locations, usually indicates a stratified earth. With close spacing of electrodes the current is necessarily concentrated near the surface and yields surface voltages dependent only on the near-surface characteristics, whereas with larger spacings the current penetrates to lower depths and surface measurements will reflect the characteristics of the underlying medium. The hypothesis of a stratified structure is corroborated by geological studies which show that a large portion of the earth's surface has been formed by layer deposits.

The simplest type of stratified earth would be two horizontal layers with the lower one infinite in depth. The experimental resistivities would then approach the resistivity of the upper layer at the small spacings and that of the lower at the larger spacings. The transition depends on the thickness of the upper layer and the resistivity ratio of the two layers. These quantitites are determined from a set of field measurements by reference to families of theoretical curves, each for a different ratio of lower layer to upper layer resistivity. The curves are plotted on log paper, with the ratio of apparent resistivity to upper-layer resistivity as ordinates, and the ratio of electrode spacing to upper-layer thickness as abscissae. Curves of this kind are shown in Figure 2 and Figure 3 for ratios of apparent to upper layer earth resistivity less than

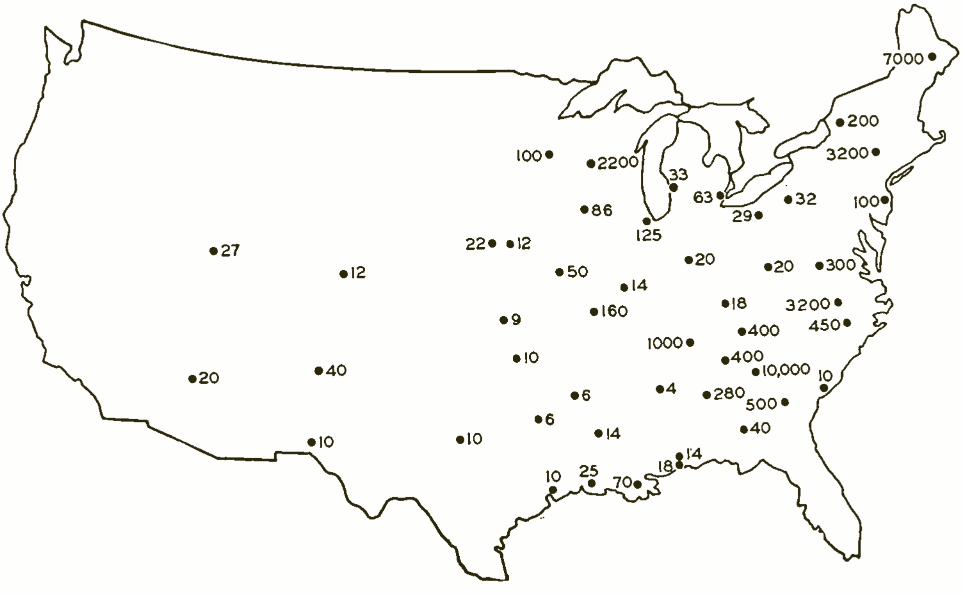

Fig. 4—Earth resistivity measurements in different parts of the United States show that the resistivities are usually lower in regions of recent geological origin. The values are expressed in ohms for a meter cube

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or greater than one, respectively. The experimental results are plotted to the same scale as the theoretical curves by using as ordinates the ratio of apparent to upper layer resistivity —the latter is taken as equal to the apparent resistivity at the closer electrode spacings. As abscissae the electrode spacings are used and they are interpreted as the ratio of electrode spacing to an upper layer depth of unity. The experimental curve is superposed on the family of theoretical curves which it most nearly resembles in shape, and is slid along laterally until a fit is obtained. The ratio of lower to upper layer resistivity is found and the depth of the upper layer is determined by comparing corresponding points on the axes of abscissae.

Since the earth may be approximated by a horizontally stratified two-layer structure in a majority of locations, the coupling between two ground-return circuits may be determined by reference to coupling curves plotted for this condition. When the region portrays more complicated variations with spacing, the nearest two-layer equivalent structure or an average uniform resistivity is estimated. Usually an involved variation of resistivity with depth is also accompanied by variations from one location to the next so that a greatly detailed investigation of variations of resistivity is not warranted. The best overall resistivity must still be an average of those indicated at the locations explored.

By comparing the results of measurements at over one hundred locations throughout the United States, an attempt has been made to correlate the resistivities with the geological structure of the earth in the same region. The experimental sites have been spotted on maps which cover a major portion of the United States and labeled with the average resistivities determined from the tests as illustrated in Figure 4. These data, correlated by R. H. Card, show that the resistivity is usually lower and the structure more regular in regions of recent geological origin than in those identified with the older pre-Cambrian rock, although alluvial deposits and glacial drifts influence a local resistivity. With the maps and a knowledge of the geological details it is now possible to make an approximate estimate of the magnitude of the resistivity and the possible heterogeneity of the sub-surface structure for most areas. This is often sufficient for preliminary estimates, though measurements are necessary for more precise figures.

