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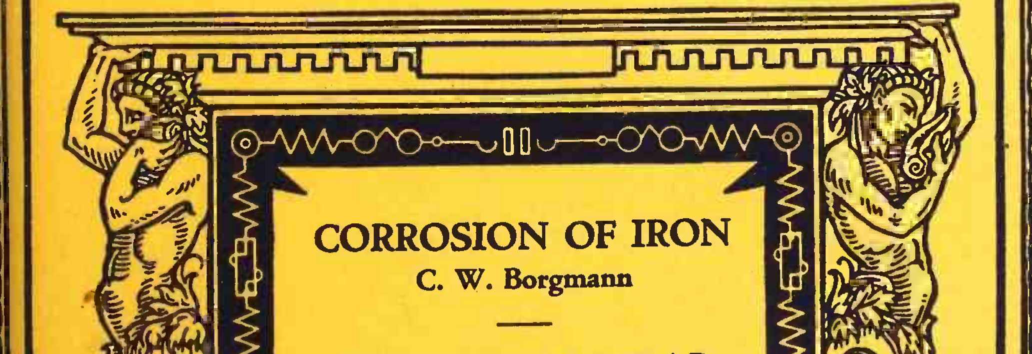

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BELL TELEPHONE LABORATORIES, INCORPORATED
463 West Street, New York, N. Y.

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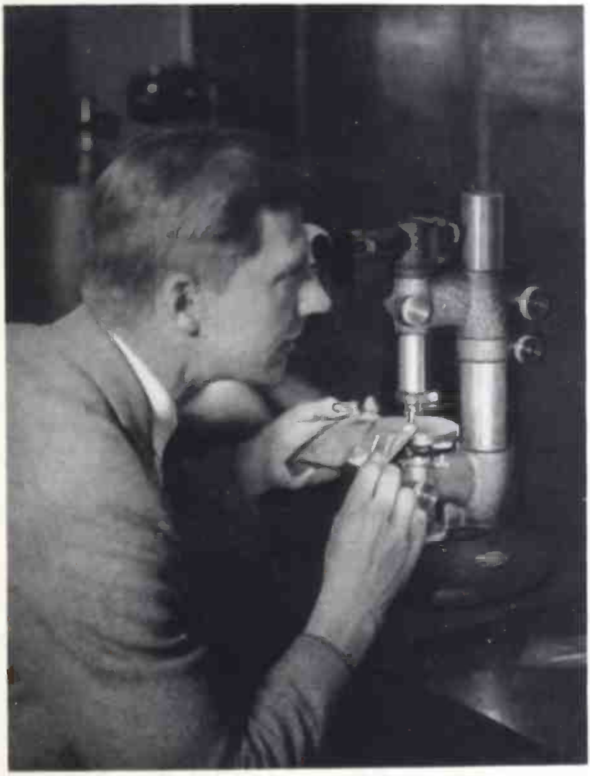

VOLUME TEN—NUMBER SEVEN
for
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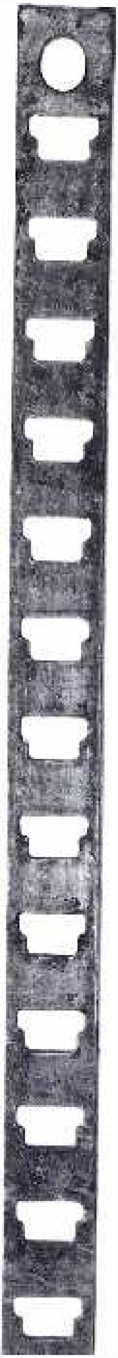

Corrosion of Iron

By C. W. BORGMANN

CORROSION of metals is often called oxidation, but it is a mistake to interpret this as meaning that corrosion is a direct formation of metallic oxides. In this case, as in all others where it is correctly used, the term oxidation is much broader. A metal atom is said to be oxidized when it loses one or more of its outer electrons and thus forms a positive ion, which may remain in the solid structure or be detached and go into solution. Corrosion is a type of oxidation distinguished by the formation of metal ions dispersed in water solution.

The mechanism of the formation of such ions can best be approached from the electrochemical side. A familiar example of it is found in the ordinary primary cell. When a zinc electrode and a carbon electrode are dipped into a suitable electrolyte, there is created a potential difference between them, which will drive a current through the closed path of a circuit. This current passes at the expense of the zinc, which dissolves in the electrolyte, or "corrodes."

For ordinary corrosion to occur at the surface of a metal or an alloy, as for action to take place in the galvanic cell, two conditions are fundamentally necessary. There must first be a cause of potential difference between two adjacent portions of the metal, cor-

Fig. 1—Exposure to moisture in a manhole may corrode a cable rack almost beyond recognition and entirely beyond use, if the rack has not been properly galvanized

responding to the electrodes of the galvanic cell. There must also be a closed conductive path permitting the flow of electric current driven by the electromotive force. In the galvanic cell, one part of this circuit is continuously provided by the electrolyte, and the other part is provided by wire when all connections are closed. In a corroding metal, on the other hand, the metallic half of the circuit is continuously provided by the metal itself, and the other half is furnished whenever an electrolyte is present.

The most familiar cause of a difference in potential between two electrodes is a difference in their chemical nature, such as is used in the galvanic cell. Different metals appear to have different inherent tendencies to ionize. In corroding metals these differences are found as differences between a metal and its impurities, or differences in the composition of different portions of an alloy.

But such differences are not the only possible causes of corrosion. The extent to which a metal can follow its tendency to ionize depends not only on the strength of the tendency in the metal but on the homogeneity of its environment. Thus every metal in contact with an electrolyte shows an electrode potential which is affected by the composition, concentration and temperature of the electrolyte, and on the surface condition of the metal itself. Differences in any of these factors over various regions of a metallic surface will set up potential differences leading to corrosion, even if the metal is pure or the alloy uniform.

At one electrode, called the anode, of the electrolytic cell formed as a result of these differences, each of the metal atoms ionized loses a number of electrons characteristic of the metal. The electrons pass into the body of the metal, and the ions into the electrolyte. These ions migrate toward the other electrode, called the cathode, and if they arrive there, tend to reenter the atomic state through the acquisition of as many electrons as the atoms previously lost. Because of their tendency to migrate to the cathode, these ions are called cations.

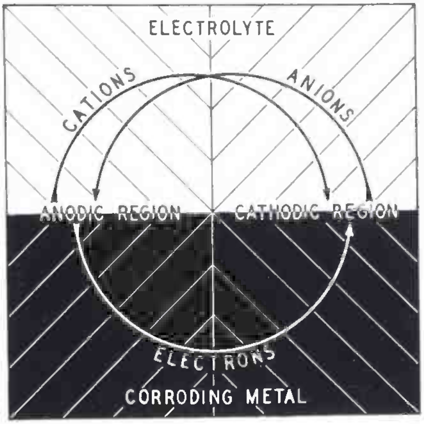

Fig. 2—*All corrosion is accompanied by a flow of cations from anode to cathode through the electrolyte and of electrons through the metal, and a flow of anions through the electrolyte in the reverse direction*

In the rusting of iron and steel in normal waters or in the atmosphere, however, the iron cations never reach the cathode. In the anodic regions of the corrosion cell, one iron atom after another loses two electrons, enters solution as a ferrous ion, and migrates toward a cathodic region. In the presence of dissolved oxygen, each ferrous ion oxidizes to a ferric ion by losing one more electron.

Meanwhile in the cathodic regions molecules of water dissociate, and their hydrogen ions receive electrons from the cathode and enter the atomic state. Complementary hydroxyl ions, the other product of aqueous dissociation, having each an extra electron, are oppositely charged from the hydrogen ions and migrate toward the anode as "anions." Thus they meet the opposing stream of ferric cations, and combine to form ferric hydroxide, a relatively insoluble product, which is precipitated from the electrolyte as the familiar rust. Here, as in all severe corrosion, the products of disintegration are formed at a finite distance from the corroding surface and hence usually do not afford protection to the underlying metal.

The action of short-circuited galvanic cells such as occasion corrosion would stop due to polarization if other factors did not come into play. Polarization of a corrosion cell may be due to an accumulation of metal ions at the anode or to an accumulation of atomic hydrogen at the cathode. Those factors which tend to keep the cell active or depolarized are the formation of insoluble corrosion products, such as ferric hydroxide, agitation of the solution which removes the metal ions at the anode, and the presence of oxygen or an oxidizing agent at the cathode which combines with the accumulated hydrogen to form water and depolarizes that electrode.

The velocity of corrosion of a metal where a given potential difference exists is dependent on several conditions: chiefly, the nature of the corrosion product, the movement of the solution, the accessibility of oxygen to the cathode, and the conductivity of the electrolyte. The nature and mobility of the anions formed by dissociation of the constituents of the electrolyte also play important but

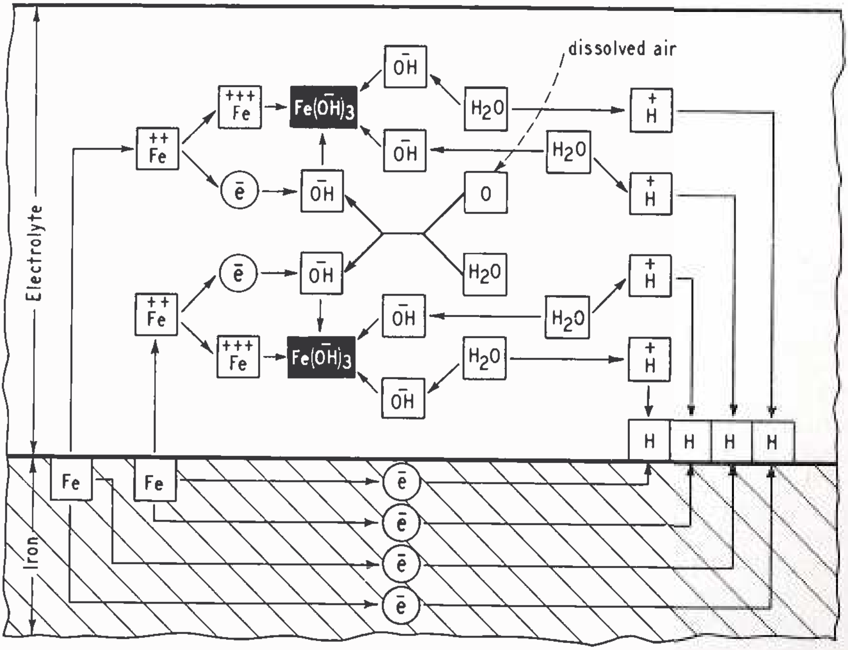

Fig. 3—In the corrosion of iron, ferrous cations are oxidized to ferric cations which are then precipitated from the electrolyte as insoluble ferric hydroxide, or "rust"

complicated parts in determining the speed of attack.

Since oxygen is present in great excess in atmospheric exposure, the velocity of atmospheric corrosion of iron and steel is largely dependent on the presence and nature of the electrolyte. Whether or not an electrolyte is present is dependent on the relative humidity and rainfall. The nature of the electrolyte is determined by the gaseous impurities of the specific environment.

Differential concentrations of oxygen may occur, however, causing corresponding differences in potential. In the case of iron and steel, such potentials appear to be especially large. Potentials so caused, reaching .25 volt for iron in contrast to .07 volt for zinc and .08 volt for cadmium, have been measured in these Laboratories.

From extensive studies in recent years, the effects of the corrosion-product layer are now judged as of extreme importance. Iron rust has been found to have a gel structure which retains from twenty to fifty per cent of water when exposed to dry atmospheres. In these dry atmospheres the water present in the corrosion product is adsorbed on the surface of this gel and is not "free" to be used as the solvent for an electrolytic solution. At relative humidities of about 40 per cent or higher, however, more and more of the adsorbed water is freed to act as a solvent for atmospheric gases. Hence for iron and steel there is a critical corrosion humidity (approximately forty per cent relative humidity, at normal temperatures) above which rapid attack of the iron takes place.

