BELL LABORATORIES RECORD

RADIATION-COOLED POWER TUBES
H. E. Mendenhall

SOLDER AND CABLE SPLICING
H. Baillard

TRANSMITTER FOR BROADCASTING
A. W. Kishpaugh

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In this Issue

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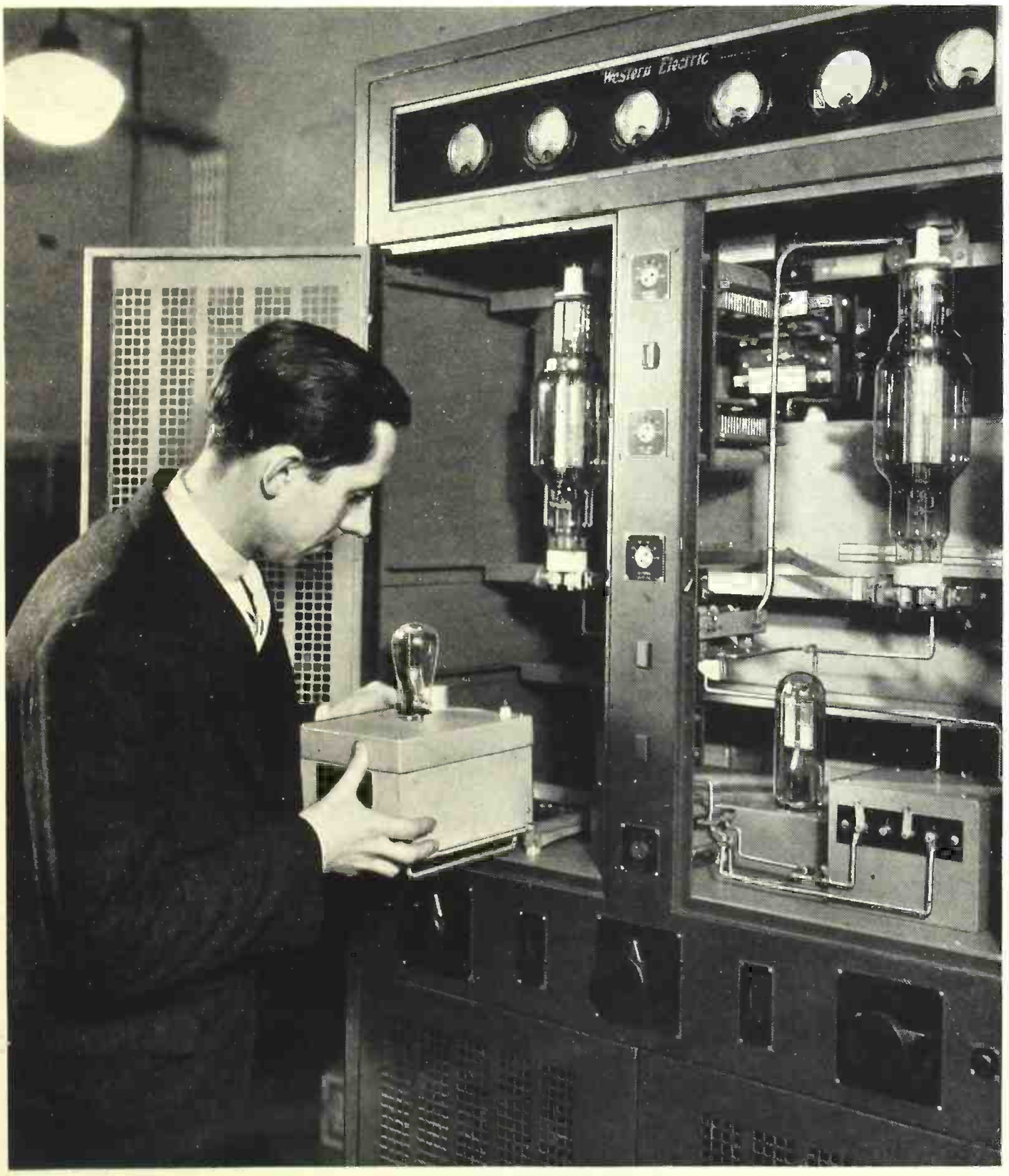

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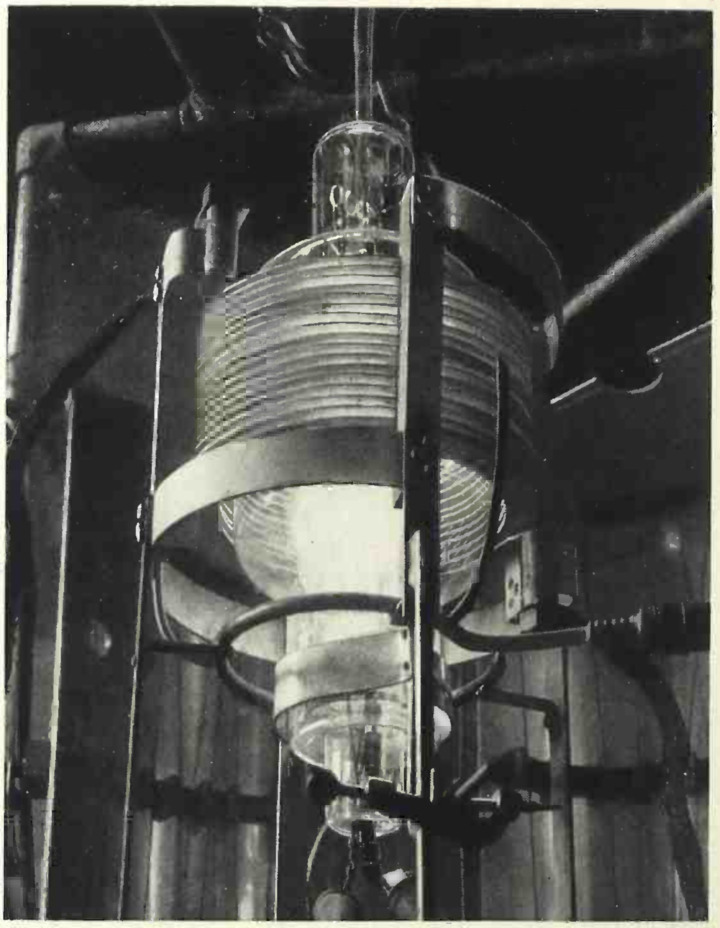


Radiation-Cooled Power Tubes for Radio Transmitters

By H. E. MENDENHALL
Vacuum Tube Development

RECENT broadcast transmitters developed by the Laboratories, with capacities ranging from 100 to 1000 watts, have required power amplifiers intermediate in size between those of the largest radiation-cooled types and the water-cooled tubes of much higher ratings. Since 100% modulation is employed in all Western Electric radio transmitters, the output of the power amplifier must be four times that of the rating of the transmitter itself. Tube capacities required for the new transmitters were thus from 500 to 2000 watts, while our largest existing radiation-cooled tube had a capacity of 250 watts and the smallest water-cooled, of 5000 watts. Three new power tubes have been developed, therefore, to fill this gap. They are all of the radiation-cooled type with peak power output capacities of 500, 1500, and 2000 watts respectively.

The higher the rating of a tube the greater, as a rule, is the plate potential and the greater is the heat developed at the plate, which must be dissipated.

Water cooling, being the most effective way of removing heat from metal surfaces, is therefore universally used for the larger sizes. Although it is an effective way of removing heat, water cooling has certain operating and economic disadvantages, since hose connections, a water supply, and possibly a cooling system for the water are needed, and add to the operating and maintenance expense. To avoid these various disadvantages, the three new tubes have been designed to dissipate the heat developed in their plates by radiation alone.

To make this possible several new constructions and materials have been adopted. The amount of heat that can be radiated from a surface varies directly as the area and the radiation coefficient, but as the fourth power of the absolute temperature. Heat is most effectively radiated, therefore, by increasing the temperature of the plate, but with nickel or iron—the ordinary plate materials—the increase possible is distinctly limited by their comparatively low melting point. For the new tubes, therefore, molybdenum was employed for the plate material because its melting point is considerably higher than that of nickel or iron, and with its use the plates may be run at a temperature as high as 1000° Centigrade, a cherry red heat.

In addition to the gain obtained by the higher temperature, dissipation is further increased by roughening the surface of the plates by carborundum blasting. The emissivity of such a treated surface may be double that of the smooth. A still further gain is made by increasing the size of the plates and by adding radiating fins. The number and arrangement of these fins varies with the rating of the tube. For the smaller size little additional radiation is required by these means, but for the largest capacity the arrangement and number of the fins has been carefully designed to secure the optimum amount of dissipation.

Since the plates are to operate at so high a temperature, both the grid and filament also have to be designed for higher temperatures than are ordinarily used. Molybdenum was employed also for the grids but here another special treatment had to be resorted to. When these tubes are used in radio telephone transmitters,

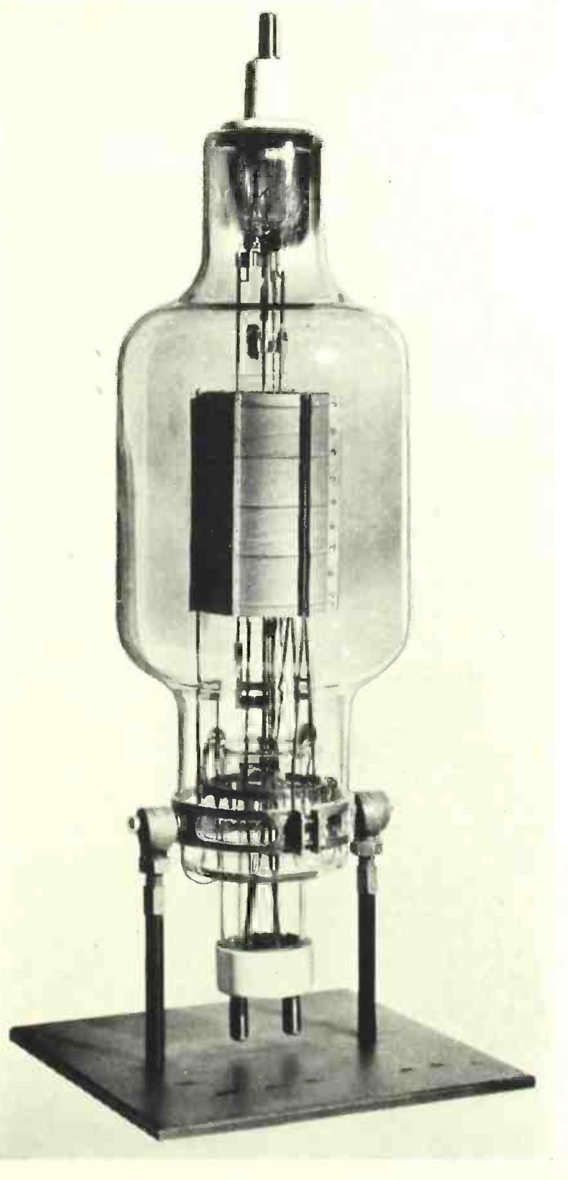


Fig. 1—The 251A tube. Compression springs of tungsten are employed in all tubes to take up the filament expansion

the grid may be carried to a positive potential with respect to the cathode during a portion of each carrier cycle. During this period, therefore, a portion of the electron stream will be diverted to the grid where it will produce secondary emission. Without special treatment of the grid surface the number of secondary electrons emitted may be greater than the number of electrons striking the grid, so that a reversal of the grid current may take place. This secondary emission, and thus the current reversal, also varies widely from tube to tube.