Earth resistivity measurements are not only useful in studies of inductive effects in telephone lines from existing exposures to power circuits, but also to determine the expected induction in locations where the construction of new lines is contemplated. In electrolysis and lightning studies a knowledge of the resistivity near the surface of the earth is often quite important.

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Power-Factor Correction Equipment for Central Offices

By L. J. PURGETT
Power Plant Development

TELEPHONE power plants employ motor-generator sets to supply 24-volt and 48-volt direct current for the main office supply, and a number of smaller sets to supply ringing, signalling, and tones. In a panel office there will also be a number of small motors to operate the elevators on the panel frames. These motors all operate at a lagging power factor, which varies in value with the percentage of full load at which the motors are operating. The power required is usually obtained from the local utility company at three-phase 60-cycle and at either 200 or 230 volts nominal circuit potential. The rate paid not infrequently depends in one way or another on the power factor, and the telephone companies have generally attempted to maintain a high power factor by the use of synchronous motors. Such motors are more expensive than induction motors, however, and are much more expensive to maintain, and so their use is not always justified. It has been found difficult, moreover, to obtain synchronous motors that do not generate harmonic potentials that may cause noise in telephone circuits. This difficulty, together with the recent availability of an inexpensive condenser suitable for power-factor correction, led to a survey of the entire situation and the provision of a line of capacitor-reactor units that would give economical and satisfactory correction for telephone power plants, particularly those of the larger 301C type.*

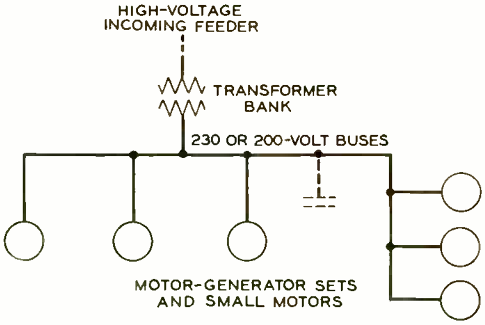

Fig. 1—A central-office power plant is usually supplied from a high-voltage line and a transformer that feeds a three-phase bus at either 200 *or* 230 *volts*

A generalized central-office power supply system is indicated in Figure 1, where for the sake of simplicity a single line is used to represent a three-phase circuit. The load current is at 60 cycles, but on the incoming feeder there also may be voltages of any or all of the odd harmonics of 60 cycles. These usually are relatively small in value, and because of the high impedance of the power plant equipment to these higher frequencies, the high-frequency currents are usually too small to induce objectionable noise in nearby telephone circuits. If a condenser is connected to the

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*Record, *Oct.*, 1937, *p.* 43.

bus to improve the power factor, as indicated by the dotted lines, the situation is changed, however. The feeder, including the transformer, has inductive reactance and thus at some frequency would form a resonant circuit with the condenser. Under these conditions the impedance to the resonant frequency is only the resistance of the circuit, which is very small. As a result a relatively large value of the harmonic current may flow and cause disturbances in telephone circuits paralleling the power supply feeder. Before recommending such a condenser installation, therefore, all likely conditions must be determined, and precautions taken to avoid objectionable disturbances.

This is not the only thing that must be considered, however. The load of the plant, flowing through the impedance of the feeder and transformer, results in a drop in voltage when the power factor is lagging. From no load to full load this drop is of the order of 5 per cent, but it depends on power factor, and at leading power factors it results in an increase instead of a decrease in voltage, which may become great enough to be objectionable. If a separate condenser were used for each motor, there would not be much likelihood of high voltage because each condenser is proportional to the size of the motor, and when the motor is disconnected, the condenser also is disconnected. With a single group of condensers connected to the bus at all times, however, this is not true. The condenser must of necessity be large enough to give the required correction at full load, and at light load, as a result, its large leading current may result in a low leading power factor, and the voltage at the bus will necessarily rise. The use of separate condensers on each motor feeder is more expensive than using a single large condenser, and thus was not felt advisable, but as a result it became necessary to consider the possibility of high voltage in designing the corrective equipment. It was also necessary to make sure that under no condition would the voltage across the condensers themselves become higher than the limits recommended by the manufacturers.