Reducing atmospheric corrosion by adding copper to steel may prove to be a case in point. It would be supposed that the chemical difference between copper and iron would accelerate corrosion by the formation of electrolytic cells with the two metals as electrodes. Apparently this effect is more than counterbalanced by the fact that the presence of copper changes the nature of the corrosion-product layer so that it retards further attack. It may be that this change increases the critical corrosion humidity.

A fresh piece of iron or steel which has come into contact for a short period of time with a relatively dry, pure atmosphere will develop an oxide film over the surface. Where this film is free of cracks or pores the electrochemical properties of that surface are radically different from those of a freshly scraped piece of iron. The oxide film makes the metal chemically passive, like more noble metals. This air-formed film on iron is usually so thin as to be invisible, but under favorable conditions it grows thick enough to show interference colors. The temper colors on tempered steel are due to this type of film. On iron and steel, however, the film tends to crack readily, and it is at these cracks that anodic areas are formed and corrosion first occurs. Imperfections in the film result also from impurities such as slag inclusions which form no film.

One of the biggest of recent advances in combatting the corrosion of steel has resulted from alloying with chromium and chromium-nickel. These constituents appear to impart to the alloy the ability to maintain an impervious protective film under most conditions of exposure. Well known as stainless steels, these alloys are continually finding wider application.

Printing the Test-Board Instructions

By F. S. KINKEAD

Toll Systems Development

IN order to maintain high grade service over long-haul telephone and telegraph circuits, it is necessary to provide test and order wires along each route, which are not connected with the circuits used by customers but are solely for the use of repeater and testboard attendants. Over some of these wires communication is telephonic, but over others it is telegraphic. Telegraph signalling over the latter type of wires has hitherto been by Morse keys and sounders, and has been audible at all stations on the same circuit whether or not all stations were concerned with the message.

In recent years certain disadvantages of such signalling have become apparent. The use of teletypewriters on commercial telegraph circuits has become so widespread that it is difficult to secure repeater attendants trained as Morse telegraph operators. Furthermore so many order wires pass through the larger long-distance offices that the clatter of their sounders confuses an attendant listening to but one, from which he may be some distance away when he is called. There has been developed for test and order wires, therefore, a signalling system in which the keys and sounders are replaced by teletypewriters and a selective calling arrangement causes only those at the interested stations to operate.

The system provides at each station on the wire a teletypewriter, of which one of the No. 15 type is shown in Figure 1, and the selecting equipment shown in Figure 2. Any circuit suitable for half-duplex teletypewriting can be used for the calling and signalling line; the teletypewriter and selector at each station are connected in series in a subscriber's loop from a terminal repeater in the circuit. Control units associated with each selector, shown at left and right of Figure 1, consist of a dial, keys, and lamps. These units provide means of calling and controlling the power supply to all stations on the line.

With this system an operator can dial any other station or group of stations on the line. During dialing, the selectors at all stations operate; when dialing is completed, those at the called stations sound alarms and apply power to the motors of the teletype-

Fig. 1—In the current installations of the selective calling system, a teletypewriter of the No. 15 type is used. Control box and dial are mounted adjacent to it

writers at the calling and called points. When the motors have started, any station can transmit, and all stations where the motors are operating will receive simultaneously.

Since the dial pulses are within the frequency range of the teletypewriter signals, it is necessary to prevent the selectors from being falsely operated by these signals. This is accomplished by virtually removing all selector units from the line circuit when it is in use by slow-release relays which remain operated through normal signals. The selectors will respond, however, when the break key of any teletypewriter is operated to send a long open pulse over the line.

The depression of a key in the control box, causing pulsing relays to transmit five break signals, will stop all motors, clear all selections, and restore all selectors to the original calling condition. When, during communication, another key in the control box is operated, causing the transmission of three instead of five break signals, the motors stop and the selectors return to the line, but the original selections remain. It is then possible to dial another station and add it to those receiving the communication without redialing the stations originally receiving.

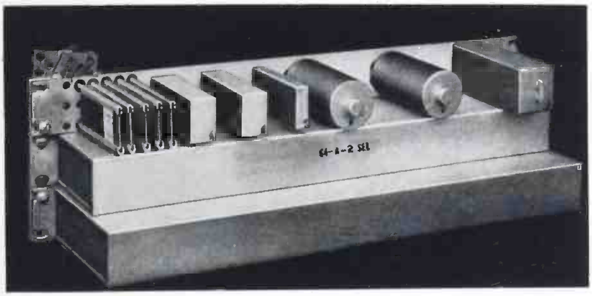

Fig. 2—The selector, containing a No. 204-type selector switch, and selecting and controlling relays, can be mounted on a standard relay rack. It is shown here in the form it takes for one station on any line having any number of stations up to forty-two

Since the line can be used for only one communication at a time, the busy lamp on each control box is lighted while either dialing or printing is in progress at any stations. To indicate trouble, another lamp is lighted when the line is open.

In general the system is similar in its manner of functioning to the familiar rural telephone line. There calling is accomplished by interrupting the ringing current into a code of long and short pulses, analogous to dial pulses, which energize all ringers. The subscribers are the selecting mechanisms, recognizing their code numbers and answering the calls. This similarity points to the fact that the new system is adapted not only to order wire service but to any teletypewriter service where, as with the rural line in telephone service, the distribution of the stations, or the relative infrequency of calls, makes maintenance of a central office uneconomical.

The new system offers, moreover, all the unique possibilities, advantageous in certain services over either telephony or Morse telegraphy, which teletypewriters contribute. Misunderstanding and repetition are eliminated. Messages can be transmitted even though nobody answers the call, and can be filed for permanent record. The possibility of sending to unattended stations is especially helpful when a broadcast is sent to several points.

Mechanically Locking Keys

By G. A. RITCHIE

Telephone Apparatus Development

FOR four-party ringing on subscribers' lines, traffic and operating conditions make desirable the use of push-button keys in trunk and cord circuits. One button is associated with each party letter. Keys of this type commonly consist of the required number of spring assemblies, operated by push buttons and mounted on a frame which is in turn arranged to mount in the keyshelf of the telephone switchboard. The keys have been of two types, broadly speaking, for association with two alternative types of ringing, the older "manual ringing" and the later "machine ringing."

Using a "manual ringing" key, it is necessary for the operator to repeat the operation manually if the subscriber fails to answer on the first ring. It is necessary to provide such keys with an indicating device to assist the operator in relocating the button associated with a called party. In the old manual ringing key (Figure 1) the indicating device consisted of a series of small plates to which a longitudinal motion was imparted by the conical under-side of the downward-moving push buttons acting upon upward turned extensions of the plates. When any button was depressed the plates to the rear of that button moved

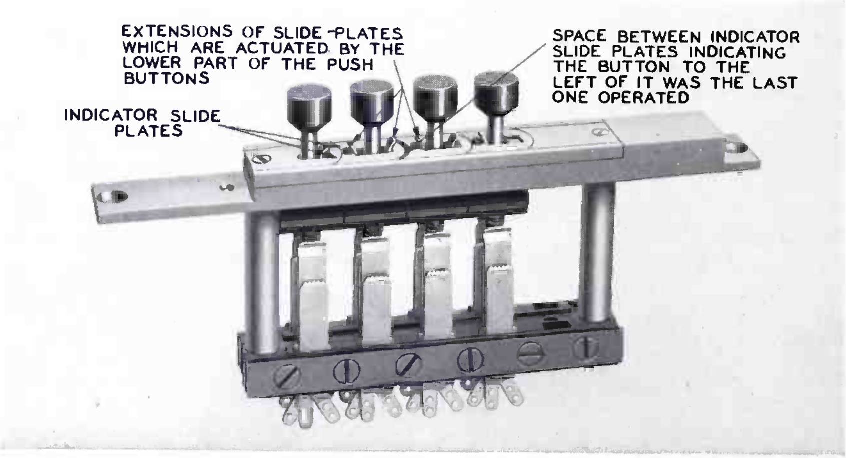

Fig. 1—The push buttons of the old "manual ringing" key contained no locking mechanism, but embodied as an indicating mechanism the small sliding plates appearing on the top. The heavy line which appears to the right of the second button indicates that this was the last button operated

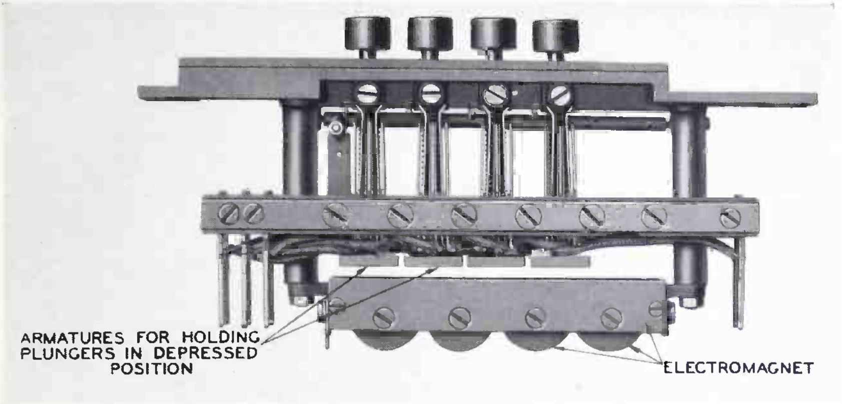

Fig. 2—In the early keys for "machine ringing" the plungers were held in the operated position by an electromagnet

toward the rear of the key and the remainder of them moved toward the front, exposing a red background behind the button.

While manual ringing is used to some extent today, the other arrangement is more usual: that in which ringing, once started by depressing the ringing button associated with the called station, continues intermittently until the subscriber answers or the call is abandoned. Such "machine ringing" necessitates the use of a key in which any one of the buttons will be held in the operated position. Formerly this was accomplished by equipping the keys with electromagnets which were energized when the button was depressed, thus holding the plunger down until the subscriber answered or the call was abandoned. Either of these occurrences automatically cuts off the

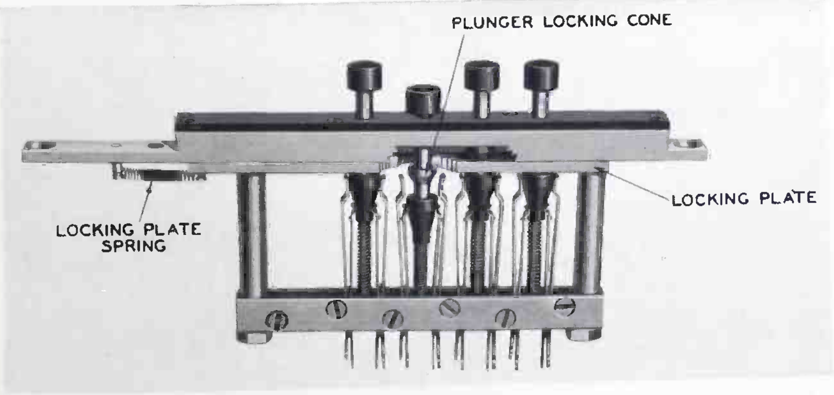

Fig. 3—In mechanically locking keys the action of an electromagnet is replaced by that of a sliding latch plate. The side of the key and the locking plate have been cut out to show the locking mechanism

magnetizing current and permits the button to return to the normal position. These keys were known as electrically locking keys (Figure 2).

To economize space and power and to simplify design, this type of key was subsequently replaced by mechanically locking keys. In these keys the plunger of any depressed ringing button is held by a mechanical locking device in the operated position where it remains until the operation of another ringing button releases it.

In its early form (Figure 3) the mechanically locking key was equipped with a sliding locking plate perforated with holes through which the plunger rods passed. When a button was depressed a metal cone which formed part of the plunger rod associated with that button caused the locking plate to move longitudinally against the pressure of a spring until the top of the cone passed below the lower surface of the locking plate after which the latter returned to its initial position and held the plunger in the depressed position. The longitudinal movement of the locking plate due to the subsequent operation of another plunger would disengage the plunger previously depressed, allowing it to return to its normal position.