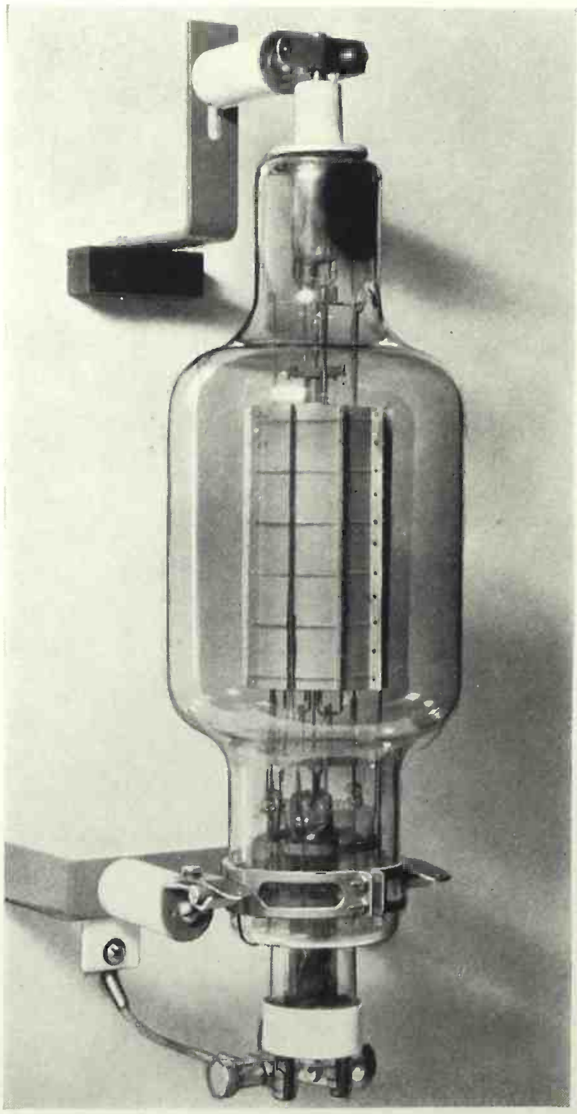


Fig. 2—On the 279A tube nine radiating fins have been designed to obtain maximum radiation

The reversal of the grid current itself gives considerable difficulty to the circuit development engineer, and the superposition of large variations from tube to tube makes the circuit problem still more difficult. Both the amount of secondary emission and its variation have been decreased by spraying the grid with a thin coating of carbon. In the manufacture of the new tubes, however, a special treatment for the grid has been employed which not only gives a surface that produces less secondary emission, but decreases the variation to a marked degree.

The high temperature at which the plate is run also affects the type of filament used. Since the radiation requirements of the plate are already severe it is undesirable to dissipate any more heat in the filament than is necessary since most of it must be re-radiated by the plate, which surrounds it. A high efficiency filament is therefore very desirable, but the oxide-coated filaments used with tubes of smaller capacity, although highly efficient, operate at a temperature which is actually 200° lower than the normal operating temperature of the plate. Either pure tungsten or thoriated tungsten would be satisfactory, but since at the same energy input a thoriated filament is about five times more efficient than the pure tungsten, it was selected. Such a filament consists of a core of tungsten containing about one per cent of thorium dioxide. This is covered by a thin layer of tungsten carbide over which lies a monatomic layer of metallic thorium. This single atom layer lowers the energy required for an electron to escape across the surface, and thus increases the efficiency of the filament much as the monatomic film of barium does in the oxide coated filament already described in the RECORD.*

The highest efficiency is maintained only so long as a monatomic layer covers the entire filament. During normal life it tends to disappear, partly due to evaporation but chiefly due to bombardment by positive ions generated by ionization of the residual gas in the tube. This loss of the monatomic thorium layer is overcome by building up a reservoir of the metal in the tungsten carbide layer, and by so completely exhausting the tube that little gas remains to be ionized.

Fig. 3—All tubes are exhausted on a special high-vacuum system and during the process the metal parts are heated to rid them of occluded gases

The formation of the surface layer of thorium and of the reservoir in the filaments of these tubes is accomplished during the evacuation process as is common practice in the manufacture of all vacuum tubes employing the thoriated type of filament.

A special high-vacuum exhaust system is used to remove all traces of gas from the tube, and during the early stages of the operation the tungsten carbide layer is formed by glowing the filament in an atmosphere of hydrocarbon gas. The pressure of the gas, the temperature of the filament, and the time of glowing are all so regulated that the quantity of carbide formed is accurately controlled. Following this the hydrocarbon gas is removed and the lengthy process of freeing the glass and metal parts from occluded gas is begun. The entire tube, while the vacuum pumps are running, is first baked in an electric oven at a temperature just beneath the collapsing point of the glass. The metal parts are then heated by high frequency induction to a considerably higher temperature than that of normal operation. Some ten hours of continuous exhaust are necessary to gain the desired freedom from occluded gases.

During the assembly of the tube a few milligrams of magnesium in an annular mounting have been attached to the central glass supporting structure near one end of the tube. Just before sealing off the tube from the exhaust station this magnesium is vaporized. The vaporized magnesium condenses on the lower portion of the glass wall of the bulb where it forms a mirror that acts as an absorbent of any gases that may be formed during the operation of the tube. At the time of flashing, the magnesium also reacts with small amounts of oxygen

*RECORD—*October*, 1930, *p.* 54.

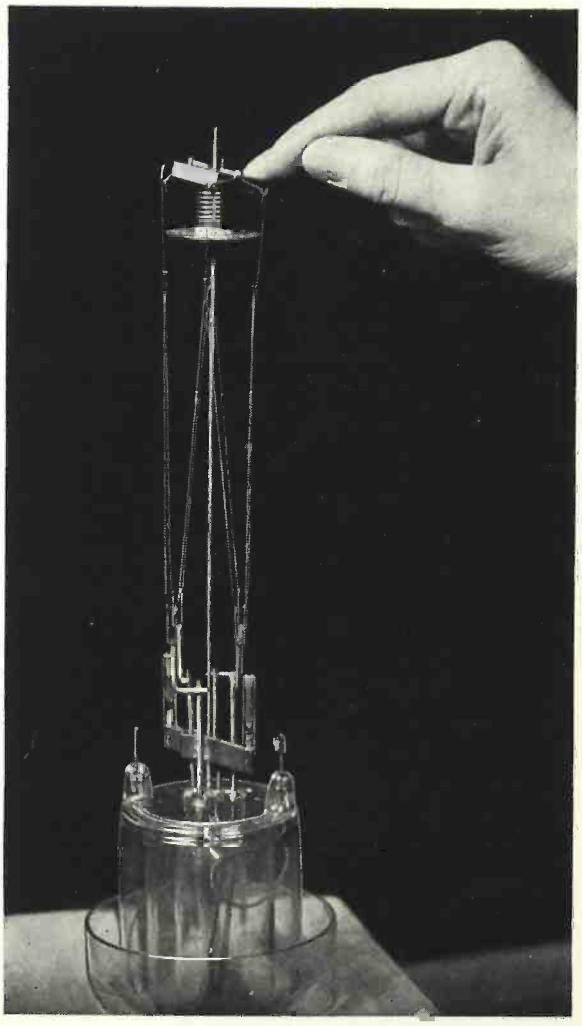


Fig. 4—The development of a central tensioning-spring structure enabled the grid to fit closely around the filaments

or water vapor that may be present and removes them.

After the tube is sealed off the exhaust station, the filament is operated at a temperature well above its operating value, and during this period, as well as during the previous heat treatments, the tungsten carbide reacts on the thorium dioxide in the core of the filament. This results in the reduction of a certain amount of the oxide and the building up in the carbide layer of a definite quantity of metallic thorium. Both the temperature of the filament and the time of heating are accurately controlled to form the right amount of metal. During the life of the tube this metal gradually diffuses outward and maintains the monatomic layer on the surface. All the steps of the process are so controlled and the operating temperature of the filament so adjusted that there will always be an adequate supply of thorium to replace that lost by evaporation or ion bombardment throughout a life of several thousand hours.

All three of the new tubes incorporate the molybdenum plates and grids and the thoriated tungsten filaments, and are subjected to the same manufacturing processes in respect to them. They differ from each other, however, in many other respects. The two larger tubes, the 279A with an output capacity of 2,000 watts and the 251A with an output capacity of 1,500 watts, are of the cylindrical anode type. Both anodes have vertical radiating fins as aids to increase anode dissipation. The 279A tube employs a greater number of these fins than does the 251A tube. This was necessary due to the greater energy dissipating requirements of the larger tube. Its anode is made of nine sections with a radiating fin at the contact surface of each pair. The development of this anode, and of the assembly tool in which all of the sections are held while they are riveted together, presented a number of mechanical and physical problems. The cylindrical plate construction gives unusually low interelectrode capacities, which make the tubes suitable for high frequency applications. At reduced power ratings they may be used for frequencies as high as 40 megacycles. These tubes are employed as required in the 71A amplifier unit, used as the final amplifier stage in the 500 watt and 1,000 watt broadcast transmitters.

They are also used in various point-to-point radio telephone systems, such as ship-to-shore and airplane-to-ground systems.

One interesting feature of the 279A tube is a new type of structure for tensioning the filament. Instead of employing a separate tensioning spring for each filament V, a central compression spring is used to tension all four V's. This unit spring is supported by the center rod of the filament assembly, and is specially insulated and shielded. The insulator at the upper end supports a platform member which in turn supports the two whiffle trees or rocker arms. The platform has only point contact with the top insulator so as to give it a universal joint action, enabling it to rock freely in any direction. The universal joint action of the top platform, in addition to the whiffle tree action of the two rocker arms, insures uniform tension on all legs of the filament from a single spring. A weighted jig is used to depress the spring to the proper tension and hold the top platform and cross-arms in their correct relative position during the assembly of the filament hooks. The free ends of the filament hooks, which are in contact with the filament, are looped back like a safety pin.

The smallest of the three tubes, the 270A, has a continuous output rating of 500 watts. Its electrical characteristics have been so adjusted that with grid modulation its rated output as a radio-frequency amplifier can be obtained with a maximum instantaneous grid voltage of zero with respect to the cathode. Since the grid does not have to go positive to obtain full output, the input circuit requires practically no power and may employ tubes of minimum rating: a feature of which advantage is taken in all of the new broadcast transmitters. In obtaining this desirable electrical characteristic it was not possible to employ the cylindrical type of construction. The anode is in the form of a flattened cylinder with its principal area in the two plain parallel plates.

