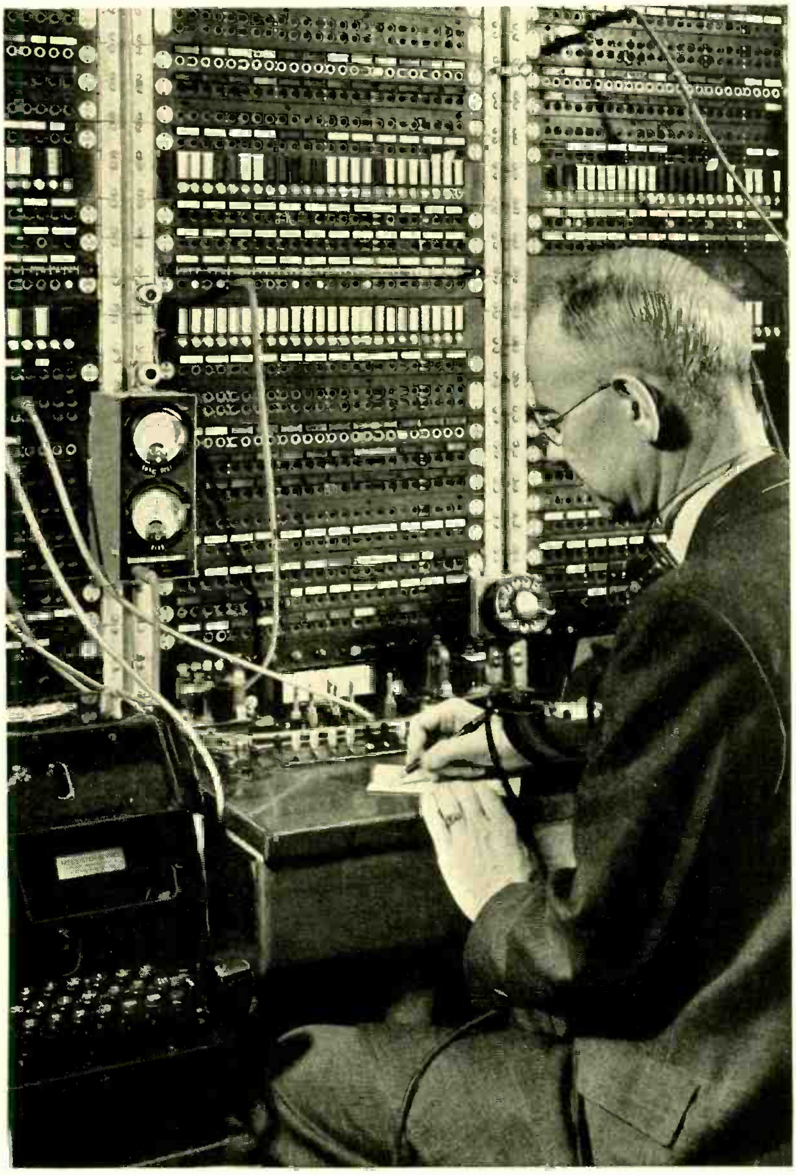
BELL LABORATORIES RECORD



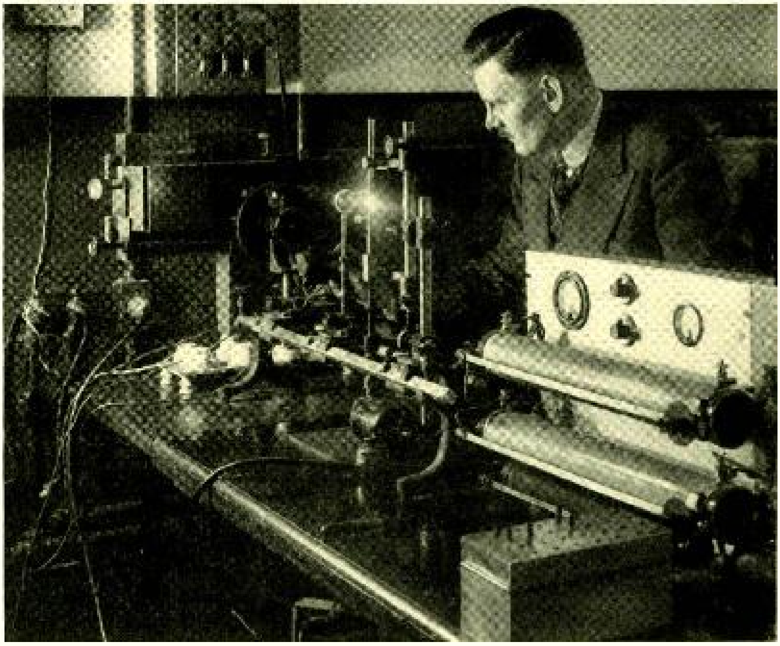
MARCH
1939

VOLUME XVII

NUMBER VII

Measuring Telegraph Transmission

www.americanradiohistory.com



Spectrochemical Analysis

By A. E. RUEHLE
Chemical Laboratories

WHEN a substance is heated to incandescence or excited electrically, each of the elements present emits light of wavelengths which are characteristic of that element. By analyzing the light emitted with a spectrograph the nature and amount of the elements present can be found. Several thousand chemical determinations are made each year at the Laboratories by this method. It is an extremely sensitive method and will detect minute quantities of matter.

A sample of the material to be analyzed is heated to incandescence in the cup-shaped electrode of an electric arc whose light then takes on the character of the elements in the unknown substance. This light is split by a quartz prism into a spectrum and recorded as lines on a photographic plate. The elements present in the sample are identified by comparing the positions of these lines with those of the known lines of the different elements. With a spectrograph of good dispersion, any metallic or metalloid element can be detected in a mixture.* Non-metals require special methods of excitation and the intensity of their spectra varies greatly with the nature of the mixture in which the element is found.

The intensity of a spectral line depends on many factors besides the abundance of the element in the source, but the experienced spectroscopist can make a fairly good esti-

*Record, *May*, 1928, *p.* 289.

www.americanradiohistory.com

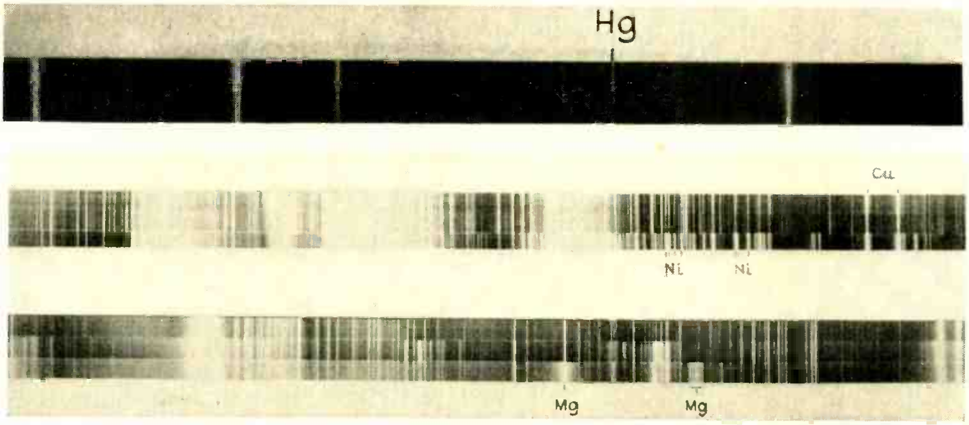


Fig. 1—(Above) Detection of mercury at the point of failure of zinc supports for aerial cables. (Below) Detection of minor components, magnesium, nickel and copper, in aluminum alloys

mate of the amount of each element present. This serves as a convenient guide for a later quantitative determination either by spectrochemical or ordinary methods.

The identification of contact materials is an excellent example of the technique of estimation. It permits finding of what materials a contact is made without removing the instrument from its mounting, without impairing the contact for further use, and without more than momentarily interrupting its service. The surface of the contact is rubbed with a small piece of pure abrasive paper, the paper is burned in a carbon arc and the resulting spectrum photographed. From the lines in this spectrum, which do not appear in that of the abrasive paper alone, the elements which compose the contact can be identified and their proportions estimated (Figure 2).

The most direct method of quantitative analysis is to compare the spectrum of the sample with the spectra of prepared standards taken under the same conditions and on the same photographic plate (Figure 3). It is generally difficult to prepare a series of homogeneous solid standards for this purpose. A more practical method is to put the sample in solution and to compare it with standard solutions of known concentration. Measured portions of each solution, dried on graphite electrodes, then serve as the test pieces for the analysis. This general method can be applied directly to a large number of cases without appreciable modification. Difficulties arise only when one

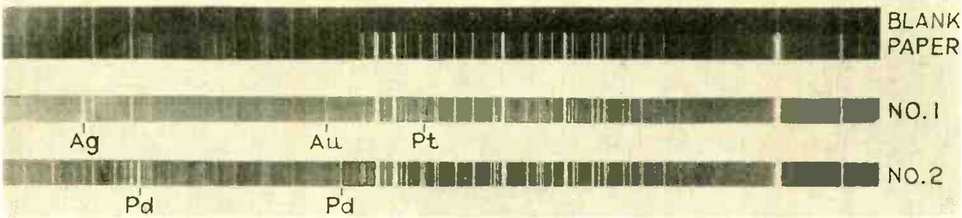


Fig. 2—The elements in contact alloys can be identified without destroying the contact

www.americanradiohistory.com

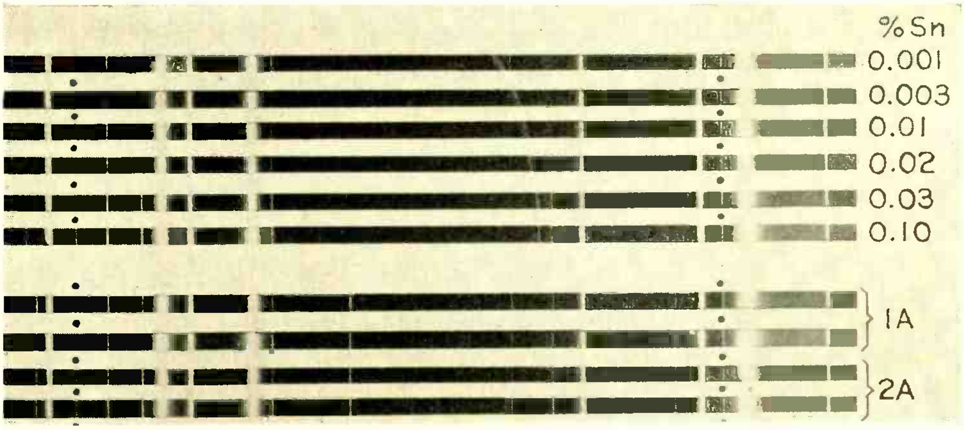


Fig. 3—Quantitative determination of tin in cable sheath

or more components of the sample in question are not readily held in a reasonably concentrated solution. By this method the amount of an element present in the sample can be determined to within about ten per cent.