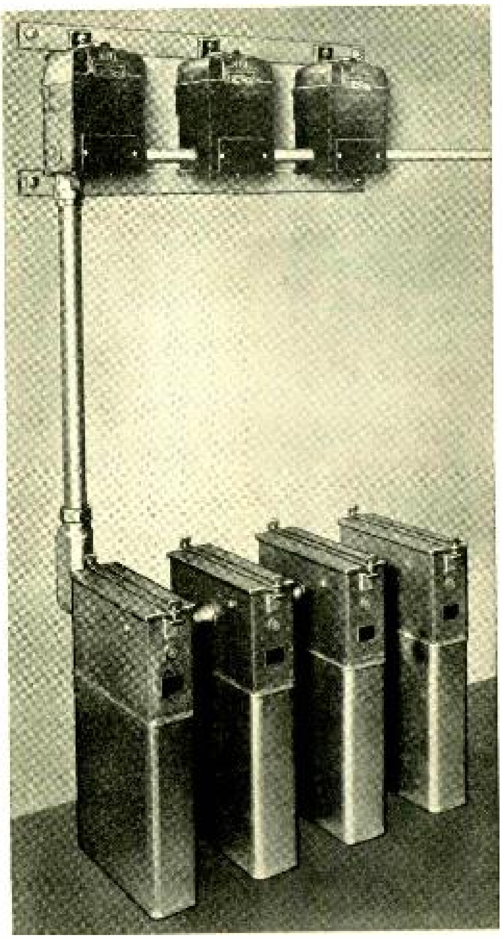
Fig. 2—Each installation consists of one or more condenser units and three reactors

In undertaking the development it was necessary first to determine the range of load of the various possible power plants and also the variations in load at different times of day. Once this is determined, it is possible to correlate the standard sizes of capacitors available so as to make proper recommendations for the various sizes and types of offices. It was necessary, in addition, to design the equipment so that the higher harmonics would not cause interference with exposed telephone circuits and so that excessive voltages would not appear.

To reduce the effect of the condenser on the harmonic currents, it was decided to install a reactor in series with it. With a condenser and reactor in series, the combination is resonant at some one frequency, and at this frequency its reactance is zero. Below this frequency the reactance is capacitive and above it, it is inductive—rising rapidly with frequency at both sides of the resonance point. By selecting a reactor that would bring the resonance frequency above 60 cycles but below the frequency of the lowest important harmonic, therefore, leading current would be obtained at 60 cycles for power-factor correction, and a high-inductive reactance would be presented to the harmonic frequencies.

The lowest odd harmonic is 180 cycles, but on a three-phase supply the 180-cycle voltage between phase wires is small. While it would be undesirable to have resonance come at 180 cycles, there would be no harm in having it fairly near it. The major objective was to bring resonance well below 300 cycles, which is the lowest harmonic potential likely to exist.

The standard capacitors available, which are all three-phase delta-connected units, are as follows:

230 Volts		460 Volts	
KVA	MF	KVA	MF
2.5	125	6	75
5.0	250	10	125
		15	189

When connected in a circuit in series with reactors, the arrangement would be as in the upper sketch of Figure 3. For convenience in calculation, however, the values for an equivalent impedance in a Y-connected group, as shown in the lower sketch of Figure 3, are used. Since the equivalent Y capacitance is three times the Δ capacitance, the values to be used may be taken directly from data given above, where the capacitance listed is the total capacitance of the unit or three times that in one leg of the Δ. From this value of capacitance, the reactance may readily be calculated from the equation $X_C = 10^6/2\pi fC$.

Considering only one phase of the three-phase Y circuit, the circuit is as shown in Figure 4, where V represents the line voltage. The phase to neutral voltage, which is that across the condenser and reactor in series, is $V/\sqrt{3}$. Since the voltages across C and L are in phase opposition, $V/\sqrt{3}$ will be the difference between V_C and V_L rather than their sum. For a 200-volt circuit, $V/\sqrt{3}$ is 115.6 volts, so that the difference between V_C and V_L must be 115.6, and the inductance L of the reactor must be so chosen in relation to the value of C that this difference in voltage will result. This voltage does not determine a single value of inductance, however, because there are an infinite number of pairs of values for V_C and V_L that give the same difference. This difference relationship merely means that V_L is 115.6 volts less than V_C. According to the manufacturer's specifications, however, it is not safe to operate the condenser at a line-line voltage of more than 240 volts, and this fact determines the upper permissible limit for V_L, and thus for the inductance.