Notable improvement in the precision of glass working has been obtained in this tube. The anode is first sealed, accurately centered, into one end of the bulb with a special lathe type of seal-in machine. After the seal

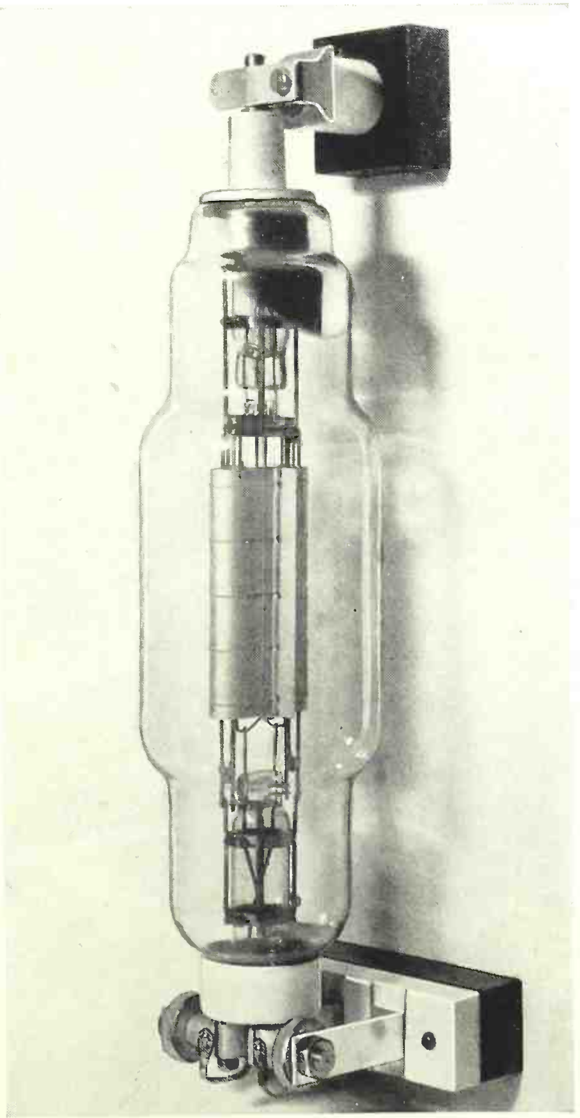


Fig. 5—The 270A tube is smaller in diameter than the others, uses a plate oval in cross section instead of cylindrical, and employs only two radiating fins

is cooled, the filament-grid structure is sealed in the other end on the same machine. There is no central mechanical tie between the plate structure sealed in one end and the filament-grid structure sealed in the other, and the process must be so accurate that the two structures are exactly coplanar and coaxial.

All of these tubes have been placed in manufacture in the Vacuum Tube Shop. In their development a wide variety of physical and mechanical problems have had to be solved, and many members of the vacuum tube development group have contributed to the ultimate success obtained. In coöperation with the technical staff of the Vacuum Tube Shop, the special processes and tools required for the manufacture of these tubes have been worked out so that the manufactured product is realizing the design capabilities of the tubes.

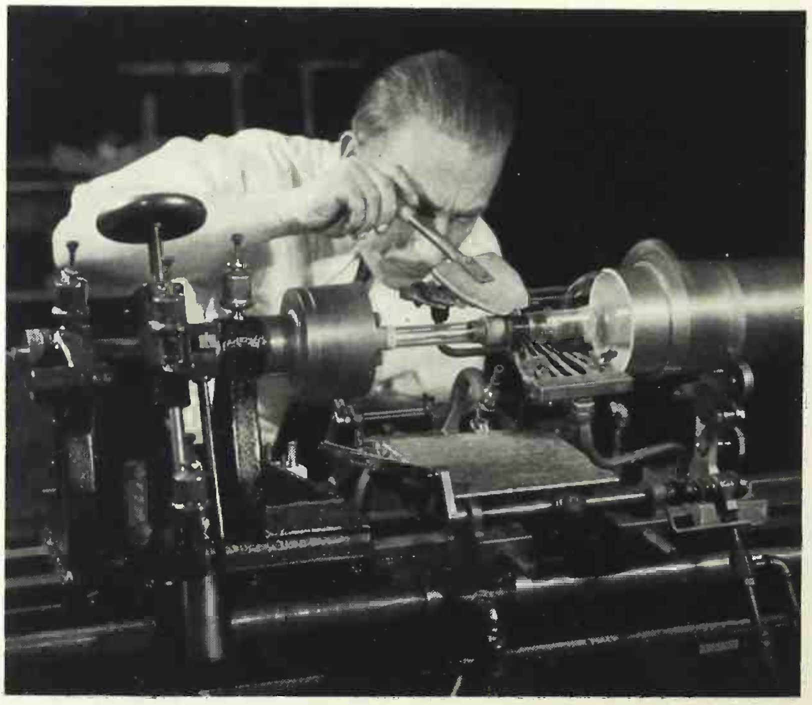


Fig. 6—The seal-in process is performed on a special lathe type machine

A Low-Power Broadcast Transmitter

By A. W. KISHPAUGH
Radio Development

AT the beginning of the third decade of this century, radio broadcasting stations were not only few and far between, they were of comparatively small power as well. They represented but the initial efforts of a youthful industry. To compensate for what the broadcasting stations lacked in power, the enthusiastic and rapidly increasing army of radio listeners were constantly seeking higher power receivers to enable them to pick up stations at greater and greater distances from their immediate vicinities. Now, some half score or dozen of years later, when stations rated from five to fifty kilowatts are commonplace, there is a natural tendency to underrate the effectiveness of the smaller stations.

When fully considered, however, these smaller stations are found to be capable of rendering very substantial service in the fields for which they are adapted. Many programs have only a local or community interest and are well served by a low-power and thus less expensive transmitter. In addition to this field for them, however, low-power transmitters, connected by Long Lines networks, may be used advantageously to broadcast to a group of small areas scattered over the country. Nearly half of the broadcast stations of the present time, a fact perhaps not generally realized, fall within the low-power class—usually defined as one kilowatt or less. There is no fundamental reason why those listening to the programs from this large group of small stations should not be entitled to receive the same high quality of transmission that is secured from the larger stations.

To make it possible for these small-power stations to broadcast programs of high quality without the burden of very expensive equipment, the Laboratories has recently developed a broadcast transmitter that covers the power range from 100 to 1000 watts. It consists of a basic 100 watt transmitter unit, shown in Figure 1, and an amplifier unit, of the same physical size, which may be employed to increase the output to 250, 500, or 1000 watts. Each of these units is three feet wide, about two feet deep, and stands six and a half feet high. The enclosures are of steel, with doors that open to give access to the apparatus, and the back and sides may be easily removed if necessary. All controls are brought to the outside of the cabinet—either to a narrow transverse panel or to a vertical panel between the two upper doors—and the meters are mounted above the doors on the front.

One of the distinguishing features of these new units is that they require no batteries or rotating equipment. All power is taken directly from alternating current circuits. This arrangement attains for transmitters the many advantages in simplicity of operation secured for receivers a few years ago when they were changed from battery operation to opera-

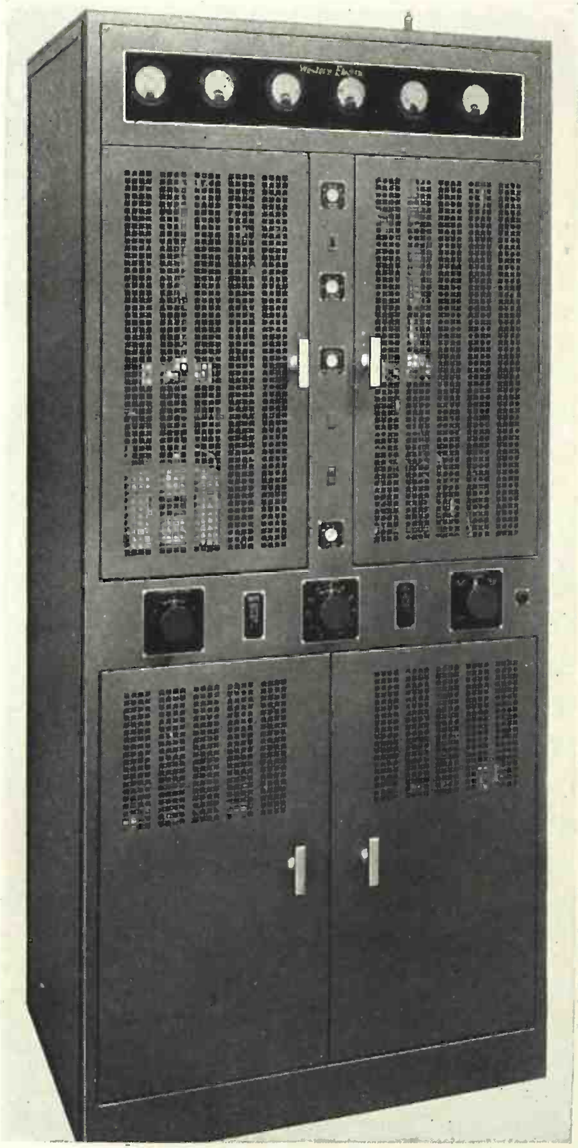


Fig. 1—*The* 100 *watt basic transmitter unit has all its meters and controls on the front of a steel enclosing cabinet*

tion entirely on alternating current.

The interiors of both units are divided into upper and lower compartments—the power supply apparatus being located in the lower, and the high frequency, in the upper. The arrangement of equipment in the 100 watt basic unit is shown in Figure 2. A quartz-controlled oscillator provides frequency stability well within the present fifty-cycle requirement with practically no maintenance. Neither thermostat nor circuit adjustment is required of the operator, and since the crystal is not handled after calibration, the frequency control is truly automatic; the hazards of careless handling or maintenance are practically eliminated. The entire oscillator circuit is housed and calibrated as a unit, and may readily be removed from the transmitter as shown in the photograph on the title page of this issue. Current for the heater circuit, employed for maintaining the crystal at constant temperature, is obtained from a three-element gas filled tube controlled by a thermostat in its grid circuit. This method eliminates the usual relay, and reduces the current carried by the thermostat contact to a negligible amount.

The amplifier stage immediately following the oscillator, to which it is resistance coupled, employs the same type of tube as the oscillator, and is mounted just to the right of it in the cabinet. Grid bias, obtained from a potentiometer, is always sufficient to insure that no grid current will be drawn. This potentiometer is used to adjust the output of the transmitter, which may be varied smoothly from nothing to full output by the operation of a control on the front of the panel. This stage is transformer coupled to the second stage, at the lower left corner of the upper right hand part of the cabinet, which in turn is transformer coupled to the power amplifier, consisting of two tubes arranged in a push-pull circuit.

It is in this power stage that the voice-frequency currents modulate the carrier. The method employed is known as grid-bias modulation. Although a similar scheme has been very successfully used in commercial carrier-telephone systems for a number of years, it is believed to be the first time it has been employed in a broadcasting transmitter. It has the great advantage of contributing to the simplicity and economy of operation by a reduction in the number of vacuum tubes required.

The fundamental circuit for this method of modulation is shown in Figure 3, and a simplified schematic for the high-frequency circuit of the 100 watt transmitter, in Figure 4. The grids are biased to considerably below cut-off, and the radio-frequency grid voltage is applied to the two grids out of phase, as in any push-pull amplifier. Audio frequency, or modulating, voltage is applied to the two grids in parallel, effectively in series with the grid-biasing voltage. Thus the effective grid bias voltage is varied in accordance with the audio-frequency voltage, which accounts for the name "grid-bias modulation." The tubes are operated so that the relation between input and output voltage is essentially linear. Complete modulation is obtained with a carrier output of 100 watts and a peak output at full modulation of 400 watts.