In a later design of keys of this type (Figure 4) the serviceable life of the key was materially increased by equipping the locking plate with rollers, engaging the plunger cones in the locked position. Furthermore, improved methods of building up the spring assemblies afforded greater flexibility in arranging different spring combinations, at the same time giving a greater margin of safety against electrical breakdown.

In Figure 5 is shown a typical manual ringing key of the type used at the present time. In this key the mechanically locking feature has been utilized as a means of indicating the button last operated, thus permitting the elimination of the sliding plate indicators used on the older type of manual ringing keys. It is similar in construction to the machine ringing key but is arranged so that the contact

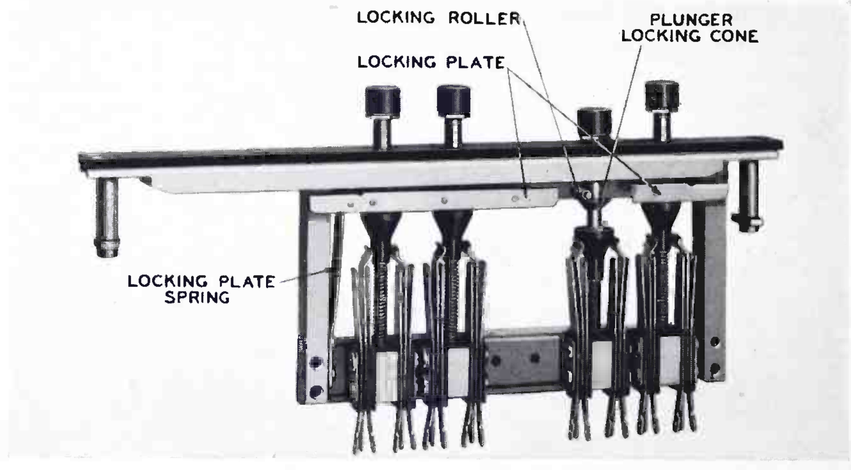

Fig. 4—By equipping the latch plate with rollers, its useful life has been increased. The side of the locking plate has been cut out to show one of the rollers

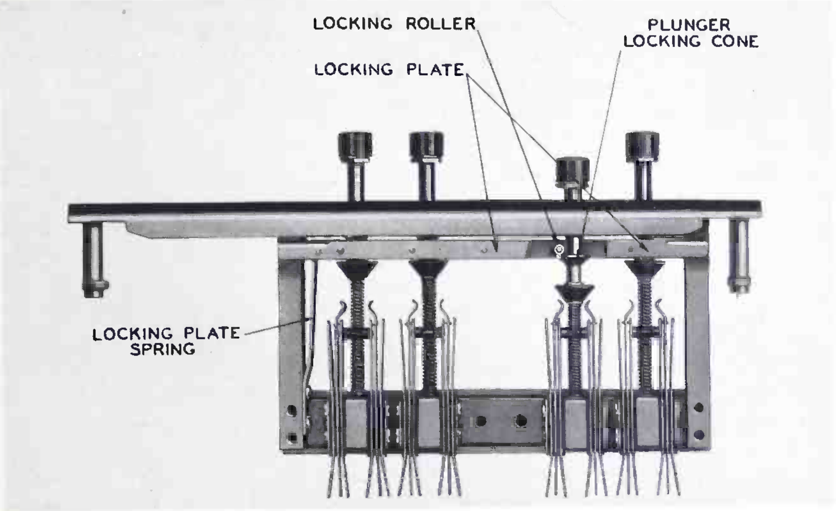

Fig. 5—In the present manual ringing key, a button after being operated returns to an unoperated but partially depressed position which serves to identify it as the button last operated

springs are operated only while the buttons are held manually depressed to the extreme downward limit of their stroke. When the operating pressure is removed the button returns to an intermediate position where the contact springs are unoperated. This partially depressed position identifies the button as the one last operated. Subsequent operation of any other ringing button moves the locking plate and restores the previously operated button to normal.

While the primary use for mechanically locking keys is in cord and trunk circuits they are also used to a considerable extent for switching at subscribers' stations. The keys used for this purpose do not differ materially in construction or operation from those previously described except that since they are usually required for mounting on a desk or table, they are provided with some form of enclosure.

Switchboard Lamps

By J. C. WRIGHT

Telephone Apparatus Development

SMALL incandescent lamps were first used for line signals in a telephone switchboard installed in 1894. During the next few years, several different designs of lamps were developed with various methods of mounting, but gradually all but the No. 2 type were abandoned. Although there are twenty-five differently coded switchboard lamps in use in the Bell System today, they all are of the same size and shape, and of the same external design as the No. 2 type, one of which is shown in Figure 1.

Probably few people realize the exacting requirements which switchboard lamps must meet. In a switchboard other apparatus may be associated with the lamp and, consequently, the characteristics of the lamp affect the operation of this other apparatus. Not only must the switchboard lamp give a satisfactory signal at low voltage, but it must not produce objectionable glare at the higher voltages and in some cases the current must be within certain limits so that any associated apparatus will function properly.

Fig. 1—All switchboard lamps of the present time, although differing widely in voltage, current, and illumination characteristics, have similar outside dimensions

The strictness of the requirements is illustrated by the demands placed on the 18-volt P.B.X. lamp. It must give a satisfactory signal with a potential at the P.B.X. of only 14 volts and with 200 ohms in series with the lamp, and must have a satisfactory life when operating at 26 volts with no resistance in series with it.

As was true of the first illuminating lamps, the early switchboard lamps all had carbon filaments. Although practically all carbon filament lamps employed for commercial lighting have been replaced by tungsten lamps, switchboard lamps of both types are used extensively in the telephone plant. For certain telephone purposes the characteristics of a carbon filament are required, while for others the use of tungsten may be necessary. During the past few years, however, the use of tungsten switchboard lamps has been increasing rapidly, and for some purposes carbon lamps have been largely superseded.

A typical No. 2 carbon-filament switchboard lamp is shown in Figure 2. The filament is attached at the ends to two straight mount wires which are supported by the inner glass structure of the lamp. These mount wires, in turn, are welded at the other end to two seal wires which extend through the glass bulb and are either soldered or welded to the inside surface of the terminals. There are four different forms or shapes of filament used for carbon lamps. The simplest is the half loop, or U. The others are the single, double, or triple loops. The type used depends upon the length and diameter of the filament required for the particular characteristics desired, but in all cases the filament is stiff enough to require support only at the ends where it is fastened to the mount wires.

The specific resistance of tungsten is much lower than that of carbon so that for lamps of the same current and voltage rating a filament both smaller in diameter and greater in length is necessary when tungsten is used. To get a length of filament in the lamp sufficient to give the required resistance, it has been found necessary to wind the filament in the form of a helix. Even then it is difficult at times to get a sufficient length of it into the bulb. In one case, for example, it is necessary to mount more than six inches of tungsten wire approximately .00035 inch in diameter, within the cylindrical space of a bulb only $\frac{3}{16}$ inch in diameter and not more than half an inch long.

The helix is formed by winding fine tungsten wire on a steel mandrel with a diameter of from .0025 to .014 inch, depending upon the type of lamp. Following this the mandrel is cut into lengths that will give the desired number of turns in the helix, and placed in acid, which dissolves the steel and leaves the helix of tungsten wire. The filament is wound on the mandrel at high speed and the delicacy of the operation can be appreciated only when it is observed through a microscope. After the removal of the mandrel, the filament is clamped or welded to the ends of the mount wires. In lamps rated at eight volts or less, the filament is short enough not to require additional supports, but for higher voltages one or two anchor wires are required to support the greater length of helix. The arrangement of a two-support tungsten filament is shown in Figure 3.

For switchboard signaling purposes the only part of the light from the lamp that is useful is that which falls on the rear surface of the glass lamp cap or translucent designation card ordinarily placed in front of the bulb. This is termed the "end illumination" of the lamp and is the average illumination in foot candles on a plane surface .28 inch in diameter touching the end of the bulb and perpendicular to the axis of the lamp. For convenience the term "end illumination in foot candles" is contracted to "end foot candles." Commercial types of photometer equipment are not suitable

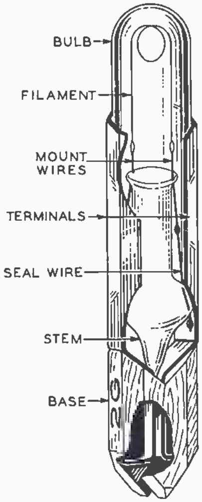

Fig. 2—Construction of the type 2 lamp except for the size and material of the filament is the same for all ratings

for measuring this characteristic so the Laboratories has developed a special photometer attachment for the purpose.

Since carbon has a negative temperature-resistance coefficient while that of tungsten is positive, the characteristics of the two types of lamps are quite different. A tungsten lamp of the same voltage and current rating as a carbon lamp usually gives a satisfactory signal at a lower voltage, and withstands over-voltage better. Also the cold resistance of the tungsten lamp is only a fraction of that of a carbon lamp of the same voltage and current rating. When voltage is first applied, therefore, a momentary surge of current flows in a tungsten lamp which causes it to reach normal brilliance more quickly than a carbon lamp. This quicker response of the tungsten lamp gives it better "flashing" characteristics than the carbon lamp so that its use is more desirable under certain circuit conditions.

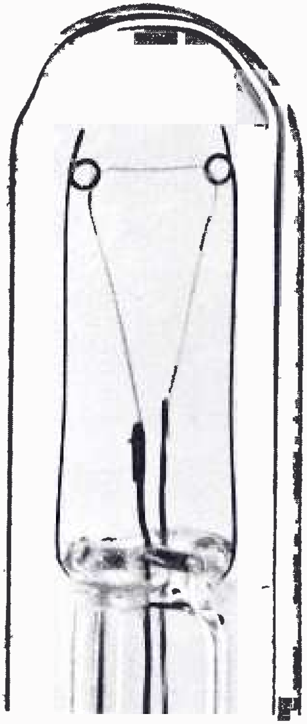
Fig. 3—Arrangement of a double supported tungsten filament

Under other conditions, where the lamp is shunted with a resistance, the positive temperature coefficient of tungsten is a disadvantage. Because its resistance falls with decrease in temperature, a tungsten filament will not shunt out when placed in a circuit designed for a similarly rated carbon lamp. Also the effect of the initial surge of current in a tungsten lamp may be more severe on the contacts of control relays.

One of the earliest needs for the tungsten lamp arose in connection with P.B.X. switchboards not equipped with line relays. For a number of years an 18-volt carbon lamp was used, but because of the severe conditions mentioned earlier in this article, this lamp did not receive sufficient voltage to give a satisfactory signal under the worst conditions. It was found possible, however, to develop a tungsten lamp which would meet both maximum and minimum voltage conditions more satisfactorily. As a result, the tungsten lamp has replaced the carbon lamp to a large extent for this service.

The characteristics of these two lamps are shown by the curves of Figure 4 from which it may be seen that the tungsten lamp has a "ballasting" effect, that is, the percentage change in current is less than the corresponding percentage change in voltage. This explains the advantage that the tungsten lamp has in this service, for when the battery voltage is low and the loop resistance is high, the loop current with the tungsten lamp will be greater than with the carbon, and when the voltage is high and the loop resistance low the current with the tungsten lamp will be less than with the carbon.

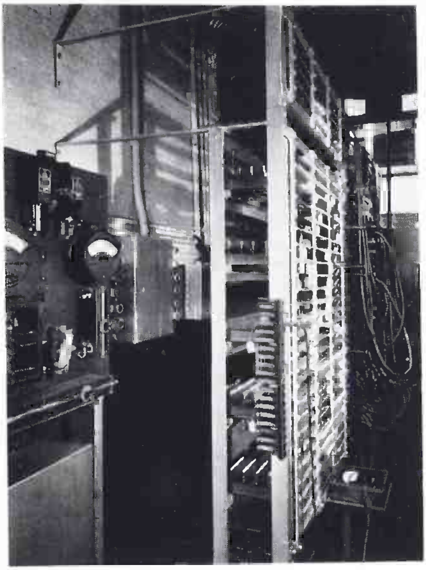

Fig. 5—A portion of the Laboratories' life-testing equipment for switchboard lamps

Tungsten lamps are also used for idle-trunk-indicating purposes in the toll tandem board, and for busy signals for toll switchboards as already described in the Record.* Here they are used in place of magnetic busy signals and are operated on commercial alternating current which is delivered to them through step-down transformers and protective devices. By using these lamps in a combined lamp socket mounting and designation strip it has been possible to effect a reduction in equipment space required on the face of the board and a lowered cost of power. Carbon lamps would not have been as satisfactory for this service because they would have required higher operating voltage and current to give satisfactory signals, and would have less satisfactory illumination characteristics and shorter life than the tungsten lamps.