Since it is desirable to operate the condenser at its maximum voltage if

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possible, so as to utilize its capacity to the greatest extent, the value of inductance chosen is that which will make V_C equal to $240/\sqrt{3} = 138.7$ volts, providing this brings the resonant frequency within the desired range. To meet the requirements of the various sizes of plants, a number of sizes of reactor-capacitor banks will have to be provided. Since only the available sizes of capacitors can be used, however, the value of capacitance will always be some multiple of one of the values given. For the 5.0-kva capacitor units, for example, the equivalent phase-neutral capacitance will be $250n$ microfarads, where n is an integer representing the number of capacitor units used. The capacitive reactance X_C is $10^6/2\pi fC$, and thus at 60 cycles will be $10.62/n$ ohms. The maximum permissible voltage of 240 gives $240/\sqrt{3}$ or 138.7 volts for the equivalent phase to neutral, and thus the current through the capacitors will be this voltage divided by the reactance, or $13.05n$ amperes. The voltage across the inductor will be 138.7 minus the line voltage of 115.6, which is the Y equivalent of 200 volts. This gives 23.1 volts across the reactor, and since the current in the reactor is the same as that in the capacitor, the inductive reactance X_L will be $23.1/13.05n$, or $1.77/n$ ohms. Since X_L is equal to $2\pi fL \times 10^{-3}$, L is found to be $4.69 \times 10^{-3}/n$ millihenrys.

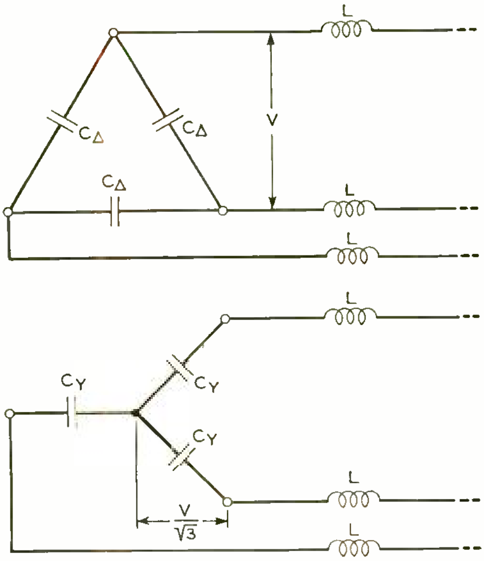

Fig. 3—Three condensers connected in delta, above, will have the same effect as three connected in Y *provided the latter have three times the capacitance*

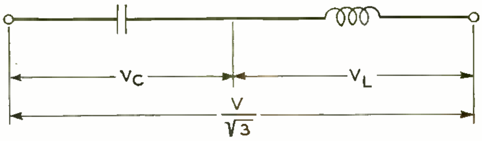

Fig. 4—With a Y*-connected capacitor, one of the condensers and the series inductor divide the phase to neutral voltage*

The resonant frequency is given by the expression $f_r = 1/2\pi\sqrt{LC}$ and by substituting the above values of L (henrys) and C (farads) into this equation, the resonant frequency is found to be 147 cycles regardless of the value of n, which cancels out. Since this frequency falls in the permissible range of frequencies, the design can be made on the basis of using the highest permissible voltage across the condensers. Units have been designed using 1, 2, and 4 of the condensers, that is, the n in the above expressions is given one of these values for each of three designs. The capacity of these units in reactive kilovolt-amperes will be $3 I^2 (X_C - X_L) 10^{-3}$ and by substituting the above values into this expression, the capacity is found to be $4.55\,n$ reactive kilovolt-amperes. For the three values of n, this gives the five capacities 4.55, 9.10 and 18.2. For larger capacities, two or more of the 18.2-kva units are installed to give required capacities. By using a

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single one of the smaller, or 2.5-kva condensers, a capacity of 2.77 reactive kva is also secured.

Similar calculations are carried out for 230-volt circuits, but here, because of the higher voltage, it was necessary to use the 460-volt capacitors.

In installing these units, it is recommended that a size be selected that will give satisfactory correction at the ultimate rating of the plant. Since the initial rating may be less than this, a reduced corrective effect may be obtained by leaving out one or more of the capacitors. Thus if the ultimate capacity of a plant indicated the 18.2-kva unit be used, which employs four capacitors, a reduced corrective effect for the smaller capacity of the original plant could be secured by installing only two or three of the condensers. When the capacitance in series with a reactor is decreased, however, the resonance frequency rises, so that this reduction in the number of condensers can be carried out only to an extent that will not raise the resonance frequency beyond the desired limit. When the capacitance in series with a fixed reactor is changed by a factor p, the resonant frequency is changed inversely as the square root of p. Thus for three condensers instead of four, the resonance frequency would be $147/\sqrt{.75}$. For two condensers it would be $147/\sqrt{.50}$, and for one condenser it would be $147/\sqrt{.25}$. These give frequencies of 170, 212, and 294 cycles respectively, and all but the latter are satisfactory. Based on similar calculations, recommendations are made as to the permissible reductions of all the equipments available.