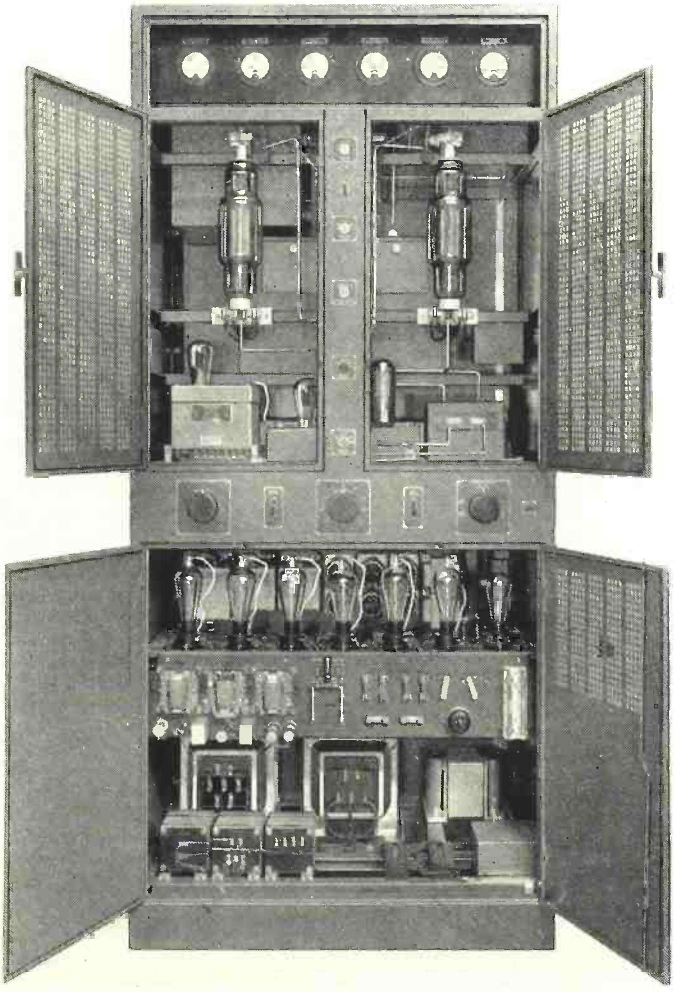


Fig. 2—Opening the doors of the 100 *watt unit reveals a power supply compartment below, and a high-frequency compartment above*

No speech amplifier is contained in the transmitter. The input transformer connected to the grid of the modulating amplifier is fed directly from the speech input equipment. The speech level is considerably higher than is commonly required at the input of a radio transmitter but is one that any amplifier capable of operating a loud speaker can supply.

Effective suppression of radio-frequency harmonics is obtained in the coupling circuit through which the out-

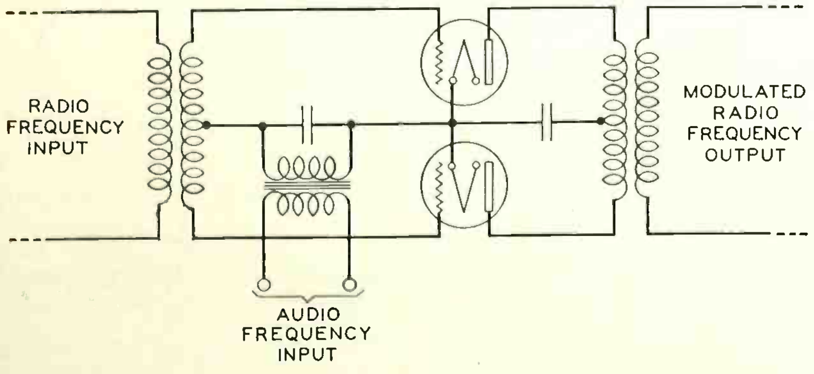


Fig. 3—Simplified schematic illustrating the method of grid-current modulation

put of the power amplifier is transferred to the antenna. This circuit is easy to adjust, and the harmonic radiation is kept well below .05% of the fundamental, thus anticipating any requirements that may reasonably be expected. The antenna is tuned by adjusting the loading inductance for maximum current in the usual manner, and an artificial antenna resistance is provided to allow the transmitter to be energized without radiating a signal, should this be desired for test purposes.

Monitoring is provided by a transformer connected in the plate circuit of the final stage. This type of monitor is new, but has the advantage of not requiring a tube or other type of rectifier. Since the audio-frequency currents flowing in this circuit result from the modulation of the output of the amplifier, they give a faithful indication of the output.

As already mentioned, the entire power for the transmitter is obtained from an

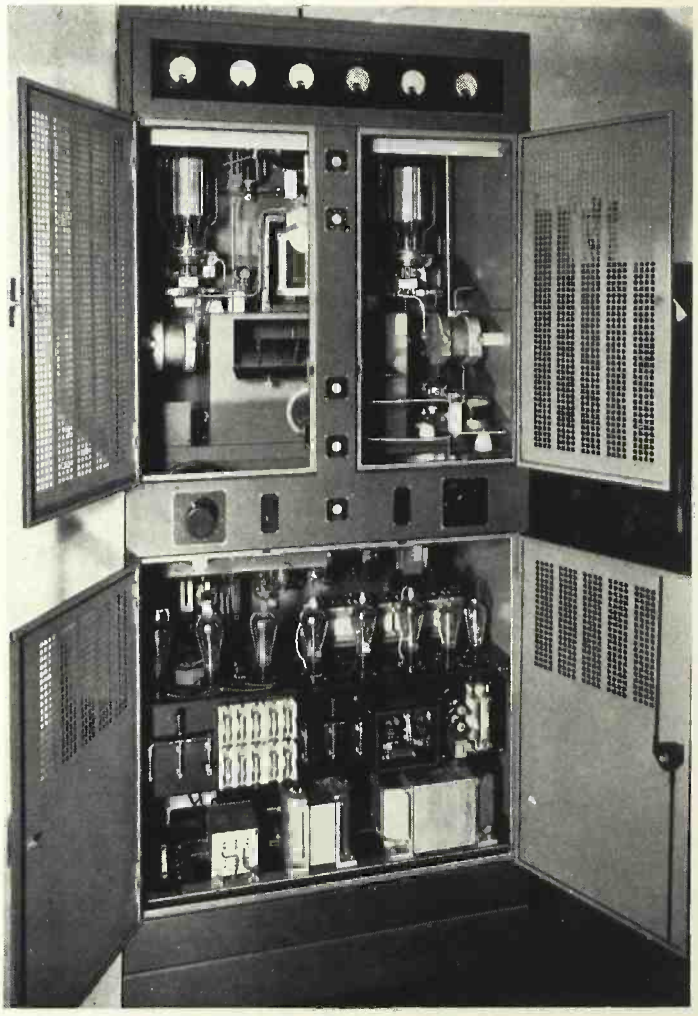


Fig. 5—The amplifier cabinet is the same size as the transmitter and like it has an upper compartment for the high-frequency circuits and a lower, for the power supply

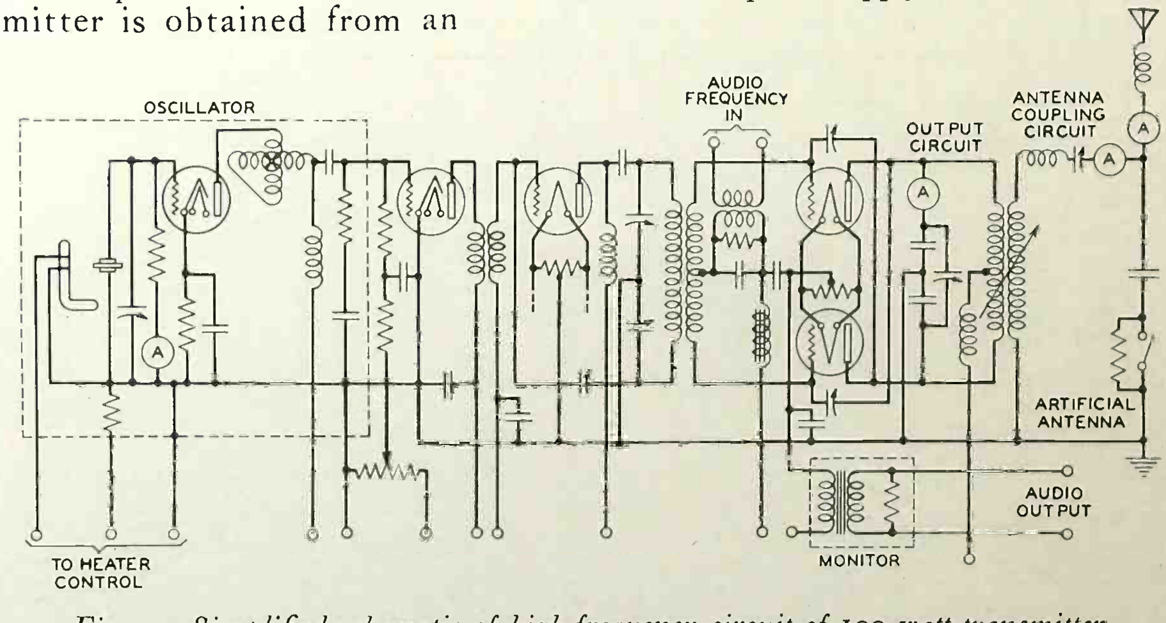


Fig. 4—Simplified schematic of high-frequency circuit of 100 *watt transmitter*

alternating current supply without the use of rotating machinery. Two rectifiers supply 3000 volts for the last stage, and lower voltages for plate and grid-bias circuits. Potentiometers, to provide stability of the desired voltages, are employed wherever voltage reduction is required. The circuits are simple, and relays are provided to introduce the necessary time delays in energizing the mercury-vapor rectifier tubes. The total power required for the operation of the transmitter is approximately 1500 watts single phase.

To extend the range of this transmitter to outputs of 250, 500, and 1000 watts, a separate amplifier unit is provided as already mentioned. The same cabinet, equipped with the proper tubes and circuit elements, is used for all three sizes of amplifier. The 1000 watt size is shown with doors open in Figure 5. The arrangement of equipment in two compartments is similar to that of the transmitter, and all circuit elements likely to radiate are completely shielded. A three-phase alternating current supply is required for its operation.

A simplified schematic of the high-frequency circuit of the power amplifier is shown in Figure 6. The circuit and equipment arrangement is alike for either 250, 500, or 1000 watts output, except for the differences necessary because of the three power capacities. The amplifier unit is connected across the terminals of the coupling condenser of the transmitter, and the circuit is similar to that of the final amplifier of the transmitter. The tubes are of the radiation-cooled type described elsewhere in this issue of the Record*.

Biasing voltage is obtained from a full-wave single-phase rectifier employing mercury-vapor tubes, and the 3000 volt plate potential is obtained from a full-wave three-phase rectifier also employing mercury-vapor tubes. A thermal delay circuit provides the necessary time interval for the fila-

*Record, *October* 1932, *p.* 30.