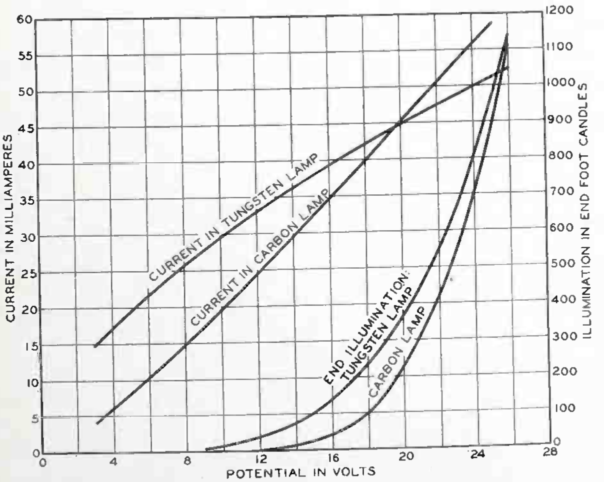

Fig. 4—Typical comparative characteristics of tungsten and carbon lamps of equivalent rating

Before new designs of switchboard lamps are adopted, or changes made in materials, construction or manufacturing processes, it is necessary to determine the effect of such changes not only upon the useful life of the lamp but upon its current and illumination characteristics during life. For this purpose it is necessary to carry on extensive life tests.

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*Bell Laboratories Record, *June*, 1931, *p*. 467.

Part of the Laboratories life testing equipment is shown in Figure 5. Alternating current is used and practically any required potential up to 110 volts is available. The lamps may be tested in both vertical and horizontal positions. The total equipment has a capacity for testing 7000 lamps.

Police Radio Transmitter Installed

A NEW WESTERN Electric 1 kw radio transmitter has recently been installed at Police Headquarters in New York, with call letters WPEG. It is similar to the 304A Radio Transmitting Equipment recently developed for broadcasting purposes.

B. R. Cole, who supervised the installation, points out interior details of the new police transmitter to Patrolman Edward Barth.

This equipment is being supplemented by two additional 400-watt radio transmitters, one to be located in the Bronx and the other in Brooklyn. These stations will form a radio transmitting network covering greater New York. The network will be controlled from Headquarters and police alarms will be broadcast over all stations from this point. This control is made possible through the 9A Speech Input Equipment which has been installed adjacent to the transmitting equipment at Center Street. A switch is provided on the control panel whereby the police commissioner or chief inspector may personally dispatch orders through microphones in their offices.

Dispatching of orders will take place from a newly fitted out operating room which is adjacent to the headquarters telephone switchboard. Incoming calls are sent to a dispatcher in the operating room who has before him on a large table detailed maps showing police precincts in all the boroughs. Small numbered discs represent the cruising police cars. With the disks arranged on the maps before him the dispatcher sees what cars are available and notifies the announcer what car or cars are to be dispatched to the scene of the trouble.

Measuring the Illumination From Switchboard Lamps

By N. INSLEY
Telephone Apparatus Development

ORDINARY incandescent lamps are rated in watts and a purchaser buys enough total wattage to light satisfactorily whatever location he has in mind. He is really interested in the amount of illumination in foot candles on some working surface, such as a desk or table, but because the lighting fixtures may be located in various positions and because the amount of reflected light varies with the color and nearness of the walls and ceiling, there is no uniform relationship between the luminous output of the lamp and the intensity of illumination on the working plane.

Switchboard lamps on the other hand are intended to give a visible signal and the characteristic of interest is the luminous intensity of the front of the lamp cap or designation strip. As it is not feasible to specify rigidly the density and diffusion of the caps, these variable factors must be eliminated from measurements which are intended to yield information about the lamps themselves. Measurement technique, therefore, has been in use for many years which gives the amount of illumination delivered to the rear face of the lamp cap since the luminous intensity of the front of any given lamp cap or designation strip is proportional to the light received by the back. Illumination is measured in foot candles and since this value is determined in the direction of the end of the lamp, the unit was styled the "end-foot-candle."

The relative positions of lamp and cap in a switchboard are shown in

Figure 1. The inside diameters of the caps now average .28 inches and the new unit is defined as the average illumination in foot candles produced by the lamp on a plane circular area .28 inch in diameter touching the tip of the lamp and perpendicular to the lamp's axis. It has proved to be an excellent measure of the signal ability of switchboard lamps.

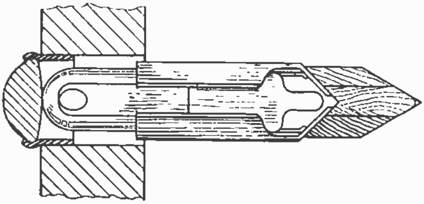


Fig. 1—As mounted in a switchboard the axis of the lamp is perpendicular to the rear surface of the lamp-cap lens and the lamp tip is touching it

As set up in the Laboratories in 1913, the apparatus for measuring end-foot-candles, abbreviated E.F.C., consisted of a portable photometer and a special switchboard lamp holder made of a thin hard-rubber shield with a .28 inch diameter hole, clamped to a disc of diffusing glass. This disc was located parallel to and about two inches from a white mat surface. The light from the lamp that passed through the diffusing screen and lighted the mat surface was measured by the photometer. Calibration was obtained by placing a standardized lamp of about 16 candle power a known distance from the diffusing disc. Because of the large filament of the standard lamp, the distance from the glass had to be greater than for the switchboard lamp, with the result that the amount of light received in the photometer was too small for satisfactory calibration when the standard .28 inch opening was used. To avoid this difficulty a shield with an opening thirty times greater was employed, and it was assumed that the illumination would be thirty times as great. The calibration was made on this basis.

For some ten years this method proved satisfactory, but with requirements becoming more severe it became necessary to measure switchboard lamps more accurately and over a wider range of illumination. Forty E.F.C. used to be the lowest reading of interest, then 20 E.F.C. became the lowest limit, and now one E.F.C. is measured as a non-signal condition. At this point the intensities seen by the operator are almost as low as moonlight.

To meet these stricter requirements it became necessary to redesign the apparatus to obtain three major improvements: better mechanical fea-

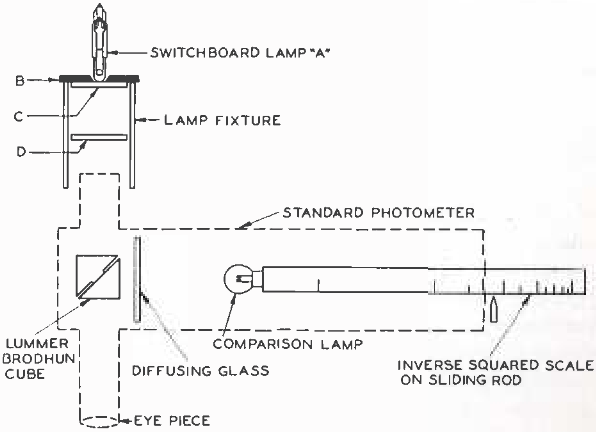


Fig. 2—End-foot-candles are measured at present by a portable photometer and a special lamp fixture

tures, reduction of the light loss in the optical system, and decrease in calibration errors. The arrangement of the present apparatus is shown in Figure 2. It has two essential parts: a standard portable photometer and a lamp fixture.

The latter consists of a bakelite shield B, with a .28 inch hole, a diffusing glass C, and a second diffusing glass D, which is evenly illuminated by the diffused light from the first diffusing glass. The second diffusing glass is employed to present an evenly illuminated area to be viewed through the photometer, and to insure that it is the average illumination through the .28 inch hole that is measured. In the earlier apparatus a white mat surface was employed instead of this second diffusing glass, and was placed two inches from the first glass instead of one-half inch as is the present one. This change, together with others, such as the use of thinner glass, resulted in improving the light transmission some tenfold. The operator can measure four E.F.C. with the present equipment as well as forty with the earlier.

To obviate the necessity of specifying the transmission characteristics of the diffusing discs C and D (Figure 2) the photometer is calibrated by delivering a known illumination to disc C, from the direction of the lamps to be measured. A 21 candle-power lamp of the automobile headlight type is mounted in a small brass housing with one opening as shown in Figure 3. The complete fixture is sent to a recognized standardizing laboratory to be calibrated for both 20 and 100 foot candles on a surface flush with the outside of the bakelite spacer A. This is done by adjusting the current in the lamp until the light on this surface is at these two values as measured by the standard photometer.

To calibrate the portable photometer equipment in the Laboratories, the spacer A—which has the same thickness as shield B of Figure 2—is removed and the fixture is clamped with its opening against the .28 inch hole of shield B of the photometer. The current in the comparison lamp of the photometer is then adjusted until, with the photometer reading 20 or 100 foot candles, the concentric discs viewed through the photometer merge into one. This determines the value of current at which the comparison lamp should be operated. Various errors, such as that due to using different sizes of holes, are thus eliminated, and the accuracy of the measurements has been greatly increased.

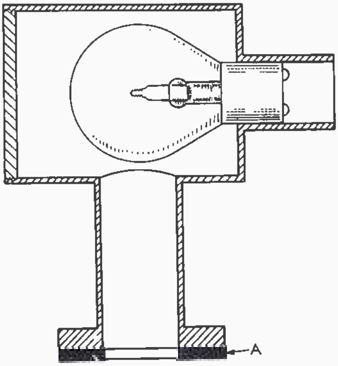


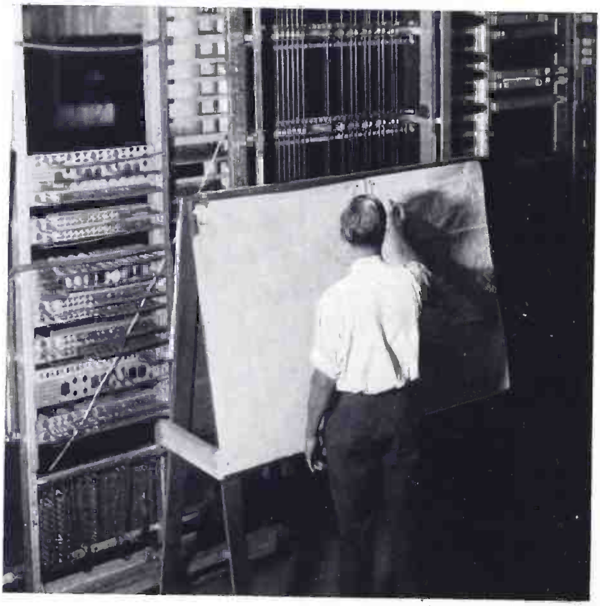
Fig. 3—An improved calibrating method employs an automobile type lamp in a special fitting

The lamp to be measured is placed in the instrument as shown in Figure 2 just outside the shield B and the comparison lamp in the photometer is moved toward or away from its diffusing glass till the brightness of the two surfaces seen in the Lummer-Brodhun cube appears the same. At this setting, the illumination in E.F.C. is read directly from the sliding scale of the photometer.