The effect of a capacitor installation on the voltage must also be determined before making recommendations. Although the voltage at the primary side of the transformers will vary slightly, depending on the system load, the chief variation of the bus voltage is due to the drop through the transformer with variations in load and power factor. With standard transformers, this drop at full load is about 5 per cent. As the load becomes capacitive rather than inductive, the drop becomes a rise. It would be as much as 5 per cent, however, only if the capacitor had as large a rating as the transformer and the motor load were substantially zero. In general the voltage can be taken as the ratio of the reactive kva of the capacitor to the kva rating of the transformer times 5 per cent. For the recommended installations, it varies up to about 2 per cent, and thus is not a serious matter.

These new condensers are built of aluminum foil and kraft paper, and use a non-inflammable liquid dielectric. Three of them are mounted in the bottom of a lead-lined metal container, and three terminals are brought out through porcelain bushings from the delta connections made inside the capacitor. The losses are small—about 3⅓ watts per kva—and tests indicate that the life of the condensers should be over twenty years. Three reactors are required for each three-phase capacitor. They consist of an inductively wound laminated core, and practically any inductance can be economically obtained. A typical installation is shown in Figure 2, with the capacitor below, and the three reactors above. Although this equipment was designed primarily for telephone power plants, it could economically be applied to any type of plant where power-factor correction with noise control is desired.

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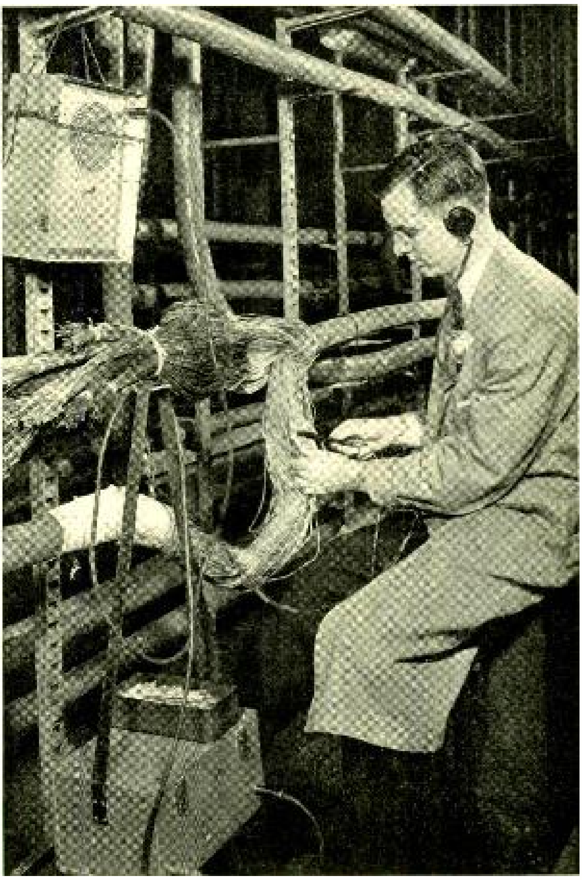
Identifying Cable Wires

By T. C. HENNEBERGER
Plant Products Development



IN TELEPHONE maintenance work, it is frequently necessary to identify a particular pair of wires out of some hundreds of pairs all alike that have been exposed by opening a cable at a splice. The 108A amplifier, already described in the RECORD,* was developed to simplify this work. Its operation requires that an audio-frequency tone be put on the desired pair at one of the terminals of the cable, and this tone is then "picked up" through capacitive induction to the blunt tip of a probe connected to the input of the amplifier. The tone is heard with a headset connected to the output of the amplifier.

In most cable-testing work, the pairs to be identified fall in the class of dead wires, and for this type of work the 108A amplifier is very satisfactory. Occasionally, however, it is necessary to identify wires without taking them out of service, and the 108A amplifier method cannot be used because the audio tone it places on the pair would interfere with normal telephone transmission. There has been developed therefore a new form of testing equipment that uses a tracing current so high in frequency as to be inaudible even though the line to which it is connected is in use for telephone purposes. The high-frequency identifying equipment comprises two portable test sets: the 72A test set for producing a 250-kilocycle current modulated by a frequency of 500 cycles, for use at one of the points between which identification is to be made; and the 71A test set, which includes a probe and loud speaker, for amplifying and then demodulating the pickup due to the tracing current so as to produce a 500-cycle note in the loud speaker. Views of these two sets are shown in Figure 1.

Consider, for instance, an underground toll cable such as the New York-Philadelphia G cable, and assume that a hole occurs in the sheath at some point between two manholes. This cable, like most toll cables, is

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*January, 1939, p. 155.