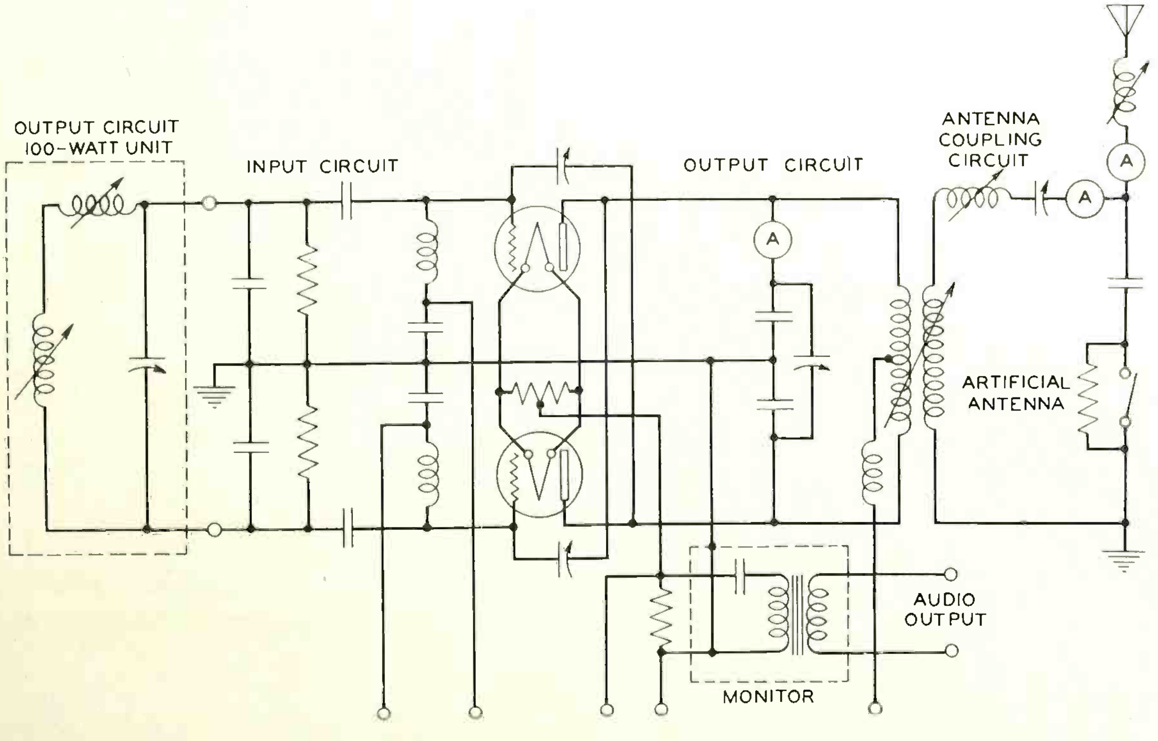


Fig. 6—Simplified schematic of high-frequency circuit of power amplifier

ments to reach operating temperature before high voltage is applied. A photograph of the complete 1000 watt equipment is shown in Figure 7, with the transmitter at the left and the amplifier on the right.

The safety and control circuits of the two units are interlocked, so that opening any of the doors on either unit removes all high voltage from both units. Although switches are provided so that starting may be sectionalized if desired, the entire transmitter may be controlled by the master switch in the 100 watt unit. When this switch is operated all the various circuits are energized in the proper sequence, and the transmitter may be "put on the air" from a cold condition in less than a minute.

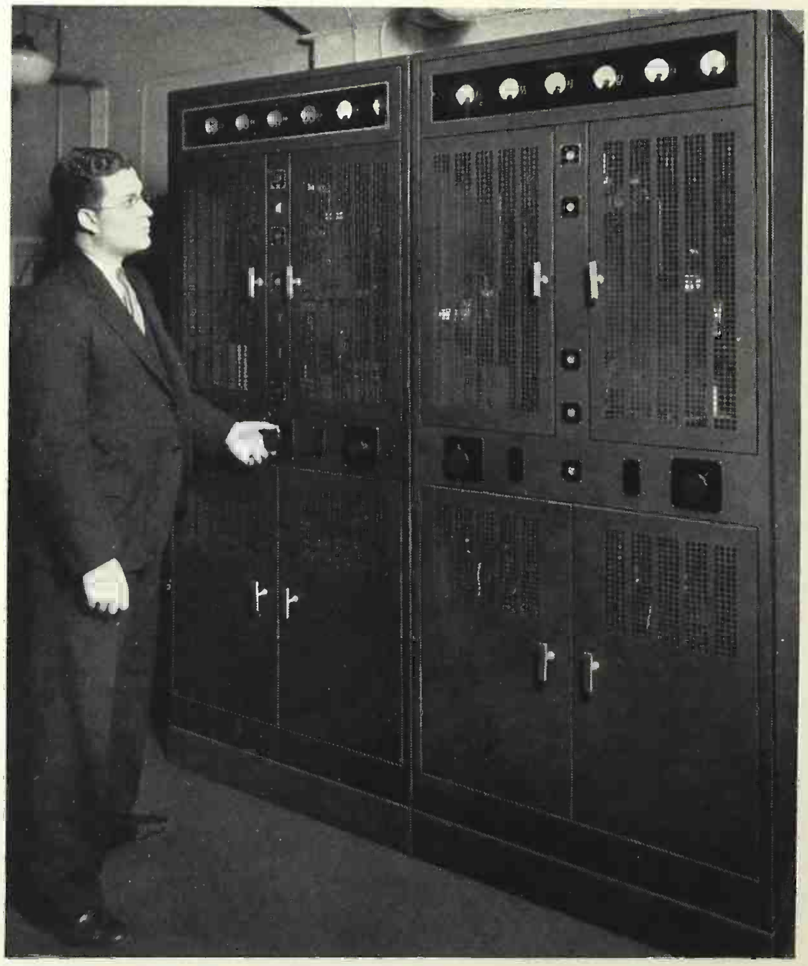
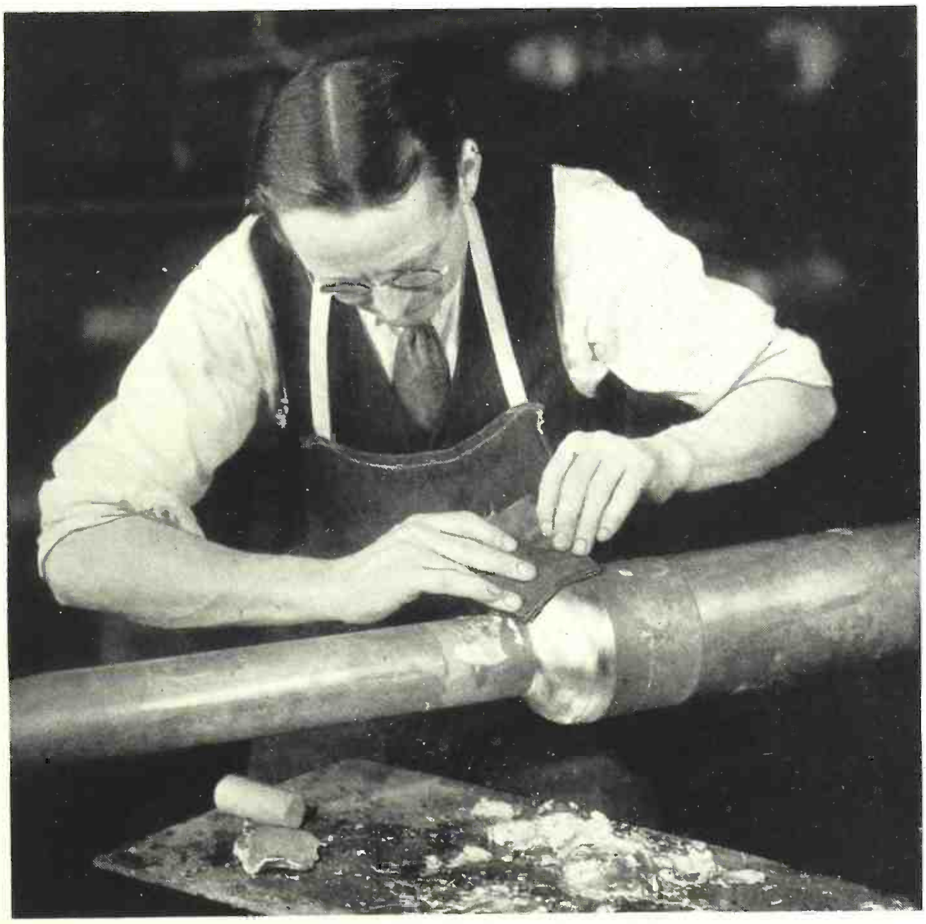


Fig. 7—1000 watt broadcast unit. Transmitter at left and amplifier on the right



Solder and the Art of Wiping Cable Splices

By H. BAILLARD
Outside Plant Development

IN every mile of lead covered cable there are some seven or more points at which separate lengths of cable have been spliced together. These joints are protected from moisture and mechanical injury by lead sleeves surrounding them and soldered to the cable by wiped joints. The Bell System uses some two and one-half million pounds of solder a year for this work. The composition used is a lead-tin alloy not unlike the soft solder so commonly employed by the plumber.

The use of such soft solders was well known when the science of communication was limited chiefly to the use of foot messengers, horses, and ships. As early as the 11th Century, a monk named Rugerous, writing an "Encyclopedia of Christian Art," included a chapter entitled "An Essay Upon Various Arts." The following verbatim specification on 11th Century soldering technique is of interest: "Beat very thinly a piece of tin, mix with a third part of lead, and cutting it up very small, lay it around the joint; and a few ignited coals being applied, as soon as it has cooled, anoint it around with resin of the fir tree, and you will instantly see the particles melt and flow about. The coals being directly removed, when cooled, the joint will be firm." Samples of medieval chain mail have been found to contain authentic soldered joints between links of the mail and adjacent plate work.

The art of using soft solders to make joints by a wiping operation came later. Wiping means essentially the manipulation by hand of half molten or plastic metal in such a way as to form it against and around the parts to be connected. The art of solder wiping requires considerable dexterity and rather more attention to the temperature and composition of the solder than a casual observer would appreciate. The handbook specification on cable splicing of the American Telephone and Telegraph Company devotes a page and a half to the delicate technique of getting the solder, heated until it is thin and pours readily, on the right spot at the right time. An experienced splicer, however, will tell you that it requires long experience to acquire the degree of skill necessary to transform the theory into successful practice. At any rate, the proper manipulation of a ladle of molten metal, usually held in the right hand, and the "catch cloth" held in the left requires a synchronization of rotary, wiping and sliding movement, the proper timing of which can best be appreciated only after examining the first attempts of the uninitiated.

Fig. 1—After the sleeve has been slid over the splice its ends are beaten down into contact with the cable

Solder wiping practices antedated the telephone by many years. Early New York City water mains made of wood were joined to lead pipe for distribution of the water through the houses. Joints in this lead pipe were solder wiped in a manner analogous to that of today.

About 1885, when cables consisted of lead pipe into which insulated wires were pulled by hand, the telephone industry had to call upon the local solder-wiping artisan, generally the plumber, for assistance in joining telephone cables. It was not until several years later that the Telephone Companies started to train their own men to wipe the splices of cables so that the resulting joints would be waterproof, airtight, and strong.

Up to 1918 the various Associated Telephone Companies bought commercially manufactured solder of two compositions, one 50% each of tin and lead, and the other 40% tin and 60% lead. In 1914, for example, some of the Companies used the 40-60 solder

News of the Summer Months

ELECTRICAL EFFECTS OF THE ECLIPSE

At Deal and Holmdel radio research groups were occupied throughout the eclipse on measurements of its electrical effects. Continuous observations were made of the height of the Kennelly-Heaviside layers, two ionized regions in the upper atmosphere whose reflecting effects are important in determining the propagation of radio waves. By sending up suitable waves and observing the time taken for each to return, the respective heights of the layers were measured. These observations were supplemented by measurements of the strength of radio waves transmitted from Bermuda and from England. Changes in the heights of the layers were found to follow instantaneously upon the obscuring of the sun, a behavior which supports the theory that the layers are due to the photoelectric effect of the sun's rays, rather than to bombardments of the atmosphere by neutral particles from the sun, as had been thought possible.