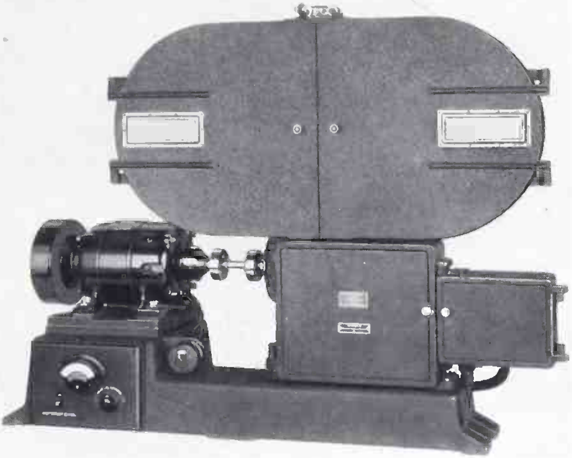
Of the difficulties encountered in photometering switchboard lamps, the large color range normally encountered is perhaps the greatest. Ordinary incandescent lamps are measured under the fixed conditions of voltage and efficiency at which they are designed to operate. Switchboard lamps, on the other hand, although they have a nominal voltage rating, may be subjected to a wide variation of voltage in service. It is necessary to know not only how much illumination a lamp gives at its rated voltage but how low the voltage may go and still produce a visible signal, and also how high the illumination is when the voltage reaches a value at which the lamp has only a few hours' life.

This wide range of voltages produces a variation in the temperature and thus of the color of the filament. The range extends from a dull red to an intense white and the illumination, from less than 10 E.F.C. to thousands. Such color variations limit the precision of reading but so far attempts to correct it have not proved beneficial. Photoelectric cells and other methods that might eliminate the necessity of human judgment have not been found satisfactory under these conditions although they are generally accepted for measuring lamps at fixed voltages.

* * *



E. H. Toney tracing a circuit in the Panel System testing laboratory



A Re-recording Machine For Sound Films

By J. J. KUHN

Special Products Engineer

A MODERN sound-picture film as "released" usually bears little resemblance to the films initially taken of the production. It is rather a modified composite built from sections of the original films with the addition of various accompanying sounds such as rain, thunder, trains, revolver shots, or orchestral accompaniments. Not only are these other effects added, but the volume levels of the various sections are adjusted to make the whole fit properly together. The building up of a complete sound picture for release is thus an art in itself, and requires apparatus and a technique distinct from those of the original taking.

In the construction of the final "released" picture, sections of the sound tracks of preliminary films, corrected for level, are transferred electrically and in the desired order onto a new film. This requires a machine to convert the variations of the sound track of a film into equivalent electrical currents to be used not by loud speakers but for the recording of a new sound track. The machine that does this, known as a re-recorder, thus plays an essential part in the making of the final form of the picture.

Such a piece of apparatus, embodying all the refinements and improvements that a wide but rapidly acquired experience has made possible, has recently been developed by the Laboratories and is being offered to the industry by the Electrical Research Products, Inc. Requirements placed on it are more severe than those demanded of a reproducer since in the process of re-recording, of which there may be several successive steps, the variations introduced by the apparatus are cumulative. The reproduction must be as nearly perfect as is commercially possible.

Front and rear views of the new Western Electric machine are shown at the head of this article and in Figure 1. Mechanically there are three major sections—a film magazine above, a sound reproducing head beneath it, and a driving motor at one end, all mounted on a substantial cast iron base. The film magazine compartment has space for two reels of either one or two thousand feet capacity. One is the supply reel and the other the take-up reel. Beneath it is the reproducing head which includes a sound lamp with the necessary optical system for focusing the light on the sound track, and a photoelectric cell for receiving the modulated light beam. To the left of the reproducing head, when viewed from the front, is the driving motor which is arranged to be synchronized with the recording machine with which the re-recorder is being used.

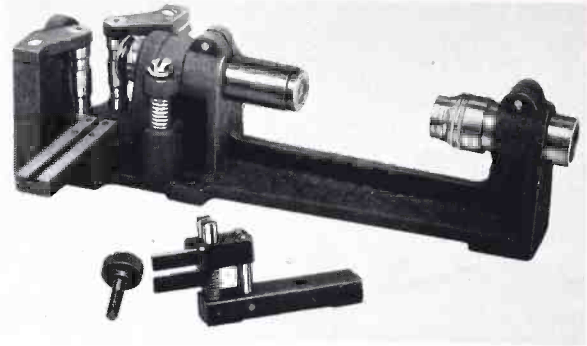


Fig. 2—The three lens units of the optical system are mounted on a common support which also carries the double roller sound aperture

Details of the reproducing head are shown in Figure 3. The drive shaft from the motor enters a gear box, which is integral with the head but faces the opposite direction, and through suitable gears drives two sprockets within the head. One, in the upper left hand corner, is a combination pull-down and hold-back, and the other is the sound sprocket, which draws the film through the light beam. These are the only driven sprockets in the compartment.

The film, coming from the supply reel of the film magazine, is held against the pull-down sprocket by a double roll retainer, then passes around an idler roller directly be-

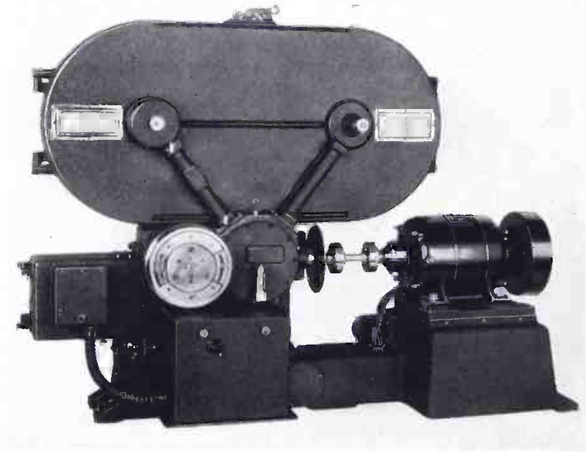


Fig. 1—On the rear of the new re-recorder are the photoelectric cell cabinet, the gear box, and the spring-damped flywheel of the sound sprocket

neath it, and then around a drag roller which maintains a constant tension on the film as it passes up through the sound aperture. From here it passes over the sound sprocket, by the other side of the pull-down sprocket, and then before passing back to the film magazine runs over the roller of the signalling device. This device, evident in both Figures 3 and 4, gives an alarm if the film should break. Like most of the other rollers in the compartment, the drag roller is of stainless steel and accurately made to insure that it runs true and with constant tension. Flanges on each side guide the film along the proper path, and tension is maintained by friction discs bearing against the sides. Tension may be controlled by adjusting a compression spring on the outer face of the drag roller. The film is held close to this drag by a roll of impregnated fabric tensioned by a flat steel spring.

The sound aperture is of the double roller type which insures a smooth, steady movement of the film past the scanning beam, and a minimum likelihood of its moving out of the focal plane. These rollers, also of stainless steel, are very accurately ground and rotate in jewel bearings. They are rigidly mounted and doweled in place so that they may be removed for inspection or cleaning. The position of the two rollers on opposite sides of the film gives a pivoting action of the film around a point midway between the two rollers. This tends to maintain the scanning point on the focal plane while if both rollers were on the same side of the film, changes in the stiffness of the film due to variations in thickness, temperature, or age would throw it out of the focal plane.

The optical system is shown in the photograph of Figure 2 and diagrammatically in Figure 4. It is mounted

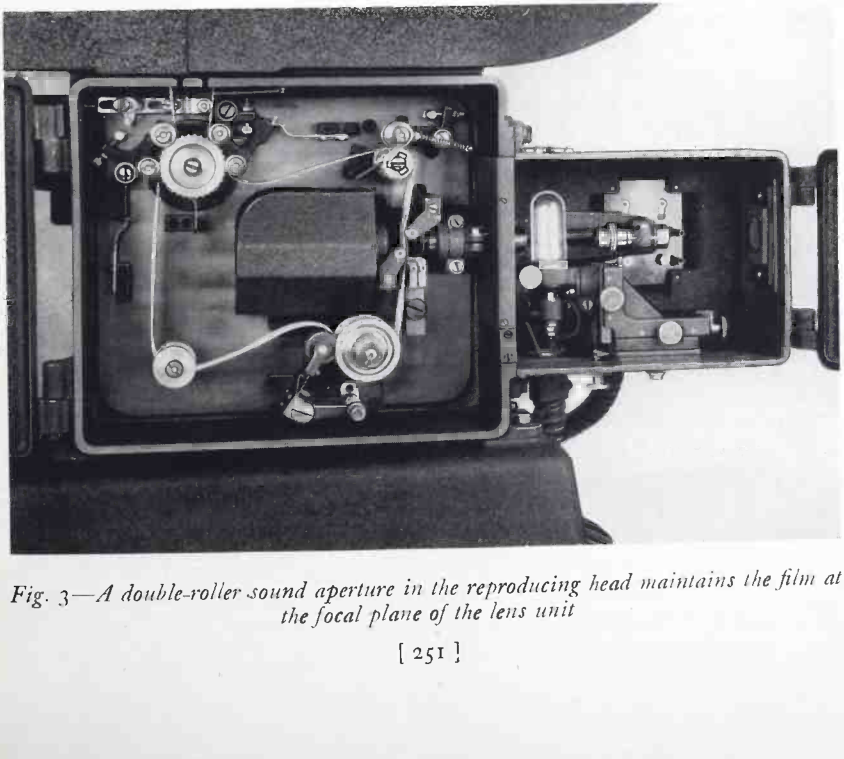


Fig. 3—A double-roller sound aperture in the reproducing head maintains the film at the focal plane of the lens unit

on a separate base which is secured to the casting of the head. It has three major elements. On the left is a collimator lens for focusing the light passing through the film onto the sensitive part of the photoelectric cell. In the middle is the reproducing lens unit for projecting the reduced image of the narrow illuminated slit onto the sound track, and at the right a lens used for adjusting lamps in the field. The reproducing lens unit consists of an objective lens at the left, a slit, and at the right a condensing lens. The slit is on the optical axis and midway between the two lenses. Its opening is accurately made the proper width, and its edges are lapped for smoothness and parallelism throughout their entire length.

A six-volt, nine-ampere, ribbon-filament lamp is employed, and the condensing lens, with a magnification of unity, focuses an image of the filament on the slit. The objective lens gives a 1½ to 1 reduction which results in an image in the plane of the film .085 inch long and .001 wide. Special care is taken to insure an image evenly illuminated throughout its length and with clearly defined edges.

Two bearings support the lens tube,

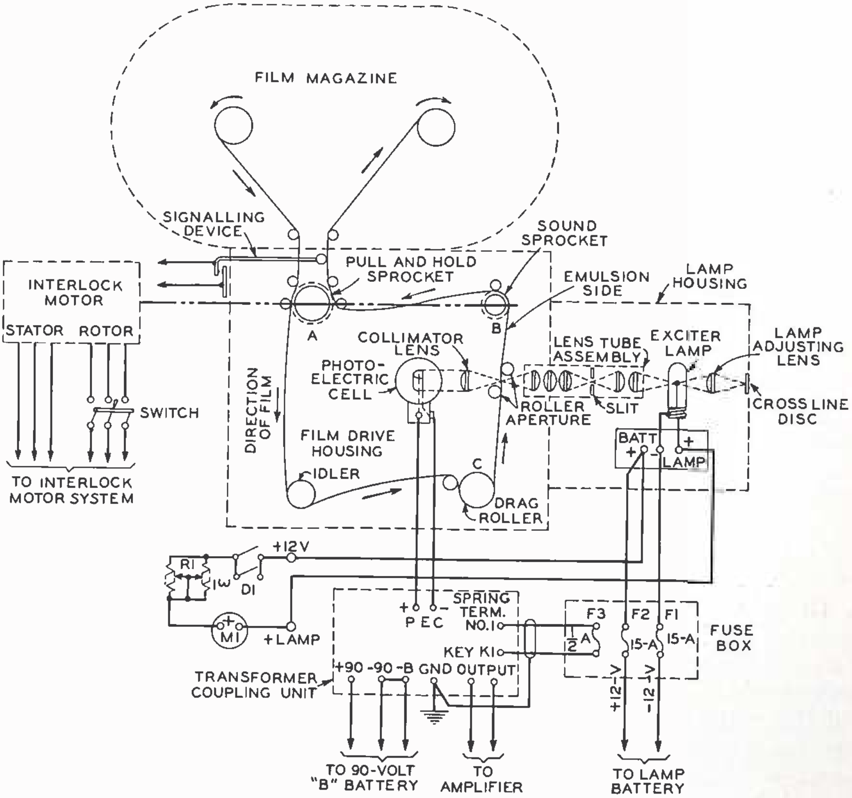


Fig. 4—A lamp adjusting lens and a cross-line disc in the end of the projector head permit easy adjustment of the sound lamp

one of them being slotted to permit clamping the tube in place. Between them is a collar which, by an adjusting screw, allows the tube to be rotated sufficiently to permit obtaining the correct azimuth adjustment. Focusing may be done in the field by a knurled head on the objective lens mounting which is then held in place by a lock nut.