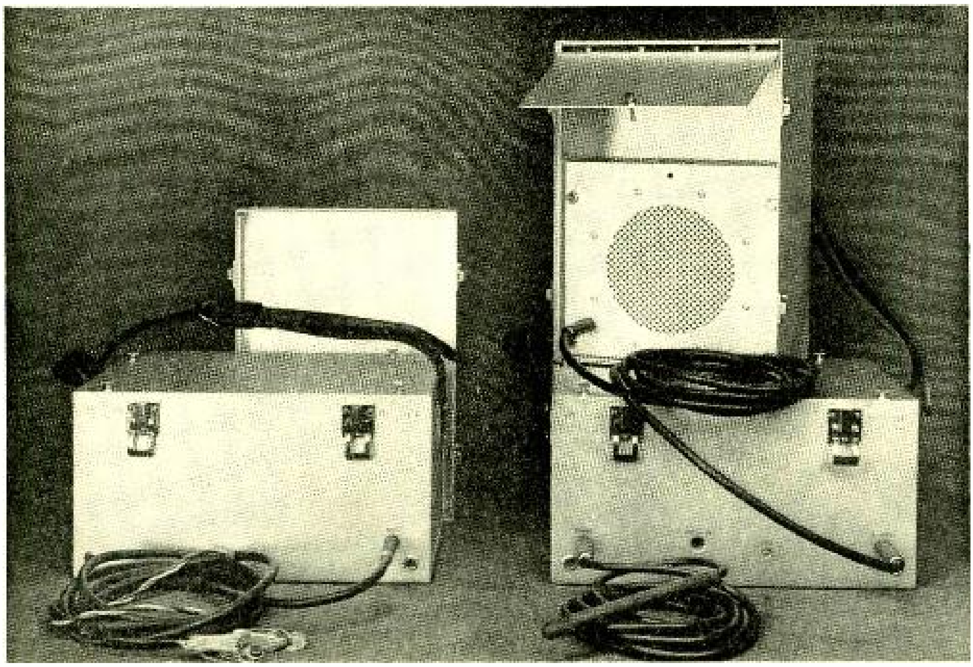

Fig. 1—Both the 71A and the 72A test sets are arranged in portable form

held under gas pressure, and gas leaking from the hole lowers the cable pressure and causes the operation of alarm equipment in the test rooms. Subsequent gas pressure measurements* are then made which locate the defective manhole section. During all of this locating work, the positive gas pressure at the hole prevents moisture from entering the cable so that the cable circuits are not affected. It is necessary, however, to replace the defective section because the hole is potentially dangerous to cable service as long as it remains.

The general process for clearing a trouble of this kind is to pull a length of replacing cable into a spare duct in the manhole section involved, and to transfer the circuits from the faulty to the replacing cable, one by one. The operation is called a working-section throw. All of the pairs of the replacing cable length are first identified between the manholes, by using standard apparatus such as the 108A amplifier, and the pairs are tagged at the two ends. A talking circuit is then established between the test board and each manhole, over a spare pair in the cable. After this preliminary work, the cableman at one manhole selects a wire in the faulty cable section and connects his high-frequency current source between the wire and ground. At the other manhole, another cableman searches among the wires with his probe. As he nears the proper wire with the probe, the 500-cycle note in the loudspeaker becomes stronger, and is a maximum when the probe is pressed against the wire. The schematic circuit arrangement is shown in Figure 2.

Having thus identified a wire, the cableman at each manhole selects the predetermined replacing wire, and splices it in parallel with the identified wire, so that temporarily the tele-

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*Record, *March*, 1934, *p.* 214.

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phone circuit is in both cables. Then the wire in the faulty cable is cut at each manhole, leaving the circuit through the replacing cable.

The highest frequency employed for normal transmission currents on cables is about sixty kilocycles, used for K carrier telephone circuits, although on toll entrance cables and short intermediate cables associated with the open-wire J carrier telephone system, 143 kc may be used. The 250 kilocycles of the identifying current is well above these transmission frequencies, and causes no interference with any circuits in the cable, although certain simple precautions have to be taken to avoid overloading the repeaters in those cases where carrier channels are employed.

The probe of the high-frequency 71A test set differs from the capacitive probe of the 108A amplifier in that it is slightly larger and contains in its tip a tiny coil having many turns of fine wire. The pickup is obtained both from the magnetic coupling between the turns of the coil and the cable wire and the capacitive coupling between the coil as a whole and the wire. This arrangement is needed because with a high-frequency tracing current, standing waves are sometimes produced on the wire being identified, particularly if the wire is loaded, and at some points the current may be relatively large compared to the voltage and at other points the reverse is true. The proportions of the probe are such that approximately equal pickups are secured for any relative strength of magnetic and capacitive effects that are encountered.