In the region of totality, at Conway, N. H., E. T. Burton and E. M. Boardman observed atmospheric disturbances at audible frequencies, using a loop antenna and vacuum tube amplification of a thousand billion times. These disturbances, audible for the most part as "tweeks" or "pings," are thought to be electrical reverberations of static crashes which are reflected back and forth between a Kennelly-Heaviside layer and the ground.

EARLY LOUD SPEAKER

A recent accession to the Historical Museum is a development model of a loud speaking receiver, invented by Sergius P. Grace and Richard A. L. Snyder in 1909, and named the Telmegaphone. According to the patent issued to Messrs. Grace and Snyder, the novelty of this loud speaker lay in its use of a specially shaped armature pivoted in the center so that voice currents in the two adjacent coils would cause corresponding oscillations in the armature. A polarizing field was provided by a permanent or electro-magnet so arranged that its flux flowed in parallel through the two halves of the armature and the two magnet cores adjacent. Vibration of the armature was communicated to a diaphragm by an arm. The underlying electrical principle is similar to that of the highly efficient magneto bell so long in use for calling subscribers.

At the time of the invention, Mr. Grace was general superintendent of plant and Mr. Snyder was plant engineer of the Central District and Printing Telegraph Company, which at that time furnished Bell Telephone service in Western Pennsylvania and adjacent territory. A clipping from the Jamestown, N. Y., *Evening Journal* records the demonstration of the telmegaphone on May 26, 1909, when the mayor of Pittsburgh addressed an audience in Jamestown. This is believed to be the first demonstration of a loud speaker worked over a toll line before a large audience. Another demonstration of the instrument was given before an audience of approximately three hundred members of the Engineers Society of Western Pennsylvania and one from New York to Pittsburgh for the benefit of the Equitable Life Assurance Society.

A handicap in the practical use of the telmegaphone was its need for more energy than was readily available in the telephone art of that day. A practical vacuum-tube amplifier had not yet been developed, and the only source of electrical speech energy was the granular-carbon transmitter. Line transmission has also been greatly improved by recent research and development.

When the speaker was close to the transmitter and the telephone line had low enough losses, good results could be secured. These limitations were too severe, however, and commercialization of the loud-speaker idea had to await the development of the vacuum tube amplifier.

The model is loaned to the Museum by Mr. Snyder, who is now Engineer of Radio Equipment for The Bell Telephone Company of Pennsylvania.

ADMINISTRATION

In his capacity as President of the American Institute of Electrical Engineers, H. P. Charlesworth spent the past month touring the western United States to address local sections of the Institute on *Extending Our Frontiers Through Research and Engineering*. By way of Lake Louise and Emerald Lake, Mr. Charlesworth reached Vancouver on August 29 to give his first address. Thence he travelled down the coast, speaking in Seattle, Portland, San Francisco, and Los Angeles. After an automobile trip across Utah with Mr. F. P. Ogden, Vice President and General Manager of the Mountain States Telephone and Telegraph Company, Mr. Charlesworth talked in Salt Lake City, and then filled his last two speaking engagements in Denver and Boulder, Colorado.

APPARATUS DEVELOPMENT

R. M. C. Greenidge while at Hawthorne investigated the use of loading coil cases which are subjected to air pressure.

R. W. De Monte and C. A. Brigham went to Oneonta, N. Y., for field tests on a system of neutralizing transformers designed to reduce interference in communication circuits from power lines.

C. E. Nelson visited both the Official P.B.X. at Newark and the Lackawanna Railroad P.B.X. at Hoboken on July 8, and also inspected bank contacts in central offices at Hoboken and Newark.

O. A. Shann visited the plant of the Gray Telephone Pay Station Company in Hartford, Conn., in connection with the manufacture of coin collectors.

During the past month, L. A. Elmer has been in Rochester in connection with work on sound picture equipment.

H. L. Walter, E. G. Fracker and H. C. Curl made visits to Washington to confer with members of the Navy Department on new developments now being carried on for it in the Laboratories.

F. H. McIntosh supervised the installation of 100-watt radio-transmitting equipment for the Reporter Printing Company, Fond du Lac, Station KFIZ, and of 400-watt radio telephone equipment for the police radio system of Dayton, Ohio, Station WPDM. He also visited Station KMBC owned by Midland Broadcasting Company, Kansas City, Mo., and Station WEAO owned by Ohio State University in Columbus.

The conversion for improved frequency control of the 1-kw. radio-telephone broadcasting equipment owned by The Outlet Company, Providence, Station WJAR, was directed by O. W. Towner. He also inspected Station WEEI, owned by Edison Electric Illuminating Company, Boston.

B. R. Cole visited Portland, Ore., to supervise the conversion of the 1-kw. radio-telephone broadcasting equipment owned by the Oregonian Publishing Company, Station KGW, to provide improved frequency control. He also inspected Station KRKD owned by Dalton's Incorporated and Station KFAC owned by Los Angeles Broadcasting Company, both in Los Angeles.

At Bradley, Maine, experimental operations on the 12-24 kw. long-wave transmitting equipment were conducted by J. E. Burrell for the American Telephone and Telegraph Company.

E. D. Mead visited Veeder-Root Inc. at Hartford, Conn., for conferences on switchboard timing-devices.

F. E. Nimmcke inspected the 500-watt radio-transmitting equipment owned by the Baltimore Radio Show, Inc., Station WFBR.

J. W. SMITH inspected and put into operation the 50-kw. radio-transmitting equipment at Station WCCO of Northwestern Broadcasting Inc., in Minneapolis.

SEVERAL RADIO broadcasting stations on the Pacific Coast were visited by B. R. Cole, including Station KERN owned by the Bee Bakersfield Broadcasting Company, Bakersfield, Calif.; Station KJBS, Julius Brunton and Sons Company of San Francisco; KXL Broadcasters, Portland, Ore.; and KXRO Inc., Aberdeen, Wash.

W. L. BLACK visited Louisville, Ky., to consult with the Graybar Electric Co. and the owners of Station WHAS, the Courier Journal Co. and the Louisville Times Co., in regard to new speech-input equipment for that station.

A PAPER ENTITLED "Program Distribution System for Large Hotels and Similar Public Institutions" by J. J. Kuhn, F. X. Rettenmeyer, and E. O. Scriven was presented by Mr. Rettenmeyer on September 7th to the New York Section of the Institute of Radio Engineers.

T. E. SHEA and W. HERRIOTT, with W. R. Goehner and J. Crabtree, visited the Eastman Kodak and Folmer-Graphlex Companies of Rochester regarding optical developments.

DURING THE PAST month H. Pfannenstiehl has been in Hartford in connection with the development of telephoto equipment.

S. C. MILLER and L. W. KELSAY were in Allentown, Pa., in connection with a trial installation of protected building terminals.

R. H. COLLEY attended the summer meeting of the American Wood Preservers' Association in Washington, D. C. While there he conferred with the staff of the Forest Service and Bureau of Plant Industry on chestnut utilization problems. Mr. Colley also visited Birmingham, Ala., and Spartanburg, S. C., in connection with the production and preservation of southern pine poles.

E. ST. JOHN went to New Haven, Conn., to observe an installation of adjustable cable shields.

AN INSPECTION of test sections of the Buzzards Bay-Falmouth aerial toll cable for evidences of sheath deterioration was witnessed by G. B. Hall, together with S. D. Ricciardi of the Operation and Engineering Department, A. T. & T., and representatives of the New England Telephone and Telegraph Company.

C. H. AMADON, with W. P. Whyland of the Western Electric Company, was in Natural Bridge, Va., and Sylva, N. C., continuing their study of the quality of chestnut poles.

TWENTY YEARS of service in the Bell System were completed by B. O. Templeton on August 12, and by J. H. Bower on September 10.

S. A. Reilly, Jr.

MEMBERS OF THE Laboratories were shocked to learn of the death of S. A. Reilly, Jr., which occurred on August 20 at Presbyterian Hospital. He had been a member of the group developing and designing transformers for use with amplifiers. Mr. Reilly was a graduate of Stevens, where he taught for a year after his graduation. Later he continued his studies at Massachusetts Institute of Technology, and joined the Laboratories early in 1927. His many friends here deeply sympathize with his parents and brothers in their loss.

On August 3 Edward Montchyk completed thirty years of service in the Bell System. After his graduation from the University of Colorado, Mr. Montchyk held the Whiting Fellowship in Physics at Harvard University, where he studied mathematics and physics. He joined the apparatus design group of the Western

E. Montchyk

Electric Company (after two years with the General Electric Company at Lynn) and took part in the design of the first toroidal coil, and of the No. 8 cable terminal. Later he headed a group editing special orders, and then a group approving apparatus drawings. In 1907 he went to Antwerp for apparatus design work in the Bell Telephone Manufacturing Company. In a few years he headed that group, and later became Chief Engineer at Antwerp and head of the Installation Department there. In 1914 he returned to the United States where during the next five years he divided his time between New York and Hawthorne. After going to Europe in 1919 to assist in reopening the Antwerp factory, Mr. Montchyk rejoined the New York organization. Here he has had charge of groups investigating insulating materials and the physical properties of materials used in the telephone plant, and has developed methods for determining strength of materials, for precise measurement of dimensions, and for accelerated testing. He is now in charge of a group analyzing dial apparatus and has most recently been concerned with the development of means for controlling contact noise in dial apparatus.

SYSTEMS DEVELOPMENT

E. H. Perkins, H. T. King and R. J. Rhael have been at Charlotte, N. C., Greenville, S. C., and Atlanta, Ga., making overall system tests of a type "C" carrier-telephone system modified to use laboratory models of a new two-way terminal-and-line repeater of a single amplifier type.

D. D. Smith spent three weeks in July at Atlanta, investigating the effects of lightning upon carrier telegraph systems.

Twenty years of service in the Bell System were completed by W. G. Schaer on August 11, and by R. B. Buchanan on August 15.

F. W. Treptow spent several days at Hawthorne discussing panel equipment problems with Western Electric engineers.

R. L. Lunsford and J. G. Ferguson, with engineers from the Western Electric General Installation Department, inspected recent installations of 370-A dial offices at Jewett and Shokan, N. Y.

In coöperation with Long Lines Department engineers, R. P. Jutson conducted tests on tungar rectifiers used for charging plate batteries at the Scranton toll office.

C. B. Sutliff was in Atlanta during August, making tests on carrier telegraph systems between Washington and Atlanta of lightning interference.

The thirty-five years of service in the Bell System which Francis A. Cox completed on the fifteenth of last month began in the Switchboard Cabling Department at the Western Electric Company's Clinton Street shop in Chicago. Four years later he became one of the original members of the Engineering Inspection Department, formed in 1901. In 1902 he came to New York and for the following three years served in the Equipment Engineering group.

All but a year and a half of Mr. Cox's

next fourteen years were spent abroad. For the first nine, he was in Antwerp, as Equipment Engineer and later as Chief Engineer. His brief return to New York was followed by three years in Adelaide, Australia, as engineer in charge of the first Western Electric machine switching installation in that country. Since his return to the Laboratories in 1919 Mr. Cox has been in the systems organization developing specifications for the requirements placed on central office apparatus and its adjustment, and on the performance of central office equipment.

F. A. Cox

In the year or so since his twenty-fifth service anniversary was noted in the Record for May, 1931, Edward E. Hinrichsen has added another five years to his service in the Bell System. This latest verification of the theory of relativity was accomplished by bridging the gap between Mr. Hinrichsen's departure from the Central Union Telephone Company and his entrance into the Western Electric Company. The rich harvest of time thus garnered from the early part of the century was successfully transmuted into a sixth star for Mr. Hinrichsen's service emblem on August 7. He took the abstract excursion all in his stride, with no interruption of the patent studies which he conducts in the special systems development group.