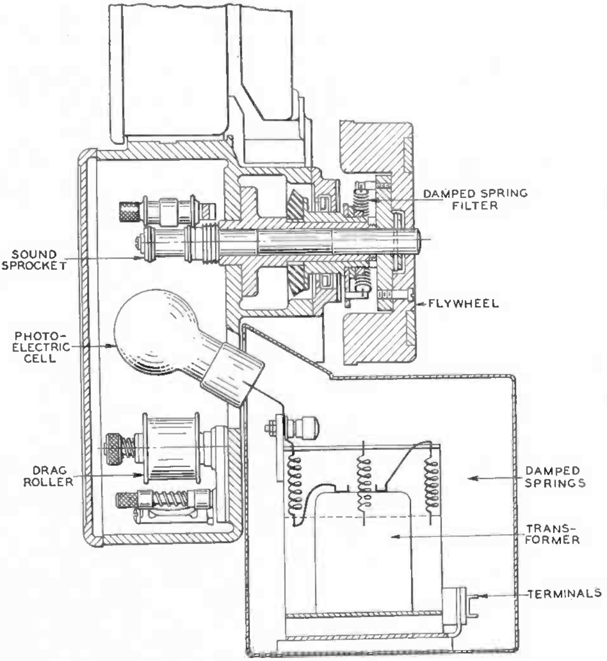


Fig. 5—The coupling transformer for the photoelectric cell is carried on a spring support to decrease the likelihood of outside interference

When first set up the various units are accurately adjusted with the aid of single-frequency films. When this has been done, the lamp adjusting lens is focused so that a sharp image of the lamp filament is projected on a ground glass screen at the rear of the lamp housing. This screen carries cross lines and is adjusted so that the lines correspond with the center of the projected image. To adjust subsequent lamps it is necessary only to center the filament image on these cross lines. This arrangement also makes it possible to tell when the filament sags and thus when the lamp needs replacement.

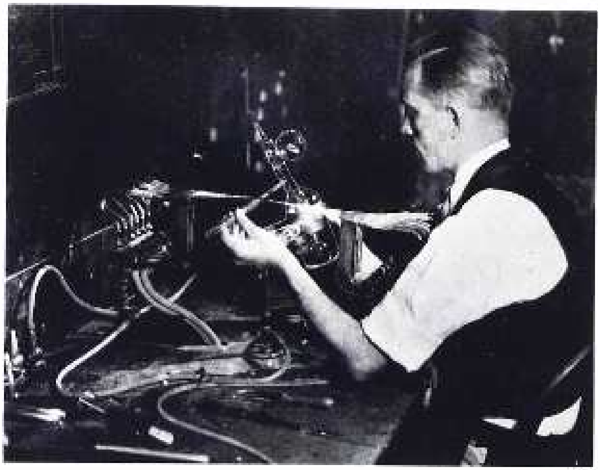
The sound lamp is adjustable in all directions as indicated on Figure 3. Contrary to normal expectation, adjustment of the lamp is not very critical. An out-of-focus condition in the horizontal position by as much as 3½ turns of the adjusting screw results in only a half db loss in volume. Although the range is not so great for the other directions, adjustment of the lamp is possible in a comparatively short time since the width of the lamp filament is 30 times that of the slit.

Projecting through the rear wall of the sound head, the photoelectric cell has its terminals adjacent to those of its coupling transformer which is mounted on springs in a separate housing as shown in Figure 5. The spring suspension insures that extraneous vibrations will not be picked up by the transformer.

One of the prime requisites for high quality reproduction is a steady motion of the film through the light aperture. As an aid in securing this the sound sprocket has on its outer end a flywheel driven by a damped spring as shown in the illustrations. The motor, rated at ¼ H.P. and running at 1200 rpm, also carries a flywheel on the outer end of its shaft. The uniformity of rotation of the sound sprocket may be checked stroboscopically by a shutter with 36 slots mounted on the motor drive shaft, and 120 lines equally spaced around the rim of the flywheel. Both the slots and lines are accurately spaced by microscopic measuring devices at the factory. The combined error in location of the 36 slots is held to a thousandth of an inch.

The motor is mounted on a plate dovetailed to the base of the machine, so as to permit its being withdrawn endwise without necessitating readjustment. Flexible couplings are employed which are rigid torsionally but allow a certain amount of end play of the armature without transmitting it to the head. A switch is located in the base so that the motor may be shut off independently of the system when the film in the magazine has been completely reproduced.

The extraordinary efforts to obtain accuracy, although costly, insure that all machines sent to the field will provide the high grade of service expected of them. Excluding the scanning loss, the frequency response characteristic of the reproducing system—from a modulated light beam falling on the photoelectric cell to the output terminals—does not vary more than one db for a frequency range of from 50 to 7000 cycles. Even at 10,000 cycles the loss is only 2 db. In addition the machine has a volume range of 57 db, which is greatly in excess of present-day practice.



E. D. Deery completing glass construction of a photoelectric cell used in research studies

Laboratory For Precision Linear Measurements

By E. C. ERICKSON
Telephone Apparatus Development

TO insure interchangeability without individual fitting of the large numbers of telephone parts, dimensions must be accurately controlled. Gauges are employed to determine whether or not the various parts meet their required dimensions, so that the dimensions of these gauges must be known to a higher degree of accuracy than those of the parts to be gauged. The instruments by which the gauges are checked, therefore, must be capable of still more precise measurements. If, for example, a certain part is to be held to an accuracy of .001 inch, the gauge used to check it should be accurate to .0001 inch, and the apparatus used to measure the gauge must be accurate to .00001 inch. As a result there is a need for very accurate measuring apparatus. This high precision requires that the temperature of the gauges to be measured and that the measuring apparatus be held at uniform temperature. Consequently the measuring laboratory is maintained at a temperature of 68° at all times by air conditioning equipment which also removes dust that might collect on the gauges. The gauges are allowed to remain in this room until they have reached this temperature. It is also important that the measuring apparatus be shielded from building vibrations. The apparatus is therefore so located that it is practically free from such disturbances.

Most linear measurements are of one or the other of two types. For one, known as end measurements, contact is made with the ends of the part itself. A common example is a measurement made with a machinist's micrometer. For the other type, the distance between two lines or points on the part is compared—usually with optical magnification—with the lines on a calibrated scale.

A machine capable of making end measurements on pieces up to forty inches long and to a precision of one hundred-thousandth of an inch is shown in Figure 1. The part to be measured is laid on two adjustable supports, shown in the center, and two other movable attachments are brought in contact with the ends. The one at the right is adjusted to give a definite contact pressure as indicated by a sensitive indicator mounted on the machine. The one at the left carries an accurately graduated scale twenty inches long. Two supports rigidly fastened to the base of the machine carry micrometer microscopes for reading the scale. The left hand one is used where the part is longer than twenty inches and the one on the right, when it is less. Measurement is made by first reading the scale through the microscope when a standard gauge block of a length close to that of the part to be measured is in the machine, and then reading the scale with the part to be measured put in place of the gauge block. The difference between the two readings added to or subtracted from the length of the gauge block is the correct length.

An instrument for line measurements is the line comparator of Figure 2. Here the dimensions of one of the racks used on panel selectors are being compared with a standard yard. To measure the distance between the slots on the rack, the two micrometer microscopes are moved along guides on the frame of the machine until their cross-hairs are accurately over two points on the slots. Then the carriage

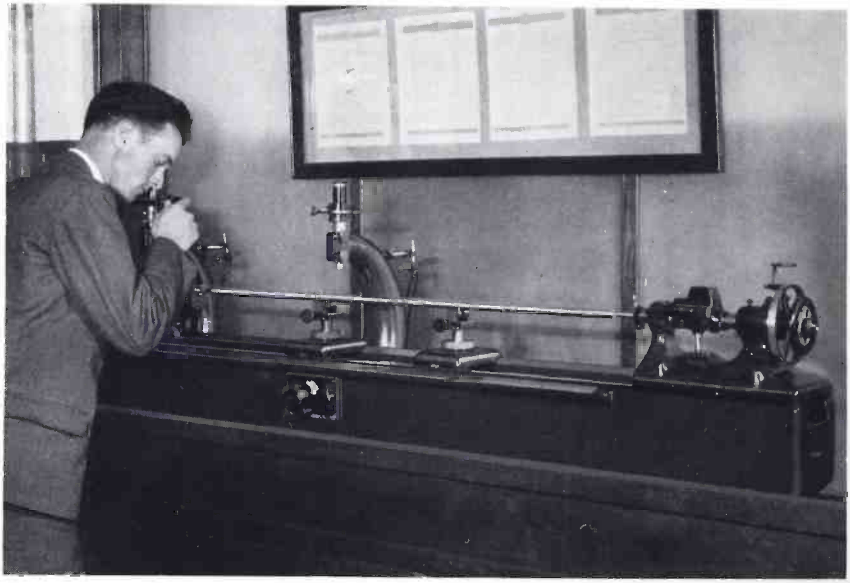


Fig. 1—R. O. Sloan making a precise length determination of a steel rod

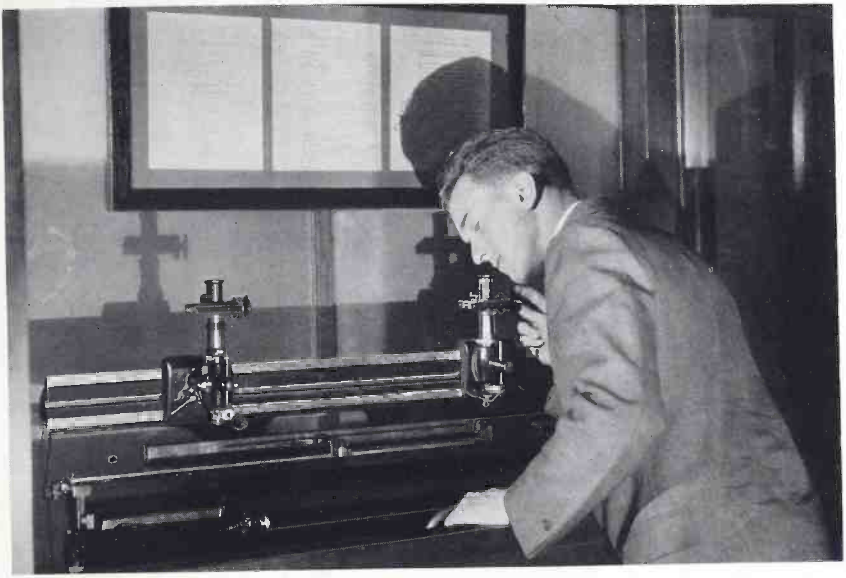


Fig. 2—Dimensions of a rack used on panel selectors being checked against a standard scale

on which both the rack and the standard yard is mounted is moved forward until the lines of the standard may be observed by the microscope. The distance between the marks on the rack can then be determined from the known values of the scale on the standard. The standard yard, which is calibrated by the U. S. Bureau of Standards from time to time, is of H form in cross section with scale lines engraved on the upper side of the crossbar of the H. The material is an alloy with a very accurately known temperature coefficient.