Much progress has been made in devising methods of avoiding the use of standard spectra on every plate for routine work. For example, a curve which shows the difference in density of an impurity line and that of a line of some invariant component of a mixture, as the amount of impurity changes, can be used as a reference standard to determine the amount of the impurity in an unknown mixture. Changes within reasonable limits in excitation conditions or photographic technique will change the density of both the impurity line and the reference line in the same direction and to the same degree. This is called the internal standard method. It gives the most precise results yet attained in spectrochemical analysis but to reach this precision it is necessary to calibrate the response of each photographic plate for different intensities of the spectral lines. This is conveniently done by a step-sector as shown in Figure 4. By rotating the sector in front of the slit, spectra are obtained with steps of different density. Plotting from densitometer readings the density of each step of a line against the logarithm of the exposure, i.e. the logarithm of the angular apertures of the sector, gives a curve which shows how the density of a line changes with intensity for that

Fig. 4—Step-sector which is rotated in front of the spectrograph slit during an exposure to determine the density-exposure characteristic of the photographic plate for light of different wavelengths

www.americanradiohistory.com

plate. Since the shape of the curve varies from plate to plate, the difference in density of two lines will not be comparable unless corrected for this variation. By taking these factors into account the precision of quantitative determinations has been more than doubled.

Many times the spectrochemical method can be applied as a probe when two presumably identical materials show unexpected differences in behavior. Nominally pure materials are never really pure and may introduce unsuspected impurities which vary with different lots of materials.

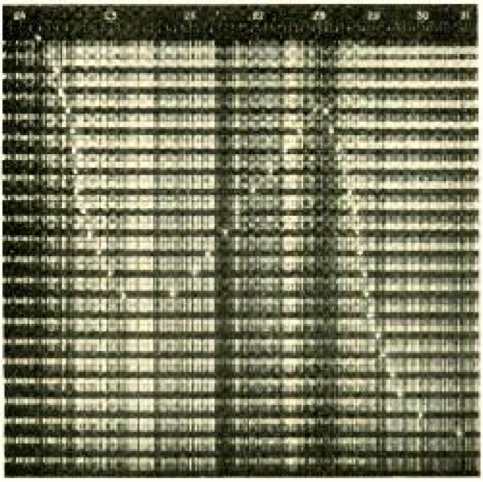


Fig. 5—Typical absorption spectra. Exposures are made in pairs: one through the absorption medium and the other through a calibrated diaphragm. By making a series of pairs with different diaphragm openings lines can be matched in density as indicated by the dots

The spectrograph shows differences in composition of the final product and thus often indicates the beneficial or detrimental effect of impurities.

Most spectroscopic analyses are made with emission spectra, but absorption spectra can also be used. If light of all wavelengths passes through a solution, the amount absorbed will not be the same for all the different wavelengths; the spectrum of the emergent light will contain bands of different intensities. The amount of selective absorption may be used as a measure of the concentration of the dissolved substance (Figure 5). Advantage is taken of this phenomenon

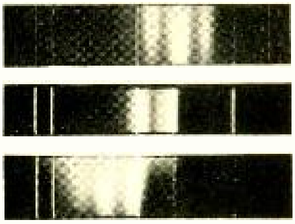


Fig. 6—Fluorescence spectra excited by mercury lines

in the colorimeter and more specifically in the spectrophotometer, which employ visual matching to determine the amount of absorption. In a similar manner the spectrograph and a suitable photometer, used to measure the densities of the absorption spectra plates, find application for this type of analysis. Either visible or ultra-violet absorption bands can be used.

Another method of analyzing certain types of organic compounds is to measure the intensity of the fluorescent bands characteristic of the compound in question (Figure 6). In this case ultra-violet light is used to excite the fluorescent bands and the intensity of the bands is compared with that of the same bands in standard solutions of the same compound.

It is only in comparatively recent years that the spectrograph has come into widespread use for quantitative chemical analysis, but it has already proved itself a powerful tool, particularly for quick estimates of composition and where only minute quantities of material are available.

www.americanradiohistory.com

Suppressing Noise and Crosstalk on the Type-K Carrier System

By A. J. AIKENS
Noise Prevention

EARLY considerations of cable carrier showed that the magnitude of disturbing fields from outside sources tended to fall off rapidly with increasing frequency, and that the shielding effect of cable sheaths became more effective the higher the frequency. In fact, as far as the outside portion of a cable telephone plant is concerned, it was found to be practicable to operate high-frequency telephone circuits down to extremely low levels, levels so low that circuit noise would be close to thermal-agitation noise. This naturally led to a study of noise arising within the telephone plant, and it was found as expected that there is an appreciable amount of high-frequency noise produced by relay operation, by charging and ringing generators, or as harmonics from d-c telegraph systems. The carrier circuits themselves are carefully shielded to prevent the direct induction of this noise, but there are roundabout paths by way of the voice-frequency pairs in the cable by which this noise could enter the carrier pairs if it were not effectively blocked. The crosstalk that occurs between carrier pairs within the cable is reduced by methods already de-

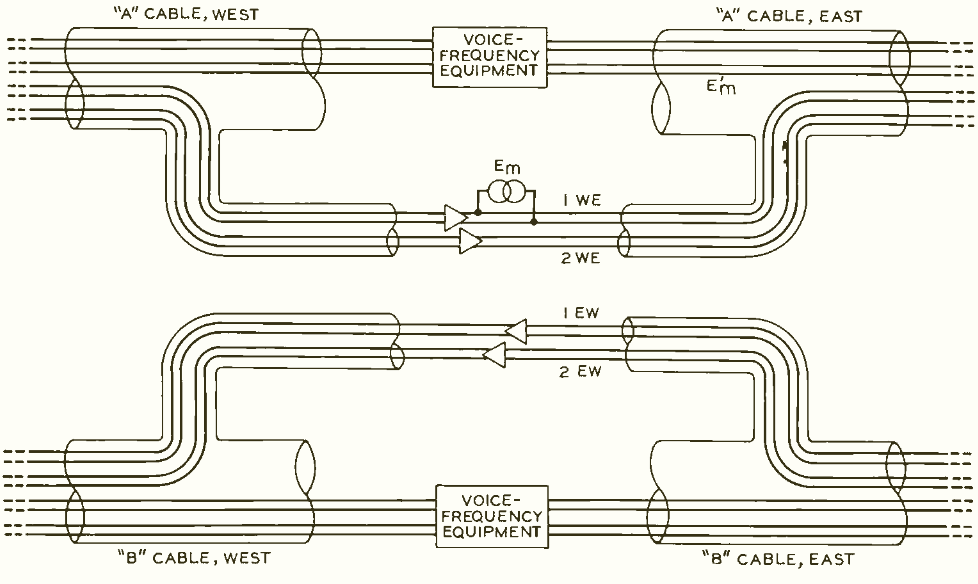


Fig. 1—The voice-frequency pairs of a cable would serve as feedback paths for crosstalk if the same cable were always used for the same set of pairs

www.americanradiohistory.com

scribed,* but these steps alone are not sufficient to block paths over which the noise enters. These and similar paths also serve as paths for certain types of crosstalk, and the remedial measures must consider both types of disturbances.

There are two ways in which currents can flow over a pair of wires: over a "metallic" circuit or over a "longitudinal" circuit. The former is the usual path followed by the signal: the current passes down one wire of the pair to the end of the circuit and back over the other wire. Longitudinal currents, on the other hand, flow over both conductors of a pair in one direction, and through the ground, cable sheath, or other low-impedance paths in the return direction. In any ordinary cable there is a coupling between these two paths largely because the capacitances between the two wires of a pair and the sheath and other conductors are not the same. Because of this imperfectly balanced condition, current flowing over a metallic circuit will induce a current over the longitudinal circuit; and similarly currents in a longitudinal circuit will induce currents in the metallic circuits. Moreover there is a close coupling between all the longitudinal circuits of a cable. As a result current in one metallic circuit can induce current in another metallic circuit by passing intermediately through one or more longitudinal circuits.

A form of crosstalk that might arise at repeater stations due to coupling of these types is indicated in Figure 1. For the type-K system a separate cable is ordinarily used for each direction of transmission, so that two cables are shown. Consider now pair 1 west-to-east. At the output of the west-east amplifier, the amplified sig-

*RECORD, *February*, 1939, *pp.* 185 and 191.

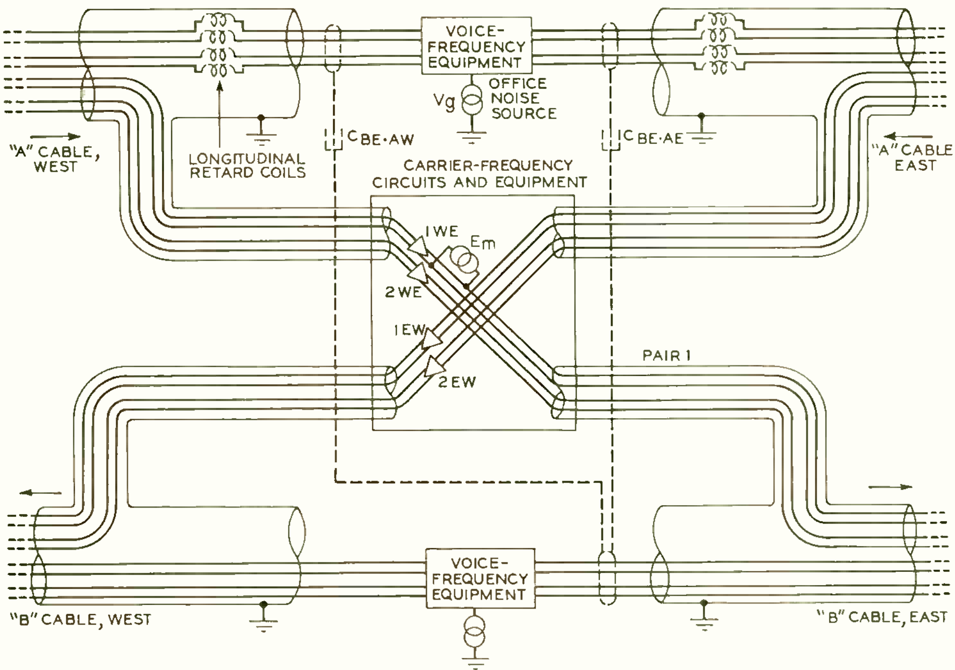


Fig. 2—At main repeater stations the direct feedback path for crosstalk is absent, but more roundabout paths still exist, and in addition there are sources of noise

www.americanradiohistory.com

nal voltage may be designated E_m, and it is at a high level because of the amplification. This E_m will induce a longitudinal voltage in pair 1, which in turn will induce longitudinal voltages in all the other pairs of cable A east. This longitudinal voltage may be designated E'_m, and it will be propagated in both directions over the pairs of cable A. That passing westward over voice-frequency pairs will, after reaching the west section of the cable, induce longitudinal voltages in the carrier pairs of this "west" section of the cable, and because of the relatively close coupling, these voltages will be almost as great as those in the voice-frequency pairs. These, in turn, will induce metallic-circuit voltage in the same pairs, and although this latter voltage will be considerably lower than the longitudinal voltage, it may be comparatively high, relative to the signal voltages in these pairs which at this point have been attenuated by a section of the cable. These voltages, such as in pair 2, will appear as crosstalk, and may be at a level above the maximum permissible.

This condition is avoided by "frogging" the carrier pairs at each repeater station as shown in Figure 2. The east-bound pairs coming in over the A cable from the west are cross-connected after amplification to the B cable east. The westbound pairs in the A cable are similarly transferred to the B cable west after amplification. Under these conditions, E_m induces longitudinal current in the voice-frequency pairs of the B cable, and these — passing west—induce metallic circuit voltages in the westbound carrier pairs. The signal voltages in these pairs, however, are at a high level because of their amplification at the repeater station, and are thus enough greater than the induced crosstalk currents to make the latter negligible.