The quarter century of service in the Bell System, which Carl E. Boman rounded out on August 4, had its inception in the students' course of the New York Telephone Company. He had received the E.E. degree from the University of Minnesota in 1905, and had spent the first two years after graduation with the Stromberg Carlson Company. Following two years of central office maintenance work with the New York Company, Mr. Boman transferred to the Western Electric Company, engaging at Hawthorne in various phases of the work of the Equipment Engineering Branch. In 1919 he came to New York for dial systems development and a year later went to London and Antwerp in connection with the proposed introduction of dial equipment in London. Since his return in 1921 Mr. Boman has had an active part in the continued development of dial equipment for central offices.

C. E. Boman

RESEARCH

A. G. Russell visited the long-wave transatlantic radio-receiving station at Houlton, Me., during the first week in August, to make phonograph records of static produced during thunderstorms.

T. Odarenko made a trip to the Point Breeze plant of the Western Electric Company in connection with manufacturing problems of high-frequency conductors.

Twenty years of service in the Bell

System were completed on the first of last month by W. C. Jones, on the twenty-third by H. A. Frederick, and on the thirtieth by G. A. Kelsall.

H. F. Hopkins demonstrated the electrical stethoscope over Station WABC, on July 25, by broadcasting heart-beats and the dropping of pins and feathers. The demonstration was made in conjunction with a talk given by O. H. Caldwell, editor of *Electronics*.

R. R. Williams addressed the fifteenth annual convention of Canadian Chemical Association at Hamilton, Ontario, on *The Critical Chemistry of the Commonplace*.

L. E. Krohn

The Laboratories learned with regret of the death from anemia on July 13 of Lawrence E. Krohn. A native of Madeira, Mr. Krohn received the B. S. degree in Chemistry from the University of London in 1924. A year later he joined our Chemical Laboratories and undertook research on tarnish and corrosion, meanwhile continuing his studies at Columbia where he received the M. A. degree three years ago. He left considerable still unpublished material supplementary to his one brief published paper.

The death of W. B. Edwards on the seventh of last month brought deep regret to many members of the Laboratories. Since the spring of 1930 Mr. Edwards had been associated with the group handling current engineering on transmitters, and had done considerable work on the mechanical design of transmitters. Mr. Edwards was a graduate of Cornell University in mechanical engineering.

W. B. Edwards

On September First Charles A. Finley completed forty years' service with the Bell System. In 1892 he joined the American Bell Telephone Company at Boston. At that time they were assembling and testing their own telephone instruments, and with the Inspection Department he was intimately associated with this work. Although the parts for the instruments were obtained from New York, the carbon was made locally and he recalls trips to a coal yard in Cambridge where he would pick out a quarter of a ton of coal by hand, inspecting each piece before accepting it. After two preliminary crushing processes, the first in a flour mill and the second between the rolls of a barrel-hoop rolling machine, the coal was powdered in a crucible, roasted, washed, sifted, and carefully inspected, all of which were done by him or under his control.

In 1898 the assembly of telephone instruments was taken over by the Western Electric Company, and Mr. Finley transferred to New York to supervise the inspection work. Ten years later he transferred to the Engineering Department where he became engaged in transmission research and was made responsible for telephone instrument standards. During the war he was occupied with the development of microphones for airplane service and for submarines, and of submarine detectors. Until the armistice he was in charge of the assembly and test of all submarine detectors. At the present time he is Transmission Instruments Standards Engineer, and is responsible for all instrument standards and for special transmission instruments.

C. A. Finley

PUBLICATION

John Mills and M. B. Long spent a few days in Chicago furthering plans for the Bell System's part in the Century of Progress.

PERSONNEL

G. B. Thomas attended the annual meeting of the Society for the Promotion of Engineering Education which was held at Corvallis, Oregon.

Nora M. Larkin completed twenty years of service in the Bell System on September 18.

STAFF

Twenty years of service in the Bell System were completed by John Bachor on August 19, and by E. Vaupel on September 27.

The presentation of a six-star service emblem to Thomas Barton on August 7 marks a period of service at West Street leading to a familiarity with our building and its ways which has much to do with making our plant the smoothly running institution it is. Coming to the Western Electric Company in 1902, Mr. Barton has had experience with the building's nooks and crannies as porter, and with

T. Barton

most of its inhabitants as watchman and elevator operator.

Services which almost all members of the Laboratories have frequent occasion to appreciate were signalized on the twenty-first of last month with the presentation of a service emblem to Anna M. Menig, Chief Operator of the Laboratories' private branch exchange. After a short time with the New York Telephone Company as student and operator at the Gramercy and Stuyvesant exchanges, Miss Menig came to serve the Western Electric Company at its branch switchboard at West Street. She soon became Assistant Chief Operator, and since the Western Electric general headquarters staff moved downtown she has been Chief Operator.

PATENT

H. A. Burgess was at the Patent Office in Washington in connection with patent matters.

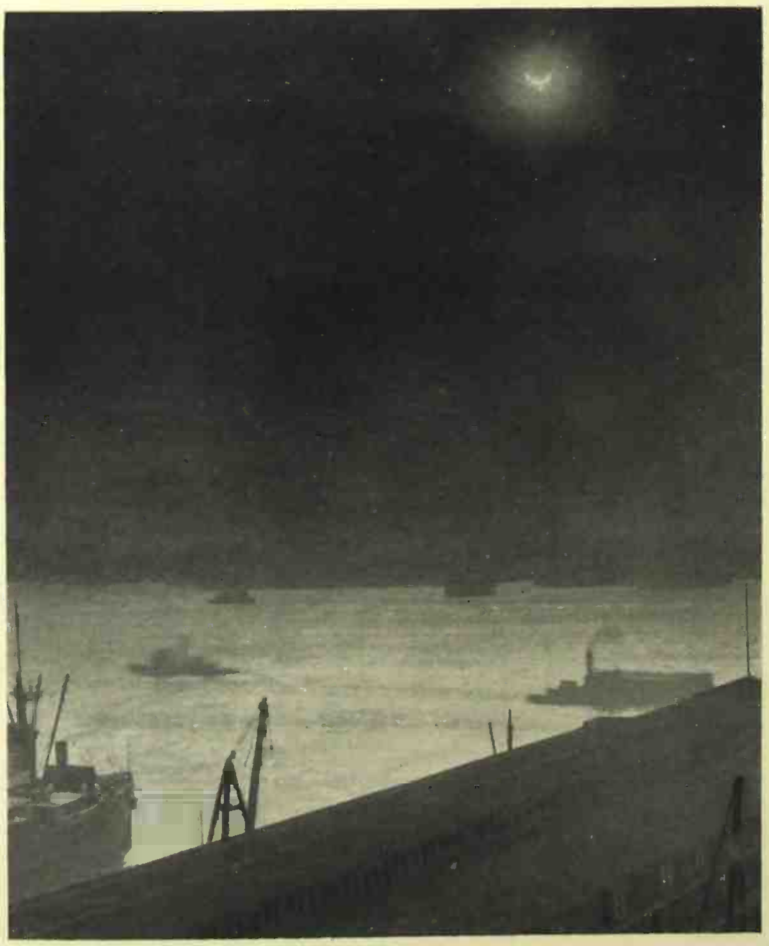
W. C. Kiesel attended a hearing before the Examiner of Interferences in Washington.

Patent litigation required the presence of E. W. Adams, M. R. McKenney and A. G. Kingman in Bay City, Mich., and of Mr. Kingman in Cleveland, Detroit and Chicago.

H. P. Franz was at Hawthorne in connection with patent marking.

During June and July patents were issued to the following members of these Laboratories:

W. O. Beck
A. F. Bennett
E. A. Bescherer
B. G. Bjornson (2)
F. A. Bonomi
L. G. Bostwick
H. G. W. Brown
G. W. Burchett
G. W. Burr
W. W. Carpenter (2)
T. G. Castner
P. P. Cioffi (2)
A. I. Crawford
T. V. Curley
A. M. Curtis
J. F. C. Dahl (2)
D. T. Eighmey
W. C. Ellis
G. W. Elmen
L. A. Elmer
J. G. Ferguson
J. C. Field
H. T. Friis
J. J. Gilbert
F. J. Given
M. S. Glass
H. W. Goff
J. W. Gooderham
F. Gray (2)
R. M. C. Greenidge
A. E. Hague
H. Hall
H. E. Haring
H. C. Harrison (2)
W. S. Hayford
H. Hovland
W. C. Jones
C. W. Keckler
M. J. Kelly
G. V. King (2)
H. L. Kitts
H. Lathrop
V. E. Legg
K. Lutomirski
R. F. Mallina
W. A. Marrison
R. F. Massonneau (3)
E. R. Morton (3)
I. H. Parsons
H. Pfannenstiehl
W. B. Prince
R. L. Quass
R. Raymond
C. F. P. Rose
B. F. Runyon
J. H. Sailliard
W. J. Scully
H. O. Siegmund
E. M. Smith
C. A. Sprague
R. L. Stokely (2)
H. M. Stoller (3)
R. V. Terry
A. L. Thuras
H. Vadersen
C. V. Wahl
H. W. Weinhart
J. H. White
W. Whitney
A. Zitzmann



The eclipse photographed from the Laboratories building by J. Papino for all wiping work whereas others purchased 50-50 solder and had their cable splicers modify it on the job by adding pieces of scrap cable sheath to the melted solder to prepare a mixture with suitable handling qualities. At about this time one of the Associated Companies assembled its more expert splicers for a grand elimination contest to determine the most widely preferred composition of wiping solder. Many joints were made from solder tempered by adding lead until the experts judged the metal mixture to be a suitable working solder. Samples were then taken from the many joints produced, and were analyzed as accurately as possible for their lead and tin proportions. The average composition of these samples was substantially 38% tin—62% lead. Thus originated the specification written in 1919 on 38-62 solder which is supplied as one of the standard solders at the present time, although in some localities the tempering of 50-50 solder, and in others the 40-60 solder, is still adhered to. In 1930 over three-quarters of the solder used was either the 38-62 solder or its near relative 40-60, the rest being 50-50 solder tempered as desired.