A loud speaker is used rather than a head receiver to give the cableman at the identifying point greater freedom of action, and because this method of listening is less tiring over

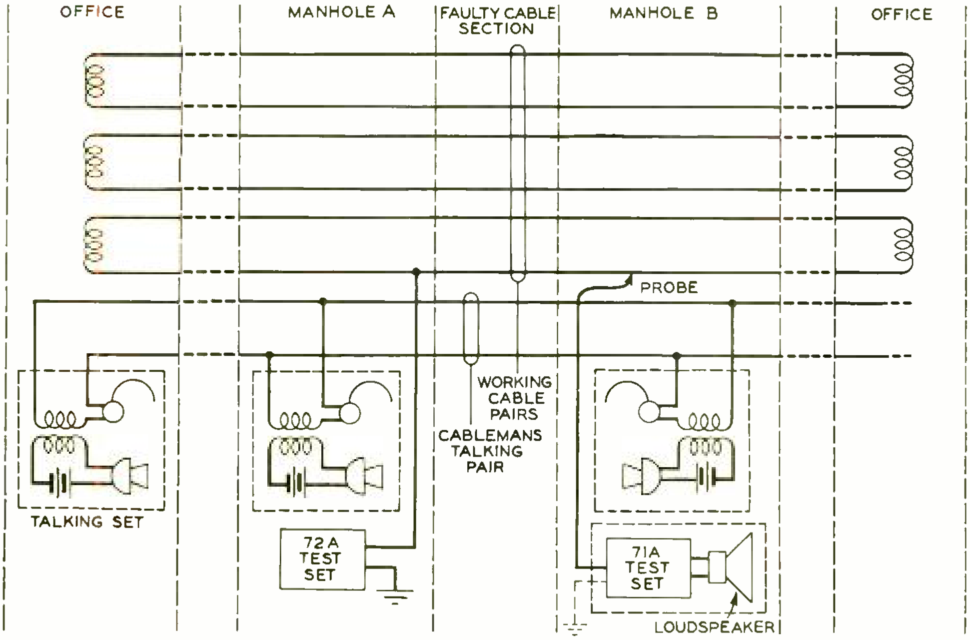

Fig. 2—Schematic representation of the method of using the high-frequency identifying equipment for identifying cable pairs with the 71A and 72A test sets

the several hours during which he is engaged in the identifying work.

Use of the 71A and 72A test sets results in a considerable decrease in testing time and expense over methods previously used for making working-section throws, with which it was necessary to reroute or "turn down" working circuits, one group after another, so as to permit the use of an audio-frequency identifying tone. The high-frequency identifying method, however, does not replace the 108A amplifier method, since it is applicable only over short distances, such as several manhole sections, because of the large attenuation of the line at the high frequencies.

The use of the test sets has been described here with particular reference to a fault caused by a sheath break in an underground toll cable. The sets are applicable also to cable transfers made necessary by other causes on both underground and aerial toll and exchange cables.

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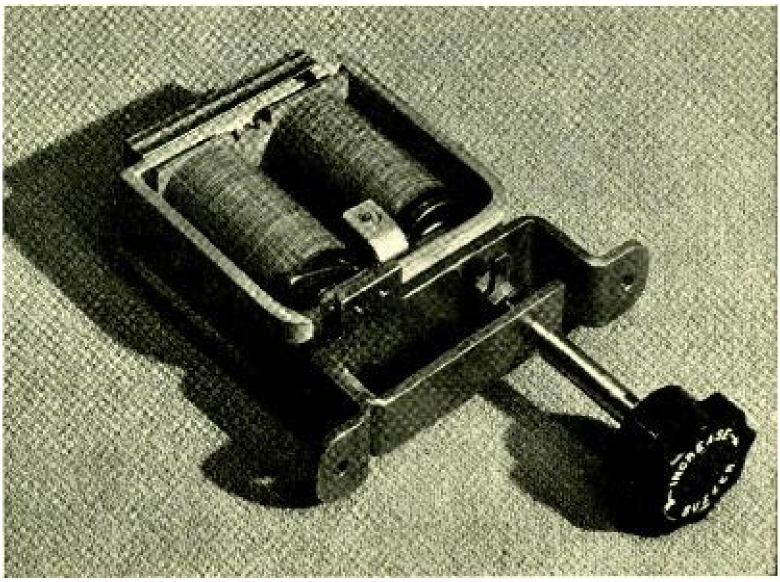