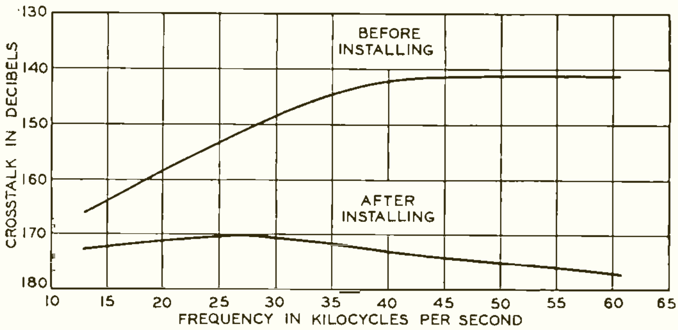


Fig. 3—Effect on crosstalk of the installation of longitudinal retardation coils in the voice-frequency quads

At auxiliary repeater stations, the voice-frequency circuits are cut straight through, without repeaters or other equipment, so that the frogging is very effective. At main repeater stations, on the other hand, the effectiveness of the frogging is minimized by the presence of circuit paths through voice-frequency equipment as indicated by Figure 2. In this case both noise and crosstalk might assume serious magnitudes if preventive steps were not taken.

Noise from the voice-frequency apparatus, for example, is readily picked up longitudinally by the voice-frequency circuits; the resulting longitudinal voltage in the A cable west, for example, may be represented by V_g. This, in turn, will induce metallic noise currents in the carrier pairs of the west cable; and since the signal currents at this point are at a low level, because of the attenuation of the preceding section, the noise currents may be at a relatively high level.

www.americanradiohistory.com

Crosstalk paths also exist. The output signal voltage E_m', for example, induces longitudinal potentials in the voice-frequency pairs of the B cable east, and these are transmitted back to the office where through coupling in the station wiring—represented by C_{BE-AE}—they produce longitudinal voltages in the voice-frequency pairs of the A cable east. These potentials are transferred through coupling in the cable to the carrier pairs, where, in turn, they induce metallic-circuit potentials that are high relative to the signal potentials, which have just been attenuated by a section of cable. A somewhat similar crosstalk path occurs between pairs 1 and 2 west-to-east, since the longitudinal crosstalk potentials induced in the B cable east pass through the office wiring to the voice-frequency pairs of the A cable west, where they induce metallic-circuit potential in the carrier pairs.

The noise and crosstalk resulting from these longitudinal potentials in the voice-frequency pairs are reduced to permissible values by inserting longitudinal retardation coils, shown dotted, in the voice-frequency pairs of the A cable. One of these coils, each of which consists of four windings on a common core, is provided for each quad. The windings are so poled as to have high longitudinal impedance at carrier frequencies but low loss to the voice-frequency metallic circuits. They are mounted in cases similar to those used for loading coils, and are usually placed in the cable vaults at the repeater stations. Their effect is indicated by Figure 3, which shows some measured values of crosstalk at a main repeater station before and after installation.

Another form of crosstalk that must be considered at repeater stations arises from the d-c by-pass sets used for shunting the testing, pilot wire, and alarm currents around certain of the repeaters. The crosstalk path is indicated in Figure 4. The signal potential E_m at the output of the amplifier in pair 2, for example, induces longitudinal potential in its conductors and thence in the other conductors, such as pair 1. If the by-pass set were not grounded and designed to give longitudinal loss, this longitudinal voltage would be readily transmitted back, through the by-pass set to the input side of the repeater of pair 1, and become a metallic potential, resulting in crosstalk. Here, also, because the crosstalk enters pair 1 where the signal potential over that pair has been attenuated by a section of cable, the crosstalk may be of objectionable

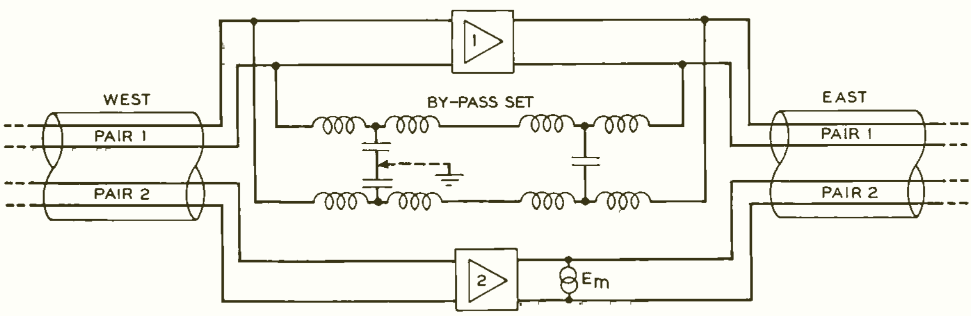


Fig. 4—D-c by-pass sets at repeaters could provide a feedback path for crosstalk much as do the voice-frequency circuits

www.americanradiohistory.com

magnitude. Crosstalk paths of this type have been effectively blocked by grounding the midpoint of the condensers of the by-pass set, as shown in the illustration by the dotted line, thereby greatly increasing the attenuation of this longitudinal path.

A somewhat similar path exists at each twist amplifier. The feedback circuits of these repeaters are connected to the output of the amplifier in such a way that longitudinal potentials are readily transmitted back through them. The situation, indicated in Figure 5, is analogous to that of Figure 4, and the remedy is to ground the midpoint of a resistance in the feedback circuit as shown by the dotted line.

Static, or atmospheric, disturbances are always a possible source of noise for telephone circuits, but where the cable sheath is continuous, noise of this type is normally kept within acceptable values by the shielding effect of the sheath. Frequently, however, open-wire lines will be tapped into cables, and since such lines readily pick up longitudinal atmospheric disturbances, they would be sources of objectionable noise if protective measures were not taken. The remedy in this case is a noise filter inserted in the open-wire lines just before they enter the cable.

The effectiveness of the sheath in shielding the conductors from induced atmospheric noise depends on the sheath's being continuous. It is sometimes necessary to break the continuity of a sheath with an insulating joint to block direct currents for the prevention of electrolysis. With such a break in the sheath, atmospheric disturbances may induce longitudinal noise currents in the conductors of the cable, and these in turn will induce metallic-circuit currents, producing undesirable noise in the circuit. With a continuous sheath, the atmospheric disturbances induce current in the cable sheath directly; and this current shields the conductors within the sheath, because it completely sur-

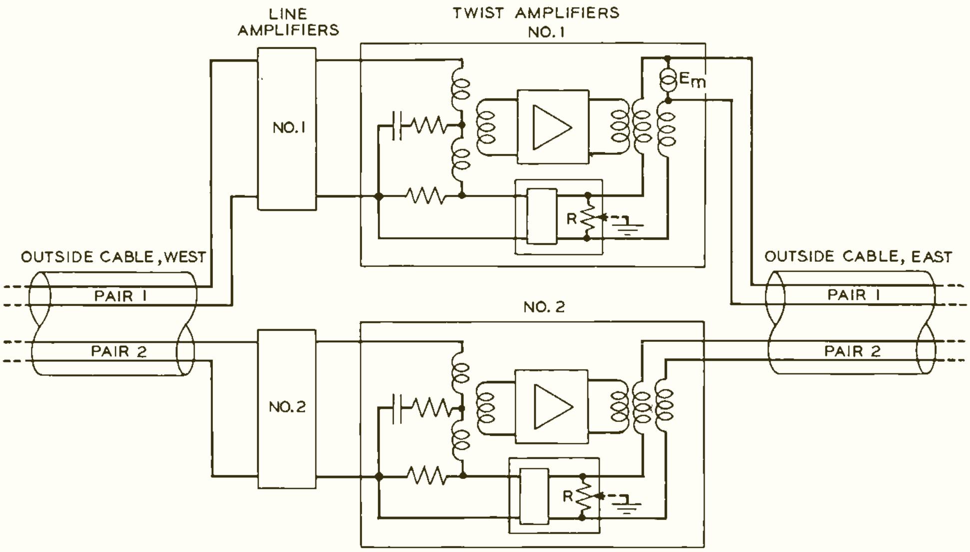


Fig. 5—At twist amplifiers a crosstalk path exists through the feedback circuit of the amplifier and the remedy is to ground the midpoint of the resistance R

www.americanradiohistory.com

rounds them. When the sheath is broken this sheath current is forced to leave its direct path and to flow to ground over the sheath-to-ground admittance, as indicated in Figure 6. Under these conditions, the shielding action is impaired, and as a result a longitudinal current will be induced in the cable pairs, and this in turn will induce metallic-circuit noise currents. This is avoided by bridging the insulating points with properly designed condensers. The impedance of these condensers at the top carrier frequency must not be more than about 0.1 ohm; an impedance of 1.0 ohm would increase the noise by about 20 db. Since the impedance of a loop of wire two feet square is around one ohm at 60 kc, the condenser must be connected to the sheath by very short and carefully arranged leads.

These are only some of the major steps that have been taken to reduce noise on the type-K carrier circuits. In addition, the carrier facilities within an office are carefully shielded and segregated from all other facilities; and the wiring and layout of all amplifiers, modulators and other circuit elements must be made insensitive to noise and crosstalk fields. Battery supply circuits must also be carefully arranged since they are common to all the circuits in an office and might be a cause of trouble.

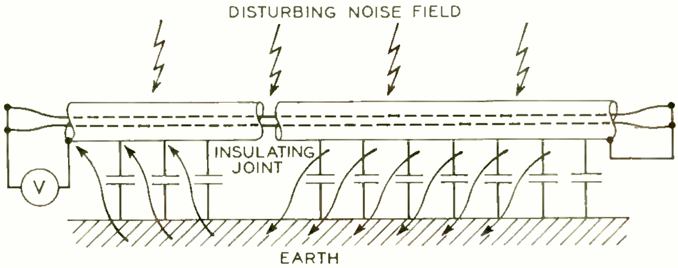
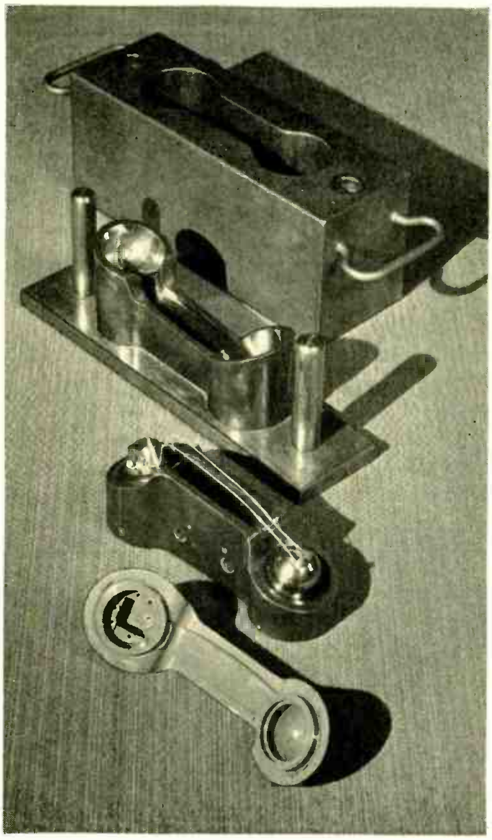


Fig. 6—An insulating joint in a cable sheath results in a longitudinal noise current because of the diverted path the sheath current must follow

www.americanradiohistory.com



Molded Telephone Apparatus Design

By T. S. HUXHAM
Insulating Materials Development

MOLDED plastics have so many properties valuable in telephone apparatus that their use has been increasing rapidly. They conform readily to intricate shapes; they take a smooth surface, often without polishing, and retain it well; and they can be made in a variety of colors where esthetic appeal is a factor.