Another line measuring instrument of somewhat different type is the star comparator shown in the headpiece. This instrument, originally designed for determining the position of celestial bodies on astronomical photographs, but adapted by certain modifications for our work, carries a microscope on a sliding carriage moving across the bed of the machine. The table to which the part to be measured is clamped may by moved at right angles to the line of travel of the microscope and may also be turned in azimuth. With this arrangement an area of 400 square centimeters may be covered by the microscope, and points within this area may be located by either rectangular or polar coordinates. Linear movements may be read to one micron—approximately .00004 inch and angular ones to one minute of arc. The flexibility and accuracy of the machine permit measurements of many complicated parts which would be impossible by other methods.

A very useful and convenient instrument with which end measurements may be made to an accuracy of .00001 inch on parts of limited lengths is the optimeter shown in the photograph on the title page of this issue. Although employed chiefly for measuring the

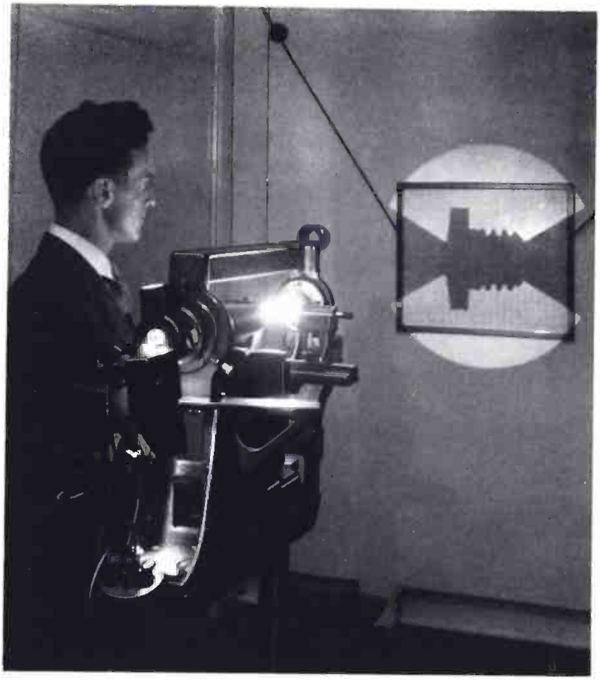


Fig. 3—Contours of small parts may be quickly and accurately measured by a contour projector

thickness of thin sheets of materials, it may be used for measuring parts up to three inches long by the aid of supplementary gauge blocks. The sheet or part to be measured is laid on a grid-like base plate, designed to minimize the effect of dust particles on the measurements, which constitutes the lower measuring surface. The upper surface is a small ball-point feeler with a total possible movement of five thousandths of an inch above or below a zero position. Its travel is optically magnified 780 times and read on an illuminated scale. When the sheet or part to be measured is more than a hundredth of an inch thick, gauge blocks are used and the reading of the instrument is added to or subtracted from the thickness of the gauge block to obtain the correct measurement.

The large variety of parts used in telephone apparatus, each having its own characteristic shape, has required a considerable amount of contour measuring. A certain amount of this work can be done on the star comparator as described above but considerable work is required in plotting the points measured when this method is used. A method of optical projection was therefore developed. Ordinary commercial lenses were found to produce too much spherical aberration to project undistorted images so that it was necessary to obtain a large number of lenses from various optical suppliers and then, after careful inspection, to select the most perfect. Those selected were employed in a commercial screw-thread projector that was adapted for the purpose as shown in Figure 3.

The part may be observed and measured directly on the screen, or permanent and accurate records may be made by a method developed in the laboratory. A transparent screen with ruled coordinates is placed in front of and in contact with a sheet of photographic paper, and the image of the part is projected upon the screen. Lines on the screen are spaced so as to give a convenient measuring scale at the magnification used, and the lines are printed on the paper along with the contour of the object. These coordinate lines not only aid in locating points on the printed images but since all photographic paper shrinks on development no errors are introduced here since the coordinate spacing shrinks with the paper and the printed image. In the illustration shown the tiny connection screw used in telephone plugs is being projected at a magnification of 100 times. The heavy lines on the screen are an inch apart and the finer lines between them—not visible in the photograph—are spaced a tenth of an inch apart so that the distance between adjacent lines represents a thousandth of an inch on the actual part. With this instrument dimensions may readily be measured or wear studies made at a fraction of the cost of previous contour measuring methods. A permanent record is also obtained which may be used for reference.

For measurements of very small lengths or small changes in lengths interferometers are used. With them the standard of length is a selected wave length of light. Since there was no commercial instrument of proper capacity available, the large field interferometer of Figure 4—with a field approximately three inches in diameter—was developed by the Laboratories for measuring variations in flatness or parallelism of lapped and polished surfaces such, for example, as the back plate of a condenser transmitter. For this purpose an optical wedge is formed between the surface of the back plate of the condenser transmitter and the flat surface of a quartz disc, known as an optical flat, placed on top of it. Interference fringes are produced as a result, and their formation and spacing permits an accurate determination of variations in the surface of the microphone plate. Measurements are readily obtained in this way to .000005 inch.

Another type of interferometer, also developed in the Laboratories, is shown schematically in Figure 5. It is intended primarily for observing very small changes in length, such as those caused by temperature changes, and is called a micro-interferometer because the fringes are observed through a microscope. In principle it compares the changes in length of a specimen X with that of a standard material, S, whose temperature coefficient is small and definitely known. An optical flat rests on two supports of S at one end and on the specimen to be measured at the other. The latter is a little higher or lower than S so that an optical wedge is formed between the flat and the lapped surface of S, which produces fringes when illuminated with a mercury arc. A change in the angle of

Fig. 4—Flatness of the back plate of a condenser transmitter being measured on a large field interferometer

the wedge corresponding to 1/10 of a fringe, equivalent to .000001 inch, is detectable.

The apparatus is mounted in a compartment surrounded with water the temperature of which is accurately controlled. As the temperature is changed the length of the specimen, if its temperature coefficient is different from that of the standard material, changes at a rate different from that of the standard and thus opens or closes the wedge. This causes a change in the number of the fringes which can be measured by the micrometer microscope used for observing.

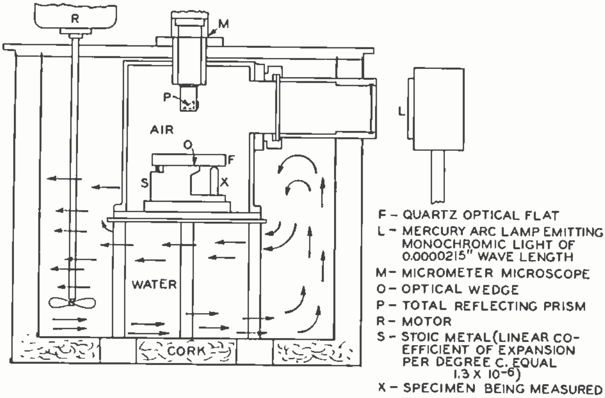


Fig. 5—Schematic arrangement of micro-interferometer used for determining temperature coefficients of expansion

The instruments described above are only the more commonly used of the many that are available. These instruments were selected for their flexibility as well as for particular uses and as a result are conveniently employed for solving many measuring problems. New instruments must frequently be devised, since commercial means are often not available. Developments in the mechanical arts at Bell Telephone Laboratories, as is true of those in the electrical art, require continuous improvement in the methods and technique of measurement.

Testing For Magnetic Characteristics

By B. E. STEVENS
Telephone Apparatus Development

MAGNETIC materials are used in hundreds of thousands of relays, transformers, loading coils and in numerous other instances in the Bell System wherever communication functions are performed by magnetic flux. In our laboratories an extensive research and development program is carried on to discover the chemical compositions, heat treatments, electrical and mechanical characteristics contributing to the most efficient performance of the materials. Corollary to these investigations are the comprehensive tests made on magnetic materials to discover their behavior under a wide variety of conditions.*

The most common and probably the most useful information obtained is that of the B-H, or magnetization, curve. This curve is made by plotting the magnetic flux density against magnetizing force. When the core of a coil is a non-magnetic material the magnetic flux produced by a current in a winding is proportional to the magnetizing force. But in magnetic cores the flux is not a linear function of the magnetizing force. Not only this but the magnetic flux lags in responding to reverse changes of magnetizing force and gives rise to what is known as hysteresis.

The B-H test determines primarily that quality which makes a magnetic material suitable as a carrier of magnetic flux. This particular quality is called its permeability. It is usually expressed by the ratio B/H which may be interpreted as the ratio of the magnetic flux density in a magnetic material to the flux density that would exist in the space if the material were not present. For instance, a material which conducts magnetic flux one thousand times better than air is said

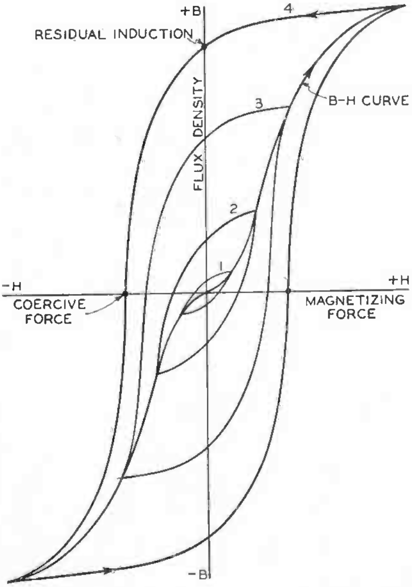


Fig. 1—Typical B-H curve and four associated hysteresis loops. Note value of negative magnetizing force required to demagnetize the material (coercive force); and value indicating magnetism remaining when the magnetizing force is reduced to zero (residual induction)

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*Bell Laboratories Record, *January*, 1927, *p.* 171.

to have a permeability of one thousand.

The B-H characteristic of a material determines largely the particular use for which that material is destined. For instance, if it has relatively high permeability at low values of flux density but relatively low permeability at high flux density, the material can most likely be used best in audio or carrier frequency apparatus. If the converse is true, the material is most suitable for apparatus such as relays and electro-magnets.

Among several methods devised for obtaining the B-H characteristics, the ballistic method is the most widely used. The apparatus consists of a galvanometer connected in series with an exploring winding on the sample. As the exciting current is changed through the magnetizing winding, the change in magnetic flux is indicated by proportional deflections of the galvanometer. By making a series of small changes in the exciting current and recording the corresponding galvanometer deflections, the B-H curve may be plotted. There have been recently developed two devices that make possible photographic tracing of B-H curves and hysteresis loops with comparatively slight effort and much saving of time. These are the Magnetization Curve Tracer(1), described by F. E. Haworth in the Record, and the Ballistic Hysteresigraph(2), detailed by H. C. Lehde in the Review of Scientific Instruments.

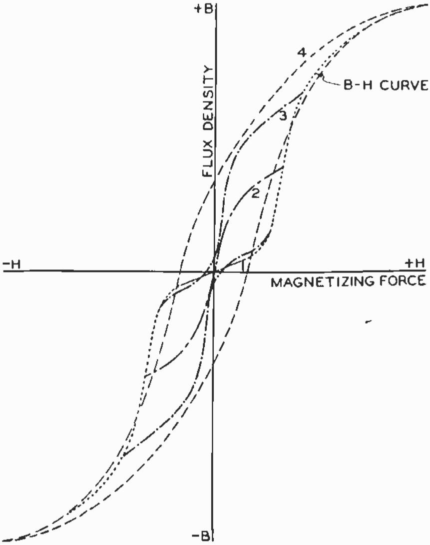

Fig. 2—A group of four hysteresis loops for perminvar showing some unique features when compared to typical hysteresis loops of Figure 1

In conjunction with the B-H test two other tests are usually made. These are the tests for residual induction and coercive force. Residual induction is the magnetic induction which remains in a magnetic material when the magnetizing force has been reduced to zero. In apparatus where a magnetic circuit is composed entirely of a magnetic material, the hysteresis loss depends considerably upon the magnitude of the residual induction. A higher loss results in a material with high residual induction than where the residual induction is low, other things remaining unchanged. In good permanent-magnet materials a high residual induction usually indicates that a comparatively large amount of flux will be available when the actual magnet is properly made. The test for residual induction is made by noting the deflection of the galvanometer in the B-H test when the magnetizing force is reduced to zero. This deflection multiplied by proper constants will give the value of residual induction in terms of flux density.