To provide for changes of the loudness of buzzers in private branch exchanges, this adjustable buzzer has been developed. By turning the knob the attendant can change the stroke of its armature and thus vary the volume of sound radiated. It operates on ringing current

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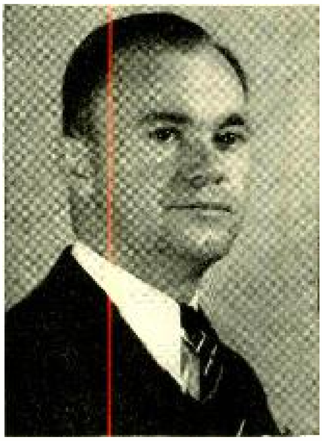
Contributors to this Issue

D. M. Terry received the B.E.E. degree from Ohio State University in 1920, and at once joined the Technical Staff of the Laboratories. Here he was first associated with the Research Department, where he worked on fundamental carrier research and on the development of picture transmission. He was in charge of the transmitting apparatus in Cleveland for the first public demonstration of this system in 1924. Two years later he transferred to the toll group of the Systems Department. His work here has been chiefly on the development of automatic control of transmission level for carrier telephone lines.

T. C. Henneberger was graduated from Lehigh University in 1921 with the degree of Electrical Engineer. For the following thirteen years he was a member of the Department of Development and Research of the A. T. and T., and was engaged in work on outside plant construction and maintenance problems. Since his transfer to the Laboratories in 1934 he has continued in the same line of work, and is at present in charge of a group handling the development of electrical apparatus for outside plant use.

George Wascheck received the degree of A.B. from Columbia University in 1924 and E.E. from the Columbia Engineering School in 1926. After spending one year as instructor in the Columbia Engineering School, he joined the Department of Development and Research of the A. T. and T. in 1927, where he was engaged chiefly in inductive coördination work on low-frequency induction between power and telephone lines. Since 1933 he has continued studies along the same lines with the Laboratories. These involve specific problems of earth-return coupling between power and communication circuits, the mitigation of induction effects by shielding due to shield wires, cable sheaths and tape-armoring; also the investigation of earth resistivities at various locations throughout the country.

After discharge from the U. S. Army in 1918, L. J. Purgett returned to Purdue, receiving the degree of B.S. in Ch.E. in



D. M. Terry

T. C. Henneberger

George Wascheck

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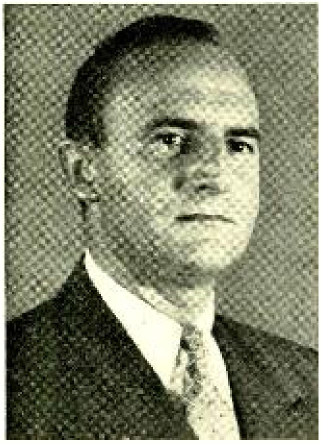

L. J. Purgett

H. L. Mueller

M. T. Dow

1920, and the degree of Ch.E. in 1940. He spent a year with the Aluminum Company of America and a year with the William A. Baehr Organization, Consulting Engineers, and joined the Western Electric Company at Chicago in 1922. Until 1928 he was concerned with the engineering, manufacture, and installation of telephone central-office equipment. At that time he transferred to the Bell Telephone Laboratories, where he has since been engaged in the development and design of power supply and other equipment for central offices.

H. L. Mueller joined the Installation Department of the Western Electric Company in April, 1913, after various activities in commercial power and railroad work. From 1914 to 1918 he attended Pennsylvania State College, receiving the B.S. degree. Commissioned a Second Lieutenant in the United States Army, he served as Personnel Adjutant of the 152nd Depot Brigade until October, 1919, when he joined the Engineering Department of the Western Electric Company. He has since been identified with the power development group, supervising power plant standardization for local central offices from 1928 to 1932. In the latter year he became associated with power apparatus development, and entered the evening courses at Columbia University, receiving the M.S. degree in 1934. At present he is supervising the developments on storage batteries and control apparatus for power plants.

M. T. Dow was graduated from Ottawa University, Kansas, in 1917 with the B.S. degree. He received a Master's degree in Physics at the University of Pennsylvania in 1921. For several years Mr. Dow was an instructor at M.I.T. and Harvard University while doing graduate work there. After two summers with the Department of Development and Research of the A. T. and T., he joined that Department in 1929 and for six years worked on inductive coördination problems with the Joint Subcommittees of the Bell System and Edison Electric Institute. In this connection he developed methods of measuring the influence of power lines and of calculating noise in exposed telephone lines. Since 1933 Mr. Dow has been concerned with noise studies in connection with carrier telephone systems and open-wire telephone lines. In 1934, with the D and R, he transferred to the Laboratories.

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