Among the plastics available are hard rubber, cellulose acetate, shellac-mica, and phenol derivatives. Some are thermo-plastic and will soften with heat; others are thermo-setting and after molding will remain hard even up to the temperature of decomposition. Each material is available in several different grades, all of them with widely different characteristics.

First-hand information has been obtained within the last few years by the Materials group on the important characteristics of molded materials, on apparatus design principles consistent with these characteristics, and on production methods. These fields are so closely related that they must be studied together. Laboratory tests have been correlated with field experience and developments in fundamental design have been incorporated in specific applications.

The factors which affect a molded design may be conveniently classified as engineering and manufacturing requirements. One of the most important and severe of engineering demands is that equipment shall operate satisfactorily during a life of from fifteen to twenty years with little or no maintenance. The equipment on subscribers' premises or in public pay stations must withstand not only a variety of widely different climatic conditions, but also hard use at the hands of a public unfamiliar with and in some cases unmindful of its sensitivity. The dimensional requirements of new designs are often fixed by the necessity of assembly with existing equipment. Central-office apparatus is subject to space limitation to facilitate the interconnection of a large number of subscribers' lines. Often added to these are a combination of operating requirements which

www.americanradiohistory.com

further complicate the selection of a design for molded telephone equipment.

Manufacturing requirements involve a number of factors, including the reliability of sources, the uniformity of quality, the cost of molds and accessory equipment, the feasibility of attaining specified tolerances, and the complexity of molding and finishing operations.

In considering the mechanical properties of molded materials the designer must not overlook fragility. The strongest of the commercially available plastics are about as strong in impact resistance as maple wood. Consequently, in relatively large moldings which carry several pounds of assembled apparatus, resistance to impact becomes a serious problem. By designing for proper distribution of impact stresses, however, breakage may be minimized. An illustration of this is in a molded design for the housing of the "combined" handset mounting. Most of the apparatus is mounted on a punched steel plate which in an early design was intended to seat on a continuous ledge inside the open end of the housing with a molded rim entirely surrounding it. When a set of this design was tested by dropping 30 inches to a wooden floor, the strongest available phenol plastic molding was broken. By a redesign, impact stresses were concentrated at less vulnerable locations; then a molding material of about one-eighth the impact strength formerly used withstood an indefinite number of drops without failure. This change made the use of a plastic material practicable.

Molded materials are generally poor in frictional wear resistance and products of wear sometimes injure electrical contacts by causing high contact resistance. The use of metal or hard rubber inserts or assembled parts which provide dissimilar materials for wearing surfaces are often helpful in such cases. Electrical contacts should be as far removed as possible from surfaces that are to suffer mechanical wear.

In subscribers' apparatus, such as the handset, appearance is important and involves several elements including shape, color, and finish as well as problems of sound transmission, weight, strength and manufacture. The addition of pigments to obtain light colors usually affects the strength and density of the materials and exposure to sunlight rapidly darkens many light-colored plastics. Some molded parts have the mold parting

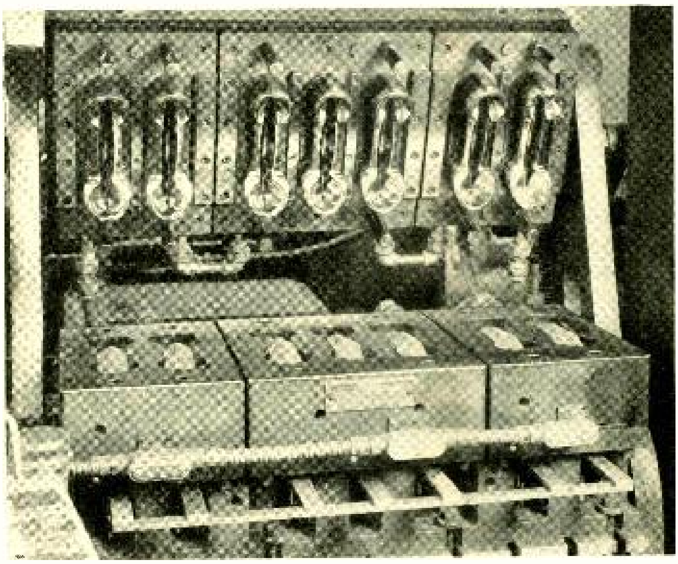


Fig. 1—Several handset handles are molded simultaneously in a hydraulic press

www.americanradiohistory.com

line in a position perpendicular to the direction of pressure and form so-called "horizontal" fin lines which introduce another appearance problem. The handset handle, which is molded as shown in Figure 1, has such a fin line and required careful grinding and buffing of a large area to produce the necessary surface smoothness. The development of an ingenious method of removing the fin automatically by machining a groove at the fin line is an outstanding improvement from the standpoints of both appearance and economy. Involved with appearance, although not strictly related to it, is heat conductivity. In apparatus such as the handset, which comes in contact with the face and hands, the use of exterior metal parts or other materials which conduct heat rapidly and feel cold is not generally favored.

Although many plastics were originally developed as electrical insulating materials, they are much more generally employed now because they provide an economical method of manufacturing irregularly shaped assemblies completely finished. However, in telephone apparatus certain dielectric properties of plastics are of importance to the designer and insulation resistance is of great interest in parts which carry closely spaced conductors. Arc resistance also requires the attention of the designer in certain types of apparatus. Some materials will continue to conduct over their surfaces after the original arc breaks. Others such as hard rubber and cellulose acetate do not form a conducting surface when burned by moderate arcing. An interesting example is the successful use of cellulose acetate molded compositely with phenol plastic so as to form an arc resistant front face for a test strip with two hundred inserts. The use of a thermo-setting material for the basic structure is mandatory to withstand the temperature rise resulting from extensive soldering operations required on the terminals.

Thermal and climatic effects require considerable attention in design of molded apparatus because practically every organic plastic is adversely affected to some extent by variations of these conditions. Most thermo-plastics "cold flow," some excessively at summer temperatures. Obviously this results in distortion which might loosen screws or other parts which stress the material. When operating temperatures do not exceed 120 degrees Fahrenheit the problem may frequently be solved by reinforcement or by other means of relieving or distributing the stress.

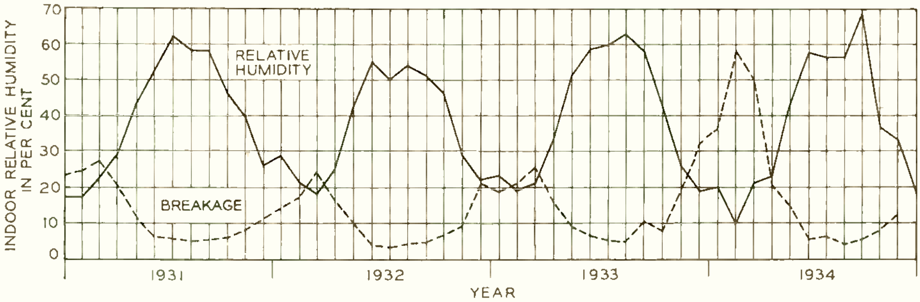


Fig. 2—Breakage of molded telephone apparatus increases during the winter months when humidity is low

www.americanradiohistory.com

Humidity has a disturbing influence upon the mechanical characteristics of many plastics and field experience with telephone apparatus has clearly indicated that impact resistance decreases with decrease of humidity. This is demonstrated in records of breakage over long periods, which show a substantial increase in failures of molded phenol-plastic parts located indoors during the winter months when the humidity is extremely low due to artificial heating. The breakage of such parts is plotted in Figure 2, where it will be noted that the strength of phenol plastics is restored by an increase of humidity. Certain cellulose acetate plastics on the other hand are subject to permanent shrinking and warping, when exposed to alternate humidifying and drying. This appears to be caused by the loss of a constituent which is volatilized with the moisture during the drying stage. The smoothness of molded phenol plastic surfaces is generally more difficult to preserve in humid atmospheres when materials of higher impact resistance are employed. Use of a cellulose filler with long wick-like fibers to improve impact resistance may allow moisture to be more readily drawn into the material with consequent roughening of the surface finish caused by the moisture swelling the fibers. Subsequent drying does not restore the original smoothness of the molded surface.

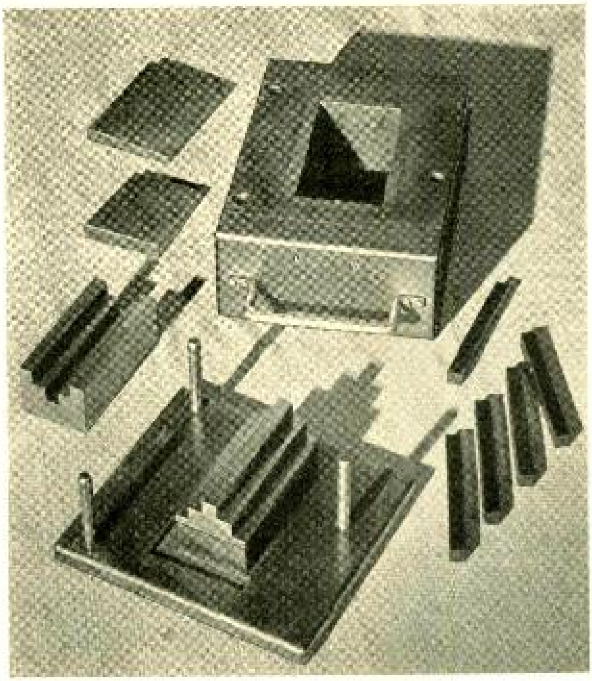


Fig. 3—A mold with step-like pistons is used where a large number of test pieces of the type shown are required for experimental purposes

To accumulate first-hand information on the characteristics of molded plastics, suitable molds and molding equipment for preparing test pieces have been provided. In addition a variety of molds for preparing round and rectangular blocks is required to supply material which may be subsequently machined into working models of proposed apparatus parts. Often by preparing simple modifications of standard molds it is possible to form in the molding operation designs which are subsequently completed by machining.

For tests of impact and transverse strength, cold flow, insulation resistance, and certain other determinations of materials, standard test bar samples can be employed. When one type of specimen is used for a variety of test purposes a large number of pieces are required and they must be molded to conform to the widely varied characteristics of the materials. A mold which satisfactorily fulfills these requirements for most plastics has been designed in a step-like form

www.americanradiohistory.com

of upper and lower pistons which operate in a rectangular box having wedges on one side and end. This gives a five-impression mold with a single cavity as shown in Figure 3. Opening of the mold is facilitated by first loosening the two wedges.

serts and which may be subsequently machined. Several of these special pistons together with some of the resulting molded parts are shown. This system of actual molding of questionable features of design is not only economical but of great value because it permits a variety of materials to be studied in a specific application and demonstrates the feasibility of novel features of design whether from an engineering or manufacturing standpoint.