Coercive force is defined as the reversed magnetizing force required to remove the residual induction. The

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(1) *December*, 1930; (2) *January*, 1931.

Fig. 3—Magnetizing a loudspeaker magnet between poles of electromagnet

test for coercive force is made by increasing the current in the opposite direction from which the core was magnetized until the deflection of the galvanometer in the B-H test indicates zero residual. All permanent magnet materials have relatively high coercive forces. Cobalt steel ordinarily has a coercive force over 3000 times as large as that of some permalloys used in electromagnetic apparatus.

Magnetic materials are often designated as magnetically "hard" or "soft." Magnetically hard materials have broad hysteresis loops; soft materials have narrow ones. If two samples, both of the same material, display loops of considerable difference, they may be hard or soft with respect to each other. This is frequently the case when two samples of the same material are heat-treated in different ways.

All of the permanent-magnet materials are hard. Carbon-manganese steel, chrome steel, tungsten steel and cobalt steel are the permanent-magnet materials used in communication apparatus where a permanent field is necessary. Some of these uses are in magneto generators, ringers, polarized relays, receivers, light valves and loudspeaker units. Many small parts are magnetized by placing them between the poles of a large electromagnet.

Magnetic iron, silicon steel, permalloy sheet, permalloy dust and perminvar constitute examples of soft magnetic materials used in cores of apparatus such as transformers, induction and repeating coils, retardation, choke and loading coils, relays, ringers and receivers. The higher permeabilities of these materials and their capacity for concentrating large magnetic forces in small space with minimum loss are the main factors dictating their use in these parts.

Perminvar, an alloy of iron, nickel and cobalt, developed in these Laboratories, has virtually no hysteresis within certain limits of magnetizing force. Beyond these limits the hystere-

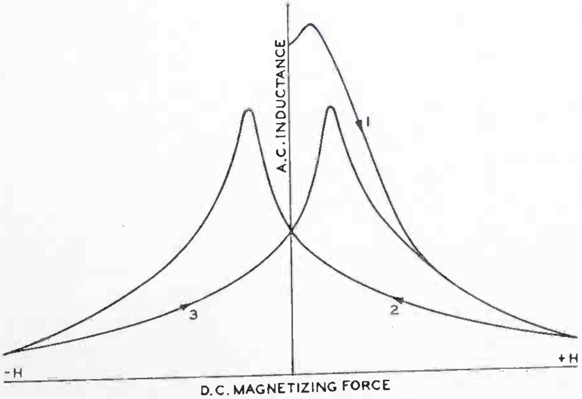

Fig. 4—The "butterfly loop" obtained by the superposed test

sis loops approach the appearance of those for other materials but they still retain a peculiar constriction near the origin until quite high flux densities are reached. These features of its hysteresis loops distinguish it as being in a class by itself. Figure 2 illustrates some of its unique features.

The characteristics of magnetic materials are usually modified when measured with alternating current. This is due to the "screening effect," or reduction of the magnetic flux by eddy currents circulating within the core. The effective permeability, or ratio of the apparent flux density to the magnetizing force, may be greatly affected by increase of frequency depending upon the permeability, electrical conductivity, thickness of laminæ and other factors. The eddy current and hysteresis losses increase with frequency and are likewise affected by the same factors that influence the effective permeability.

For obtaining the alternating current characteristics of magnetic materials, impedance and resonance bridges are chiefly used. The tests are usually made at low values of flux density and over a frequency range from 60 to 100,000 cycles or more. At high frequencies the permeability and losses are very seldom calculable from low frequency measurements.

Numerous explanations have been made as to the cause of the erratic behavior of most magnetic materials at high frequencies, but as yet no satisfactory theory has been offered. Actual measurements are the only reliable means of obtaining comprehensive knowledge of magnetic characteristics at high frequencies. One of the most common sources of trouble revealed by bridge testing and conspicuous at the higher frequencies is that of improper insulation between laminations. Such a condition in a core gives rise to excessive eddy current losses and low effective permeability. Shellacking the laminations or coating them with powdered quartz or other insulating materials, greatly reduces trouble from this source.

Another difficulty encountered in practically all coils and transformers is that of stresses arising from tightly taping and tightly winding cores, clamping or riveting laminations, or the use of warped laminations. As much as 40 per cent reduction in permeability may result from this detrimental effect.

Considerable apparatus is used in which a continuous or unidirectional flux is superposed in a core carrying alternating current flux. Such a condition modifies considerably the alternating current permeabil-

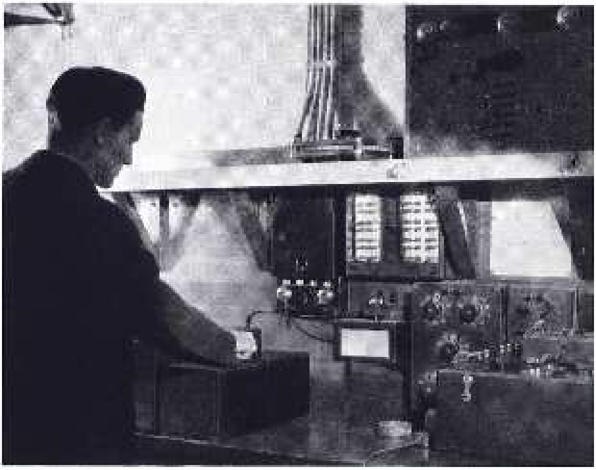

Fig. 5—Magnetic testing with impedance bridge

ity. The superposed test is made to determine how a material will behave under such a condition. It consists of determining the variation of alternating current inductance or permeability for a particular frequency and current with various values of superposed direct-current flux. The peculiar shape of the characteristics obtained is shown in Figure 4. This type of curve is often called the "butterfly loop" because it resembles a butterfly's wings.

Among other miscellaneous tests on magnetic materials is that of the measurement of magnetic flux in permanent magnets by means of the Grassot flux meter. This instrument is a highly-damped ballistic galvanometer with negligible restoring torque for the moving element. A convenient scale calibrated in maxwell-turns enables the simple and immediate calculation of the flux from the deflection obtained by slipping the magnet out of a search coil which was placed at the neutral point of the magnet.

Fig. 6—Heat treating has a pronounced effect on magnetic properties. I. H. Hirten is here shown quenching a test specimen

The methods, precautions, and limits of precision in making magnetic measurements are dependent upon the nature of the test and the purpose for which the information obtained is to be used. The determination of magnetic characteristics is not a simple task because of the large number of variables that are constantly encountered. The tests, however, give a working knowledge of a magnetic material, its essential characteristics and its eccentricities as well, which serve to guide its use in telephone apparatus.

Contributors to This Issue

C. W. BORGMANN received the B.S. degree from the University of Colorado in 1927, and joined the Chemical Department of the Laboratories to pursue corrosion studies. Last spring he received the Ch. E. degree from Colorado for a thesis based on his work here. He left for England last autumn to engage in further studies of corrosion at Cambridge University.

N. INSLEY received a B.S. degree from Hamilton College in 1918 and an S.B. from Massachusetts Institute of Technology in 1921. He joined the Laboratories early in the following year, and for four years worked on specifications and instruction bulletins. Since 1926 he has been engaged in the development of switchboard lamps, lamp caps, and resistance lamps. During this period he has also been concerned with the development of improved photometrical methods for measuring the signalling ability of switchboard lamps.

After receiving an M.E. degree from Cornell University in 1909, J. C. WRIGHT joined the Western Electric Company at Hawthorne where he took the Student Training Course. The following year he transferred to the Physical Laboratory in New York and undertook development work on dry cells and portable storage batteries. In addition he has been engaged in the development of carbon and tungsten switchboard lamps, of lamp caps, of resistance lamps, and of improved types of wire insulation. He also handled the development and construction of the special air-conditioning equipment used in the Laboratories for duplicating various atmospheric conditions to which telephone apparatus is subjected in service.

Between two school terms at Ohio State University F. S. KINKEAD worked with the Installation Department of the Western Electric Company. On receiving the B. E. E. degree in 1926 he came to these Laboratories for a more permanent connection with the Bell System. He has been successively associated with the three groups of the Telegraph Development organization: carrier, direct current, and switching. In the last of these associations he has been concerned not only with the development of the order-wire


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system which he describes in this issue of the Record but also with the teletypewriter switchboard development described by G. A. Locke in the last issue.

In 1909 J. J. Kuhn joined these Laboratories as a member of the drafting division of the Apparatus Design Department. Two years later he transferred to the special order division. When the Western Union Company became affiliated with the American Telephone and Telegraph Company, he undertook the design of telegraph apparatus. The advent of the World War supplanted this activity with the mechanical design of communication and signalling equipment for the United States Government. He retained supervision of this work after the Armistice, and also took charge of the mechanical design of repeaters, rack-mounted apparatus, telegraph equipment, ticket distributing systems, and the like. When the Special Products Department was organized in 1927, he was placed in charge of several groups responsible for the mechanical design of amplifiers, audiphones, and government apparatus. In 1929 his organization was enlarged to include the development of mechanisms employed in recording and reproducing sound pictures.

E. C. Erickson received a B. S. degree from Princeton University in 1922 and joined the Laboratories a few months later. For some six years he was with the Transmission Apparatus group engaged in the design of condensers and loading coils. Since 1928 he has been with the Materials group where he is specializing in precision linear measurements.

B. E. Stevens

G. A. Ritchie

B. E. Stevens received a B.S. degree in Electrical Engineering from the University of Minnesota in 1928. In July of that year he came to the Laboratories as a member of the Magnetic Materials Development group. He has been occupied chiefly in the testing of magnetic characteristics.

Following courses in steam and machine design, G. A. Ritchie was graduated from Pratt Institute in 1904. For the next three years he was engaged at the U. S. Navy Yard in New York on the design and marine installation of power and communication apparatus and systems for the Bureau of Equipment. In 1907 he became associated with the design and construction of highways and sewers for the City of New York. Coming to these Laboratories in 1918, he joined the Apparatus Development Department, and is at present supervising the design of keys and miscellaneous central office apparatus.

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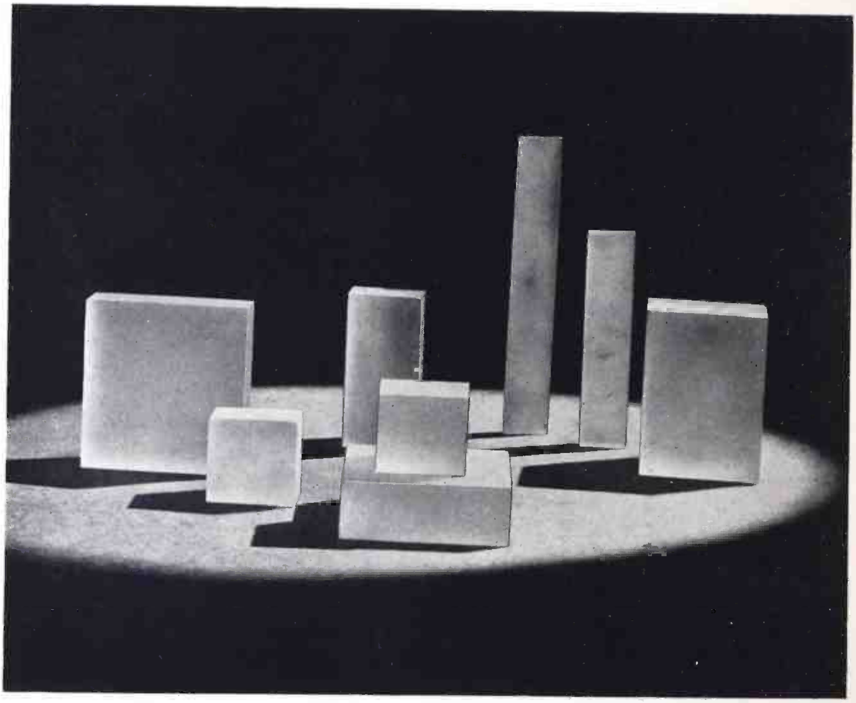

Some forms of quartz crystal resonators


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