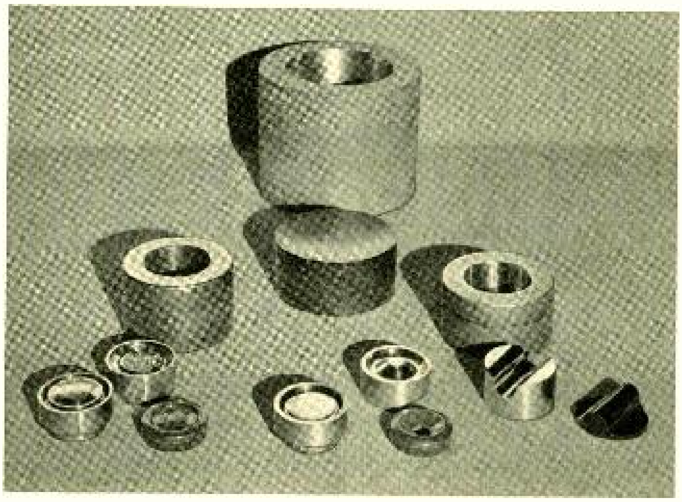


Fig. 4—Transmitter and receiver caps and certain test specimens are made in round molds with special pistons

Certain molded parts for telephone apparatus, intended for manufacture either in large numbers or with exacting requirements, justify the construction of experimental molds to produce completely molded working models of the proposed design. These can also be used for trial installations. In such cases the molds are usually made to permit molding several proposed modifications and thus give the maximum flexibility in molding methods and material selection. One of these molds is illustrated in the photograph that is shown on page 212.

For testing the surface finish of molded materials a specimen of rather unusual shape has been designed which provides curved and flat surfaces as well as thick and thin sections. The variation of surfaces and section thicknesses which sometimes occurs in a single molded part, such as a handset handle, has suggested this type of specimen for appearance tests. For a large variety of electrical measurements a six-inch-diameter disc of variable thickness is employed according to the requirements.

Several molds for producing round parts with boxes which have varying amounts of filling space are shown in Figure 4. Frequently one or more special pistons are used with these molds to prepare partially molded designs which occasionally carry in-

All of this work, however, is merely indicative of a fund of information which during the last ten years has been gathered in a coördinated investigation of molded materials. It was part of a program to accumulate pertinent information through a group of engineers and from that source to supply information for the use of designers. The wisdom of the policy is attested by the service history of the molded parts in the telephone plant.

www.americanradiohistory.com

Crossbar Trunking

By L. E. KITTREDGE
Local Central Office Facilities

THE basic switching element of the crossbar system is the individual vertical unit of the crossbar switch.* This unit consists of ten sets of contacts, and gives an incoming circuit connected to the vertical multiple access to ten outgoing paths. Any one set of contacts is closed by the operation of one of ten select magnets and of the hold magnet individual to the particular vertical unit. Since a single group of select magnets serves all the vertical units of an entire crossbar switch, these magnets cannot be put under the control of a single vertical unit, and so a control circuit common to at least all the units of a crossbar switch is necessary. Actually, a single control circuit guides the selection of all the units of one or more entire frames of crossbar switches. The many novel features of the crossbar system arise to a large extent from this use of common controller circuits.

The completion of an ordinary local call may be divided into three sets of operations. With the manual system, to take the simplest case, an operator first finds the jack of the calling line and plugs into it to get the number wanted. She then finds the jack of an idle trunk to the office called, and repeats the number wanted to the B operator there. As the final step, this B operator finds and plugs into the jack of the line called.

In the panel system these steps are first the connection of the line to a sender, then the selection of an outgoing trunk, and finally the finding of the called line. At each stage the various selectors must hunt—in one or more steps—over groups of terminals to find an idle path to the next stage. In an extremely simplified form, the panel trunking scheme could be represented as shown in Figure 1, where the three sets of operations are indicated by enclosing dotted lines. Each calling line has a number of the A selectors that can serve it, and the first selection is the choosing of an idle one. Once chosen, this selector hunts for and makes a connection to the calling line, and at the same time the B selector hunts for and connects

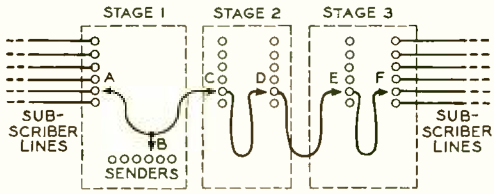


Fig. 1—Simplified representation of trunking in the panel system

to an idle sender. This completes the first set of operations. After the sender has received the office code, the C selector on the district frame hunts for an idle trunk to an office frame, where the D selector hunts for an idle trunk to the office called—thus completing the second set of operations. At the office called, in a somewhat similar manner, the E and F selectors hunt successively for idle

*Record, *July*, 1937, *p.* 338.

www.americanradiohistory.com

paths—the E selector on the incoming frame for an idle path to the final frame, and the F selector, on the final frame, for the line called.

It should be noted particularly that the A selector is chosen without knowing whether or not an idle sender is available to it. Likewise the C selection is made without knowing that the D selector can find an idle trunk; and the E selection is made without knowing whether or not the F selector will find the line idle.

In contrast with this method, which to a large extent would apply also to either the manual or the step-by-step system, the crossbar system makes sure that an idle outgoing channel is available before it seeks for an idle channel through the crossbar switches of each stage. At the first stage the line-frame controller circuit, when a call is placed, first tests for the calling line and then for an idle district junctor that has an idle sender available. Having located these two suitable end points, it proceeds to find an idle path between them through the crossbar switches. Another controller circuit for stage 2 finds the chosen district junctor, an idle trunk to the desired office, and then determines an idle path through the crossbar switches of stage 2 that is available for connecting these two circuits. This procedure is then repeated for stage 3, and only after idle paths are found is the talking path established.

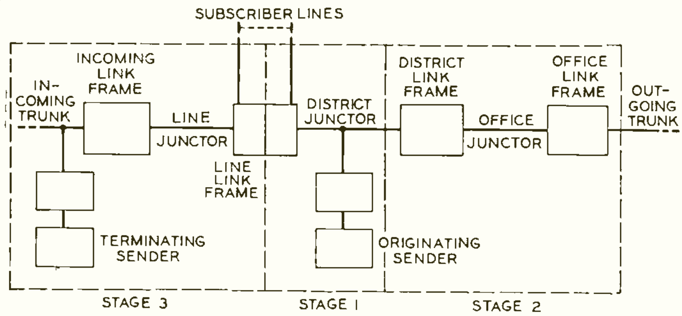


Fig. 2—Schematic of crossbar system showing the major switching frames

In previous dial systems the various selections, both within and between the three major stages, are made one after the other in direct sequence from the calling to the called subscriber. In the crossbar system, on the other hand, the selection of the talking path is guided by three common controller circuits, one for each of the major stages. These circuits first locate the required incoming and outgoing circuits for that stage, and then find an available path through the crossbar switches comprising that stage. An additional controller is employed in stages 1 and 3 for guiding the selection of an idle sender, two of which are usually employed instead of one as with the panel system.

There are four main types of switching frames in the talking path of the crossbar system: the line link, the district link, the office link, and the incoming link. The line-link frame, however, serves both for originating and for terminating calls, and thus functionally may be considered as two frames, and in addition there are two sender link frames. The first stage employs the originating half of a line link and originating sender link; the second stage employs the district and office links; and the third stage employs the incoming link, and the terminating half of a line link and in addition a terminating sender link for connection to a terminating sender.

www.americanradiohistory.com

These three stages may be subdivided to indicate the various frames as shown in Figure 2. A call from any subscriber's station may go to another station in that same office or to one in a different office, but in either event it passes through an incoming frame and a line frame. Stage 3 of Figure 2, therefore, might be in the same office as stages 1 and 2, or in a different one. This diagram also shows the terminating sender as well as the originating sender.

The selections in stage 1 are accomplished by the line-link and sender-link controller circuits. For the second stage selections, the originating marker is used, while the third stage uses a terminating marker. A sender-link controller is also used to attach a terminating sender.

As already noted, common controller circuits are employed instead of a selecting mechanism in the individual switching unit of the crossbar switch. A panel selector has access to 500 terminals, and thus inherently has the ability of hunting over large groups. With the crossbar unit, having only ten choices, the group would have to be very small, and thus inefficient, were it not for the selecting scheme adopted, which permits paths through several crossbar switches to be tested simultaneously.

This scheme can be most readily seen in connection with stage 1, shown in Figure 3, where only a single frame of crossbar switches is employed in the talking path. Each line has a choice of ten paths, because of the ten-point vertical unit, and each of these paths, through the secondary switch, may be connected to any one of a group of ten district junctors. If the first path were chosen blindly, with the knowledge only that that path was not in use, further choice would be limited to only ten district junctors—the selection at each step being over a relatively inefficient group of ten.

It will be noted, however, that each of the horizontal circuits of any one primary switch runs to a different

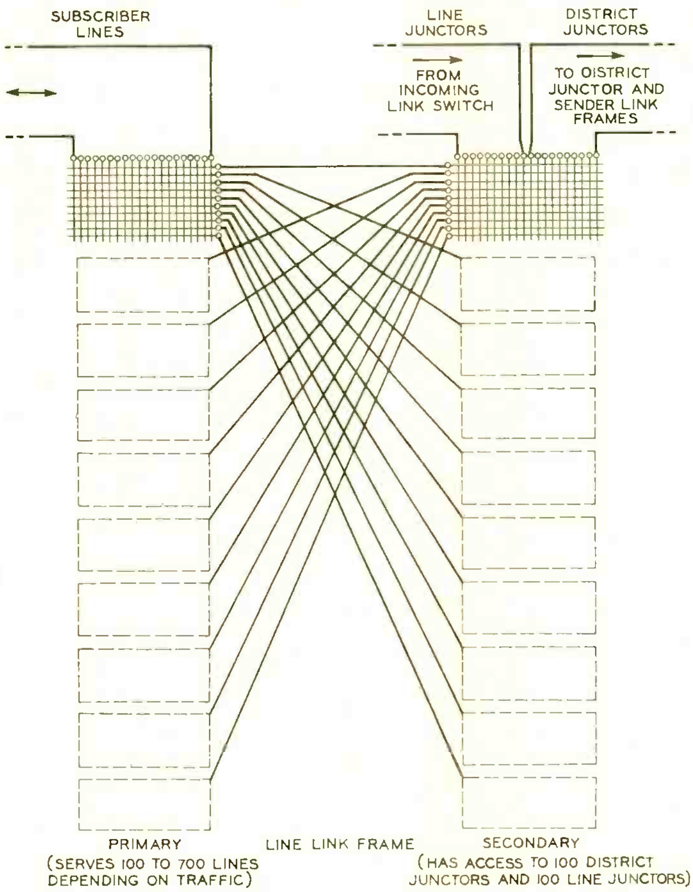


Fig. 3—Trunking scheme of the line-link frame

www.americanradiohistory.com

secondary switch in the same frame, and that each secondary switch has access to a group of ten district junctors. Each line, therefore, really has access to a hundred district junctors if, before a path is chosen at the primary switch, it is determined that idle districts will be available by way of that path at the secondary. This is what the line-group controller circuit does. Before it selects an idle line link, it determines which of them have idle district junctors available. It even goes further and determines that an idle sender is available to these junctors. The primary selection is then made so as to connect only a line link running to a group of district junctors some of which are idle and have senders available.

The controller circuit must also test for the particular line calling, to enable it to know which hold magnet to operate when the time comes for closing the circuit through. The group of district junctors selected tells it the proper select magnets on both primary and secondary switches to close. The particular junctor in the group, and thus the proper hold magnet on the secondary switch, is selected by the sender-link controller circuit, which also selects an idle sender.

The arrangement of stage two, including the district and office frames, is shown in Figure 4. Each frame has its primary and secondary switches as before. The district links are connected to the verticals of the district primary switches, and since there are twenty vertical units, there are twenty district links per switch, or 200 per frame. These district links, however, terminate on the horizontal multiple of the secondary switches, and since there are only ten of these horizontal circuits per switch, the secondary switch is split vertically so that every link from the primary may have an independent termination on the secondary. The primary switch of the office frame is similarly split, and thus there are 200 district links, office junctors, and office links per frame.

After recording the office code, the first work of the originating marker, which is the common controller for the talking circuit of this stage, is to test the trunks running to the office called and to select an idle one. These outgoing trunks are divided between the switches of two office frames, and thus the selection of a trunk determines the particular frame, and the particular switch in that frame, that will serve as the outgoing end-point for this switching stage. The marker also determines the district junctor that has been selected, and thus knows also the incoming end-point to stage 2. Its task is then to find an idle path between these two points—indicated on the diagram by heavier lines.

The district links leaving each primary switch of the district frame are divided equally among the secondary switches of the same frame, one link going to each of the halves of each secondary switch. The office junctors, leaving the district secondaries, do not all go to one office frame but are divided equally among the various office frames. The number of junctors between any two frames will depend on the number of frames employed, since it is determined by dividing the 200 junctors from any one district secondary by the number of office frames. Since there are never more than 20 office frames, there are never less than ten paths between any one district and any one office frame. This is the arrangement shown in Figure 4—all the other verticals of the district secondaries are connected to junctors running to other office frames.

www.americanradiohistory.com

The office links are connected in the same way as the district links. While there are twenty links between primary and secondary switches of the district and office frames, it will be noted that half of them run to half-section secondaries that do not have junctors to the frame to which connection is to be made. Between any one district junctor and any one outgoing trunk, therefore, there are just ten paths for the arrangement shown —each consisting of two links together with one junctor.

To be available for use, each of the three sections of any one path must be idle. Since they all may be used by other calls in other combinations, however, it is necessary for the marker to test each link of a path before the route is chosen. This is done by using what is functionally a three-winding relay for testing each path. If any one of the three links of a path is busy, the relay will operate, thereby indicating a busy path. Only the relays of idle paths remain unoperated, and the lowest numbered unoperated one is selected.

The switching arrangement for the third stage, including the incoming frame and the incoming half of the line frame, is shown in Figure 5. It is very similar to that of the second stage, except that the line frame secondaries to which the line junctors run have each only ten verticals available instead of twenty as with

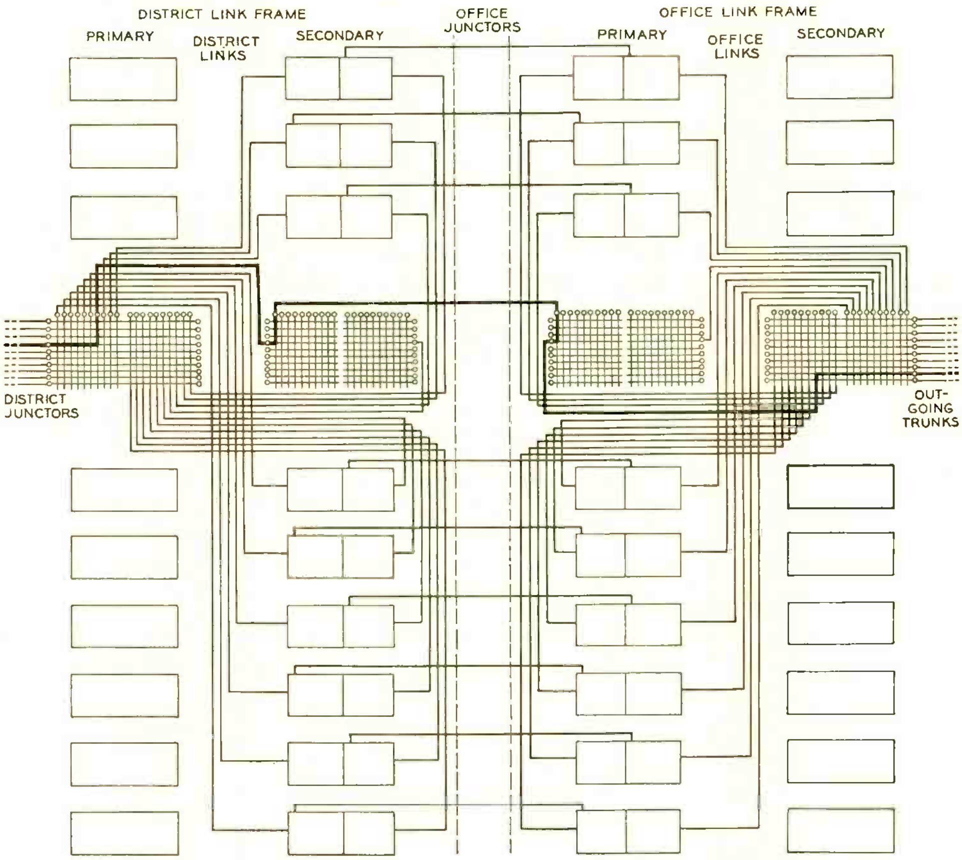


Fig. 4—Trunking scheme for the district and office link frames

www.americanradiohistory.com

the office links, because the other ten verticals of each secondary are used for originating calls. There are at least ten paths between any incoming trunk and any particular line, however, and the testing procedure is essentially the same.

The number of frames of the various types depends to a large extent on the busy-hour calling rate for the office—that is, the number of calls placed per line during the busy hour—and on the average duration of the calls. A unit known as the CCS, standing for 100 call-seconds, is used as the criterion. Thus 500 calls each lasting 120 seconds would give 600 CCS. The CCS during the busy hour is the determining factor, and for each office is a more or less definite figure. Each type of frame also has its capacity rated in CCS, and the numbers of each type of frame except the incoming may be roughly determined by dividing the total busy-hour CCS for the office by the CCS capacity of that particular frame. The number of incoming frames is determined by the number of incoming trunks, and these frames are frequently worked at less than their maximum capacity.

The capacity of the line frame is

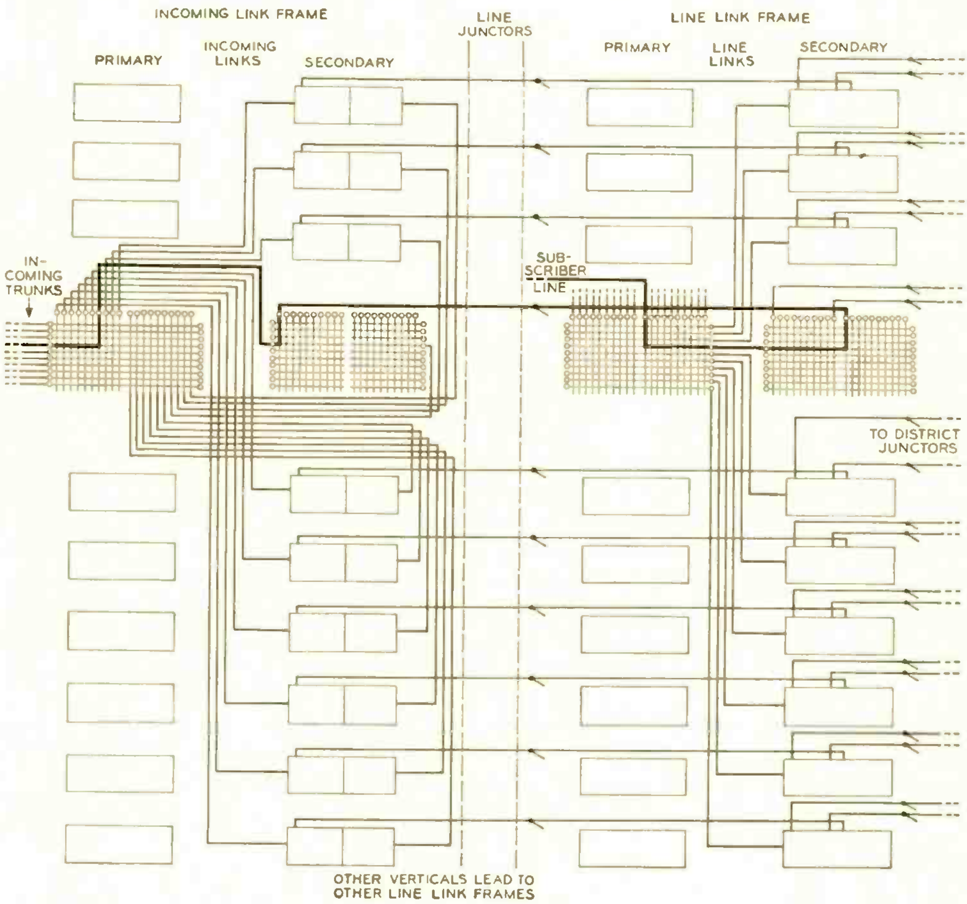


Fig. 5—Trunking scheme for the incoming-link frame and the incoming side of the line-link frame

www.americanradiohistory.com

only about half that of the incoming frame, and since, moreover, the line frame is used for both incoming and originating calls, its capacity in the incoming direction is only about one-quarter that of the incoming. To meet this situation there are about four times as many line frames as incomings, and since there are 200 terminations for line junctors on each incoming frame and 100 terminations on each line frame, each line junctor is multipled to two line frames, so that four line-link frames will accommodate 200 line junctors. Each line-link frame will serve from about 150 to nearly 700 lines, and additional primary switches are added to obtain a sufficient number of line terminations for the required number of lines. The capacity of 100 district junctors is about five times the originating-call capacity of the line frames, and since both district and line frames have terminations for the same number of district junctors, a five-fold multipling is required. The capacity of the district and office frames is about the same, and consequently there is usually the same number of each.

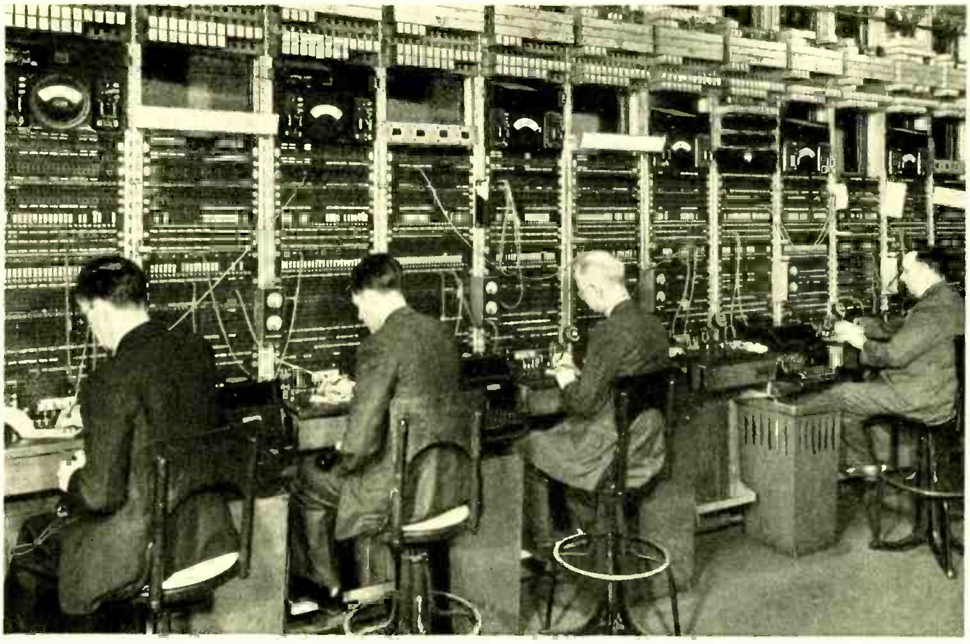
Honoring Industrial Research

"For vision and leadership in science" reads the award which accompanies the John Fritz Medal bestowed on Dr. Frank B. Jewett, president of the Bell Telephone Laboratories. The "leadership" in question is different from that which we usually associate with engineering. At the outset Dr. Jewett saw to it that fundamental theory was attacked—that the scientists under his direction were not limited to solutions of purely commercial problems. The mechanism of hearing and speaking was studied with the result that a new world was opened to philologists, laryngologists and otologists. In a word, scientific investigations were conducted that should have been undertaken in the laboratories of medical schools. Out of this work have come more efficient telephones and loudspeakers, electric boons to aid the deaf and enable those who have lost their larynxes through surgical operation to talk.

When men of Dr. Jewett's type resigned their professional chairs thirty years ago to direct industrial laboratories a shudder ran through the universities. "Pure" science was sullying itself. Now the industrial laboratories have taken the lead in many a branch of theoretical physics and chemistry, and professors yearn for the equipment, the assistance and the free hand that far-seeing groups of directors give their research staffs. From corporations in turn laboratory directors have learned the benefits that follow planning, organization and competent direction. Universities still tend to cherish the illusion that industrial research is impossible without regimentation—time-clock punching, military discipline, an eye for the main chance. They have a lesson to learn from organizations of the type that Dr. Jewett has built up—the lesson that group research is not only as free and pleasant as that conducted by lone investigators in more sacred precincts but even more exciting because of the scale on which it is undertaken.

—*Editorial in the New York Times.*

www.americanradiohistory.com



A New Telegraph Transmission Measuring Set

By R. B. HEARN
Telegraph Development

EACH teletypewriter character is transmitted by a combination of marking and spacing pulses of various lengths, totaling seven and one-half units. The number of transitions in a character—from marking to spacing or vice versa—varies from two to six for different characters; and the quality of the signal depends on the correct timing of the transition points with respect to the beginning of the first pulse of a character. The first transition releases the latch on any receiving teletypewriter in the circuit, and the selecting mechanism at once begins to rotate. If subsequent transitions occur much too early or too late, a wrong character is selected by the receiving machine. There is a certain allowable deviation of the transitions from perfect timing, but the larger the deviation, the nearer is the circuit to failure. As part of the maintenance of telegraph circuits it is necessary to measure the timing of the pulses, and new equipment, known as the 118 telegraph measuring set, has recently been developed for this purpose along the lines of an original set designed by F. A. Cowan of the Long Lines Department of the American Telephone and Telegraph Company.

The set is arranged for convenient use on working teletypewriter circuits by means of the usual cord and plug.

www.americanradiohistory.com

It may be connected directly at telegraph boards without affecting the operation of the telegraph circuit, and direct indications of the distortion of the signals are given by two meters, one indicating the maximum deviation of any transition point, and the other, the average deviation. The major part of the equipment is mounted in an open-faced cabinet, which may be installed in any convenient place in the office. An installation in New York City is shown in Figure 1. The two meters, however, together with a few operating keys and jacks for connecting to the measuring equipment, are mounted on a small panel as shown in the photograph on page 201 as well as on the main equipment. These panels are mounted at convenient places on the telegraph test board, and as many as ten may be associated with a single 118-type equipment. Each of these test-board units includes a busy lamp to indicate when the set is in use by some other position, and under this condition the jack is "locked out" so that no connection is made to the test circuit even though a plug is inserted. The jack also keeps the connected circuit closed, so that operation of the circuit under test will not be affected.

The input jacks of the test set are connected to the winding of a polar relay, which operates at each transition of the signal. The armature of this relay connects positive or negative battery, depending on which way it is operated, to three other polar relays, all of which operate simultaneously to one contact or the other, depending on the polarity applied to their winding. One of these relays releases the latch of a distributor when the start pulse is received. Other transitions operate this relay, but once the distributor has started, the relay can have no further effect on it until one revolution has been completed and it has stopped ready for the start of the next character. The contacts of the other two relays operate the timing system. These are known as the C and D relays, and their contacts are connected in the timing circuit as shown in Figure 2.

This latter circuit includes two condensers, E and F, which are con-

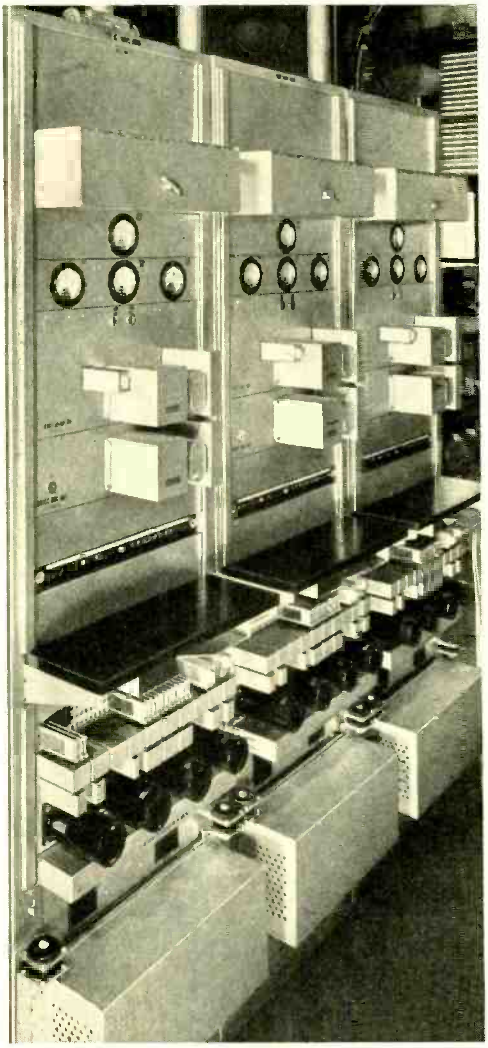


Fig. 1—Three 118A1 telegraph measuring equipments installed in the Long Lines building in New York City

www.americanradiohistory.com

nected to a constant-current charging circuit during alternate pulses of each character. With a constant charging current, the voltage across either condenser is directly proportional to the time during which it has been charged. At the next transition following its charge period, the condenser is connected to the indicating circuit in series with a reference battery. If the pulse has been of exactly the right length, the voltage of the condenser will be the same as that of the battery, and no current will flow in the indicating circuit. If the pulse has been too long or too short, however, the voltage of the condenser will be above or below that of the battery, and a current will flow into the indicating circuit in one direction or the other to indicate the deviation.

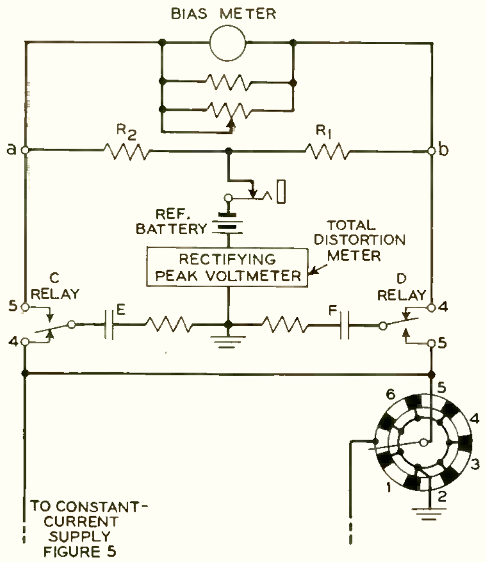


Fig. 2—Simplified schematic of the timing circuit

In Figure 2, the position of the distributor and of the relay armatures are those corresponding to the idle period before the beginning of a character. Relays C and D are not shown, but their armatures and two contacts, 4 and 5, are indicated. The "spacing" contact is No. 5 and the "marking" contact—on which the armatures rest before the beginning of a character—is No. 4. Under these conditions, condenser E is connected to the constant-current supply and is charged. It is held at a constant potential equal to that of the reference battery, however, by a potentiometer, shown in Figure 5, which is connected to it through the stop segment of the distributor. Condenser F is also held at this same potential by a connection to the reference battery through R1.

When the start pulse occurs, which is always "spacing," both relays move to the No. 5 contacts. This connects condenser E to the indicating circuit through the reference battery, but since it is already at that potential, no current flows. Condenser F, on the other hand, is connected to the charging circuit and held momentarily at reference potential by the potentiometer. Since the start pulse has released the distributor the brush now passes beyond the segment connected to the potentiometer, and the next segment, since it is connected to ground, discharges the condenser. Shortly after, the ground is removed by the rotation of the brush, and the condenser starts to charge at a constant rate.

If there were no further pulse transitions, the condenser would charge for the period of one segment of the distributor, then be discharged by the shorter segment, only about one-third as long, and then charged again for the next segment, and so on until the distributor completed one revolution and stopped. The transitions between pulses, if correctly timed, always occur at the midpoint

www.americanradiohistory.com

of a non-grounded distributor segment. At this point the condenser will be charged to just the potential of the reference battery, so that when it is transferred to the indicating circuit no current will flow in the meter. If the transition occurs too early the condenser will not be fully charged and a pulse proportional to the lack of charge will flow through the meter. Had the transition occurred too late, the condenser would have been over-charged, and a pulse in the reverse direction would have flowed through the meter. The E condenser follows an exactly similar cycle, only separated in time from the F condenser so that it is connected to the charging circuit when the F condenser is connected to the indicating circuit and vice versa—the two condensers timing alternate transitions.

The sequence of operations during the transmission of the letter "Y" is shown in Figure 3. The bottom line of this illustration represents the seven grounded and seven ungrounded segments of the distributor, while the line immediately above it indicates the pulses for the letter "Y" sent in the correct time relation with the commutator. Condenser F, to consider it first, remains at reference potential until the first grounded segment discharges it. It then starts to charge, and if the first transition occurs exactly in the middle of section 2—which is the correct timing and the way indicated—it will be transferred to the indicating meter when its potential is exactly at reference value. Had the transition occurred later, the charge would have continued as indicated by the dotted line.

At the next transition, F is transferred to the charging circuit, and since the brush has moved away from the potentiometer segment, charging continues until the grounded segment is reached, when another identical cycle begins. Exactly similar cycles are passed through by condenser E, but the first discharge begins with grounded segment 2 instead of 1. There is no transition at the center of segment 7 for the letter "Y." This is the point for the transition to the stop pulse, which is always "marking," and since with the letter "Y" the preceding pulse was marking, there is no

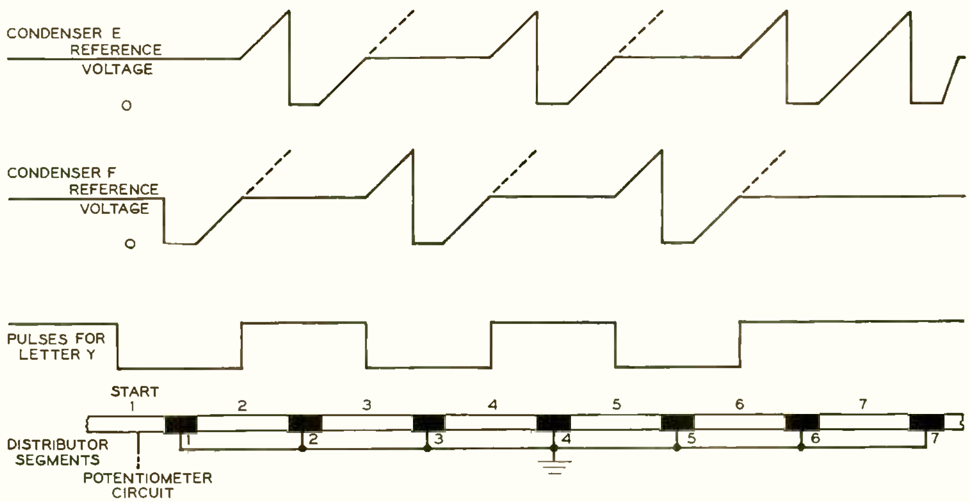


Fig. 3—Graphic representation of the 118 *measuring set*

www.americanradiohistory.com

transition that requires to be timed.

The pulses from condensers E and F pass to the peak voltmeter through the reference battery; the circuit is shown in Figure 4. Pulses of either direction flow to the rectifier tubes A and B, and cause pulses of current to flow to condenser D. The potential on the condenser, in turn, biases the vacuum tube G, and results in an unbalance of the bridge circuit that causes a current to flow in the indicating meter. The charge on the condenser is accumulative, and thus builds up as larger pulses, caused by greater deviations from correct timing, flow to it. Later smaller pulses do not affect it, but each larger one adds its excess to the charge. As a result the meter always indicates the largest error up to the observed time. A reset key permits the condenser to be discharged to initiate another set of readings.

Pulses from condensers E and F, Figure 2, flow to the peak voltmeter through a circuit comprising R1, R2, and the bias meter. The pulse from E, for example, divides at "a," part passing through R2 and part through the bias meter and R1. The impedance of the bias meter with its shunt is small compared to R1 and R2 so that approximately the same current flows in each branch. The occurrence of these pulses is in such a rapid sequence, compared with the natural period of the meter, that the latter exerts an averaging influence, indicating the average value of the errors.

Constant current for charging the condensers and the voltage of the potentiometer which holds the charge

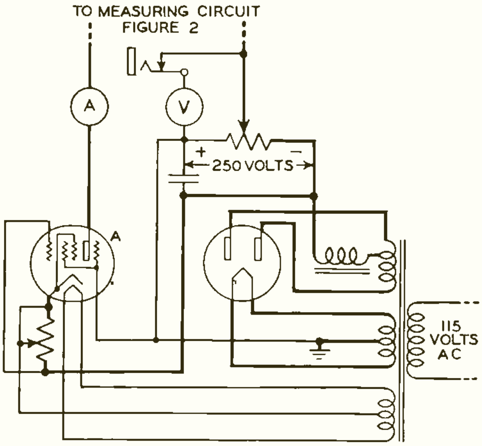


Fig. 5—Constant-current supply circuit

on the E condenser at a fixed value during the idle period are obtained from the circuit shown in Figure 5. The plate current of tube A remains nearly constant over a wide range of plate voltage, but, to secure the proper value of current, one of the grids of the tube is biased by a potentiometer in the plate circuit and acts as a regulating grid to maintain a constant output. This current remains at the same value under all conditions. When the potentiometer is connected the current divides between it and the condenser; and when the drop across the potentiometer is equal to the reference voltage all the current flows through the potentiometer.

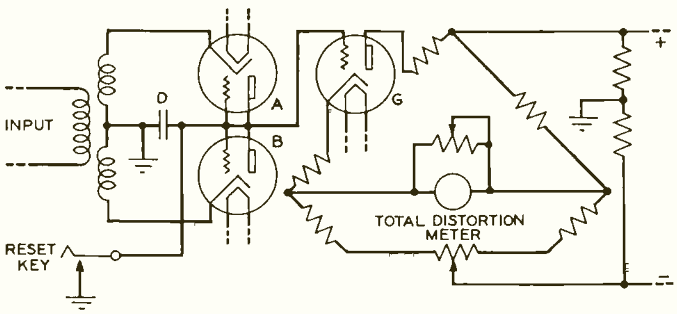
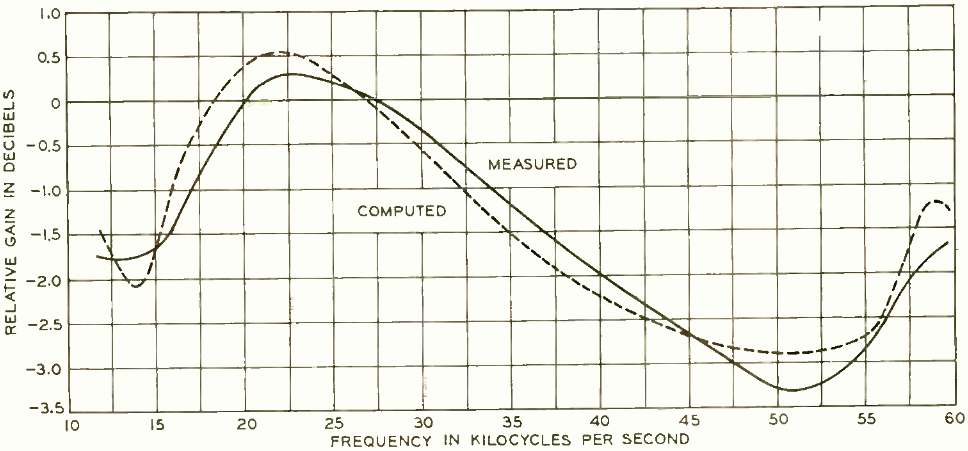


Fig. 4—Simplified schematic of the indicating circuit

www.americanradiohistory.com

This new testing equipment is available in two forms: one is the 118A1 shown in Figure 1, which is arranged for permanent installation in an office, and the other the 118B1, which is designed to be packed in trunks and shipped around to the smaller offices where a permanent installation is not required. There are a number of types of teletypewriter circuits, but ordinarily measurements are made on loops carrying 60 milliamperes in the marking condition and zero current in the spacing. The input relay of this new testing equipment is designed for this type of circuit. The set may also be used on a polar circuit, where approximately thirty mils negative and positive current is used, by operating a polar key, one of which is furnished at each test-board position. Where measurements on other types of circuits are required a small appliqué circuit is added.

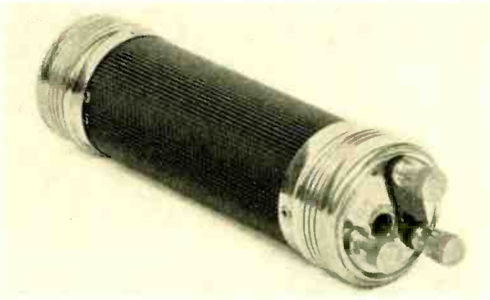


How closely a system as installed will meet predicted characteristics is always a matter of considerable interest. In the case of the type-K carrier systems recently installed between New York and Charlotte, North Carolina, the results were particularly gratifying. Some six months before the installation an estimate was made of the overall net transmission characteristics of the 627 miles of cable and the 38 repeaters. It is shown by the dotted curve above, while the corresponding measurements made at the completion of the installation are shown by the solid line. The two curves agree to within 0.4 db. Only by detailed engineering analysis and careful manufacturing control can the predicted and obtained overall characteristics be held to such precise agreement.

www.americanradiohistory.com

New Test Set for Identifying Telephone Wires

To provide a more compact and less expensive test set than that previously used by plant men in tracing wires between a cable terminal and a subscriber's premises, and wires inside a building, a new test set has been developed. It consists of a buzzer, condenser and battery, mounted in a case of the flashlight type. In use, two of the binding posts of the set are connected to the wires to be traced at some point such as a subscriber's station. The several wires at the distant point, where identification is desired, are then tested with a hand test set to determine which wires carry the test tone. The set provides also a means for checking the direct-current continuity of wire groups. The new test set supplements other tone test sets already standard in the Bell System.



www.americanradiohistory.com

Contributors to this Issue

R. B. Hearn started night courses in Engineering at Brooklyn Polytechnic Institute in 1922, and received the E.E. degree in 1931. In the meantime he did electrical testing and engineering work with a number of electrical concerns in this vicinity during the daytime. In 1929 he joined the Laboratories, where he has engaged in telegraph repeater development and in the design of circuits for telegraph testing and maintenance.

L. E. Kittredge entered the Development and Research Department of the American Telephone and Telegraph Company in 1920 after graduation from the Electrical Engineering course at Cornell University with an M.E. degree. He first worked on problems pertaining to the panel systems, both with the American Company and later at Bell Telephone Laboratories. With the advent of the crossbar system, he has devoted most of his attention to it, working particularly on the traffic and trunking studies connected with this new system.

A. E. Ruehle joined the Laboratories in 1930 after receiving the B.S. degree in Physics from the University of Idaho. His work has been chiefly concerned with the application of the methods of physical chemistry to chemical analysis, and includes studies of acidity, conductivity, micro-gas analysis and spectroscopy. For several years he was associated with Dr. R. R. Williams in the study of the chemical structure of vitamin B_1. He is now in charge of spectrochemical analysis and is engaged in a chemical study of the oxide-coated filament.

A. J. Aikens received the B.S. degree in Electrical Engineering from the University of Nevada in 1920. He spent some six years with The Pacific Telephone and Telegraph Company, and in 1928 transferred to the Development and Research Department of the American Telephone and Telegraph Company, coming to the Laboratories with that organization in the 1934 consolidation. Since joining the A. T. & T., he has been principally engaged in investigating noise and crosstalk problems with carrier systems for both cables and open-wire lines.

T. S. Huxham joined the Laboratories

R. B. Hearn

L. E. Kittredge

A. E. Ruehle

www.americanradiohistory.com

in 1929 after ten years' experience in the development of plastics and methods of molding them outside the Bell System. Since then he has been continuously associated with investigations of molding materials and design of molded products in the Materials Standards group of the Apparatus Development Department.

A. J. Aikens

T. S. Huxham

Excerpts from the Annual Report of the American Telephone and Telegraph Company

Research and development in the Bell Telephone Laboratories have been carried on without diminution. During the year, many noteworthy investigations designed to improve, extend or lessen the cost of providing telephone service have been brought to the stage of practical applicability.

In local service, experience in the operation of the two installations of the new "crossbar" system of machine switching mentioned in previous Reports has been so satisfactory that the system has been standardized for future use in the large city districts where "panel" switching has heretofore been the best available. Shipment of equipment to provide for 23,000 subscribers' lines was made in 1938 and equipment for 165,000 lines is scheduled for 1939.

In the field of transmission, broad-band systems by which a large number of telephone channels can be provided over a single circuit have proven their ability to meet exacting service requirements and are now going into extensive commercial use. Research work on the laboratory experimental coaxial cable and its equipment between New York and Philadelphia has been pushed vigorously with the result that the first commercial trial installation, viz., a 200-mile cable between Stevens Point, Wisconsin, and Minneapolis, is now being engineered.

Improvements in transmission are grounded in improvements in transmitters, receivers and other parts of subscribers' equipment and in the improved transmitting characteristics of circuits. The almost instantaneous establishment of any telephone connection, which has come about in the past few years, would be impossible were it not for improvement in the reliable functioning of switching and control devices—many of them entirely new—and in the development of efficient and economical transmission channels.

All these and numerous other major factors, however, would not be sufficient to give the people of the United States the kind of service they have at the price they pay for it, were they not reinforced by a very great number of other physical things all directed to the maintenance of reliable operation, to the elimination of extraneous interferences, and to long life.

These are the things the Bell Telephone Laboratories is maintained to do in addition to pioneering the use of the new things of science in the field of communication.

www.americanradiohistory.com