If a tin-lead alloy is made up with 63% tin, it will melt sharply at 181° C. Conversely, on cooling slowly, a melted mass of this alloy will solidify sharply at this same temperature. This is the eutectic alloy of tin and lead, the lowest melting combination of these two metals. A solder behaving in this way, however, could not be formed or wiped smoothly onto a joint. A practical wiping solder must have an intermediate stage in which it is neither completely liquid nor completely solid but has a plastic character amenable to wiping. This condition is achieved by decreasing the tin content to around 38%. A 38% tin—62% lead combination will be completely melted at 240° C. As it is allowed to cool some of the lead begins to crystallize out. This will

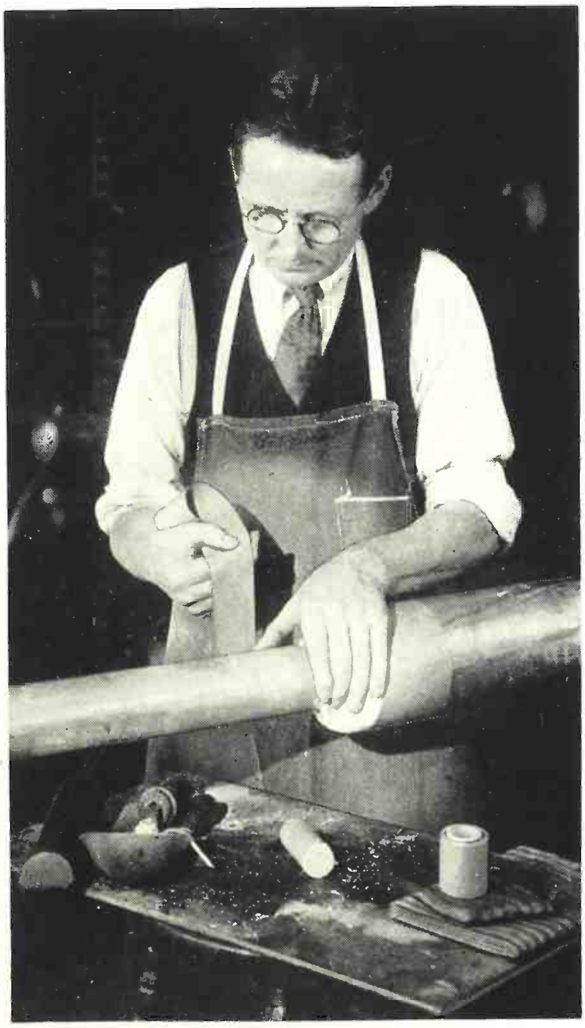


Fig. 2—Paper pasters are placed around the cable and sleeve to mark the limits of the wiping

continue as the temperature drops, the molten metal first becoming slightly mushy, then more mushy, until it becomes a plastic mass growing stiffer and stiffer. Finally, at 181° C. (the eutectic freezing temperature) all of the mass will be solid.

The period over which a solder remains plastic increases with its lead content. A high lead content is also advantageous from a cost standpoint.

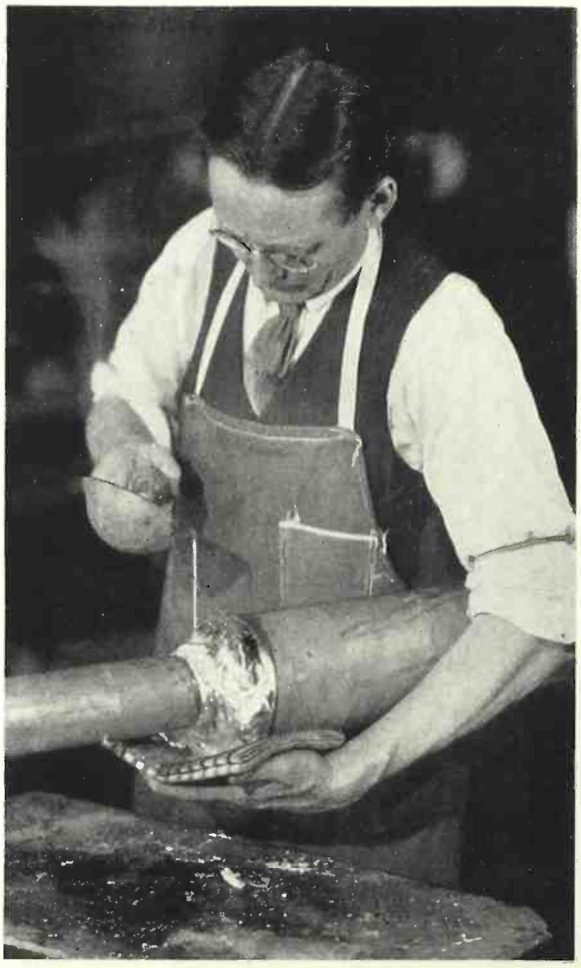


Fig. 3—Molten lead is poured over the joint to heat it to the proper temperature and to supply the metal for the wiping process

An excess of lead above the 62% limit, however, is apt to produce a coarse-grained joint accompanied by a porosity which defeats the object of making the joints water- and air-tight. On the other hand, the percentage of lead cannot be lowered much below 60%, because if this is done the time interval in which the solder remains plastic is shortened so much that few splicers can shape a joint before all the metal hardens.

Commercially refined lead and tin contain as impurities minor amounts of other materials which may produce very definite effects on the wiping characteristics and ultimate structure of the solder. More than 0.3% of antimony decreases the cohesiveness of the solder. The consequent handling difficulties, due to the fineness of grain and shortening of working time, are similar to those resulting from an excess of tin. More than .005% zinc produces a lumpy wiping material. Copper up to .05% and even .10% in some cases has no deleterious effects on either the wiping operation or the quality of the finished joint, although the general tendency is to develop a finer grain and a harder joint structure. In the presence of antimony above the 0.3% limit copper may produce an overall improvement by alloying with some of the antimony, thus removing it from solution. Bismuth and tin combine to form a eutectic which depresses the freezing point, thereby unnecessarily prolonging the cooling period. Bismuth is

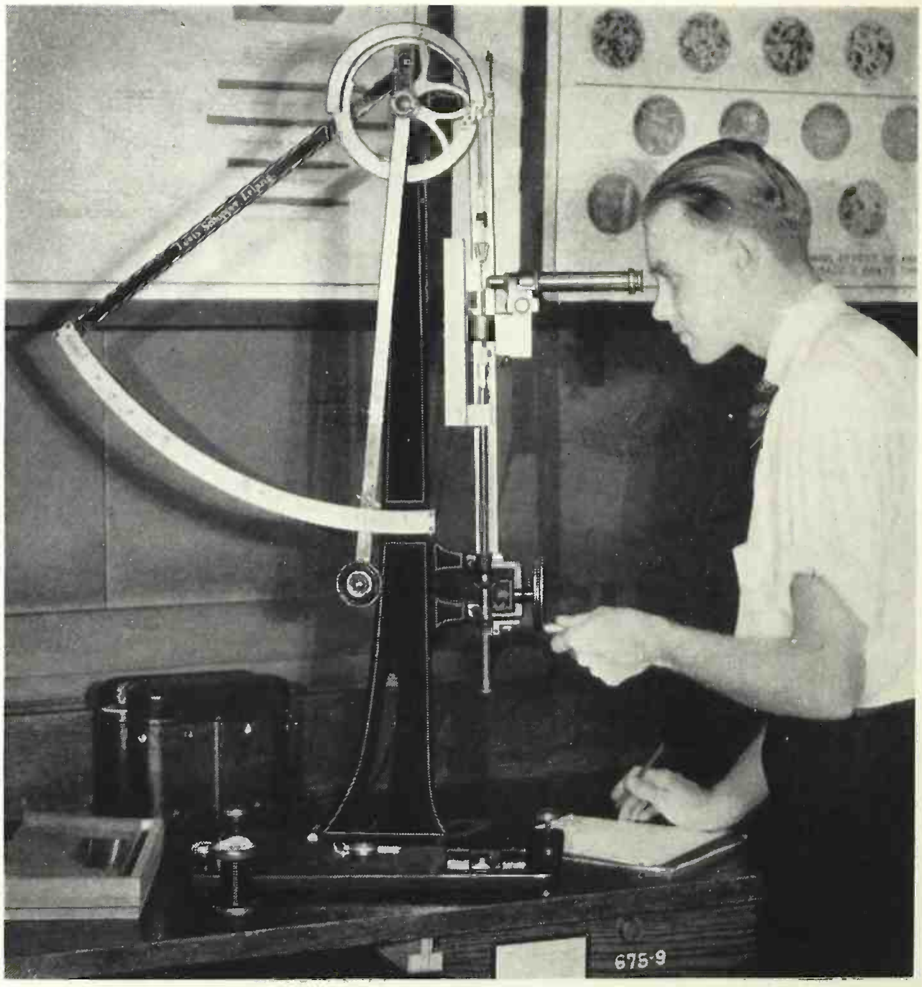
Fig. 4—The metal in plastic form is wiped to the proper shape with the "catch cloth"

therefore limited to .10%. Since the presence of these and other impurities is so important to the proper balance between facility of application and structural soundness, the Bell System specifications for solder place great emphasis upon the purity of its constituents.

During and after the World War, the price of tin rose to a value where the consideration of other metals as partial substitutes was desirable. It was found that cadmium could be used to replace some of the tin so that a combination of 9% cadmium and 24% tin appeared to meet the same requirements in wiping solder as that produced by 38% of tin alone. Cadmium was then available at a price that made its use in wiping solder yield a considerably lower overall cost, and experimental lots of 67% lead—24% tin—9% cadmium solder were used in the plant with promising results. During these trials, however, fluctuations in metal prices reversed the situation so that the cadmium-bearing solder ceased to have economic advantage. Although this situation still exists, it is quite possible that cadmium-bearing solder may be a satisfactory alternative if its use appears advantageous.

Although considerable thought has been given to devising laboratory methods for evaluating the properties of wiping solders, and further work along this line is planned, the cable splicer is still the court of last appeal in deciding upon the handling properties of a proposed composition. The introduction of gas-pressure testing and maintenance practices served to shift some of the emphasis to the mechanical properties of the completed joint, particularly its freedom from porosity. Providing a wiping solder to meet these exacting requirements has therefore become an important part of the Bell System's program of preventive maintenance.

Fig. 5—Stamping the splicer's number on a finished joint



Testing the Elasticity of Vacuum Tube Filaments

By C. H. MARSHALL
Materials Development

OWING to the prominent role of the vacuum tube in communication, exacting demands are placed on its performance. It must be dependable, reasonably free from distortion and maintenance costs must be held to a minimum, not only from the standpoint of power consumption but from the standpoint of replacement costs as well.

The filament is a highly vital element in the vacuum tube and is a prominent factor in its performance. The diameter of the filament wire used in some of the tubes is in the order of .0035-inch. Extreme care must be exercised in the assembly operation when the tube is manufactured and in handling the filament material previous to assembly. In the tube the filament is held under considerable tension to safeguard against changes in position, which may alter the electrical characteristics and result in speech distortion, noise or microphonic action. When amplified many times, this distortion or noise may be sufficient to impair the usefulness of the tube.

On the other hand, if the filament is drawn too tightly a condition results which is likely to cause premature burning-out of the filament. Applying too great a stress, either in the assembly or in any of the various series of drawings and windings in preparing the filament for its use in the tube, results in stretching of the filament material. When the length of the wire is extended by stretching, there occurs a corresponding reduction of the diameter. Where the stress is considerable the slight irregularities or imperfections which are to be found in all material result in non-uniform stretching of the wire. Because of this, there is a corresponding non-uniform reduction in the diameter, so that certain short sections are much more reduced in diameter than the remainder of the wire. This condition causes increased resistance localized at these sections. When current passes through the wire the increased resistance results in very high temperature at these places, bringing about a condition known as "hot spots." When the temperature at one of these points is sufficient to melt the filament the life of a vacuum tube is at an end.

Through knowledge of the elastic properties of a material, it is possible to guard against damage caused by overstressing. An important property is the elastic limit which is defined as the greatest stress a material is capable of withstanding without permanent deformation remaining after the stress has been relieved. Within this limit the wire behaves like a spring and returns to its normal length when the stress is removed. If precautions are taken in the manufacturing and assembly operations not to exceed this limit, the likelihood of permanent deformation of the filament is practically eliminated. It is possible to determine elastic limit by attaching to a wire an extensometer, which is an instrument for accurately measuring any slight extension or in-

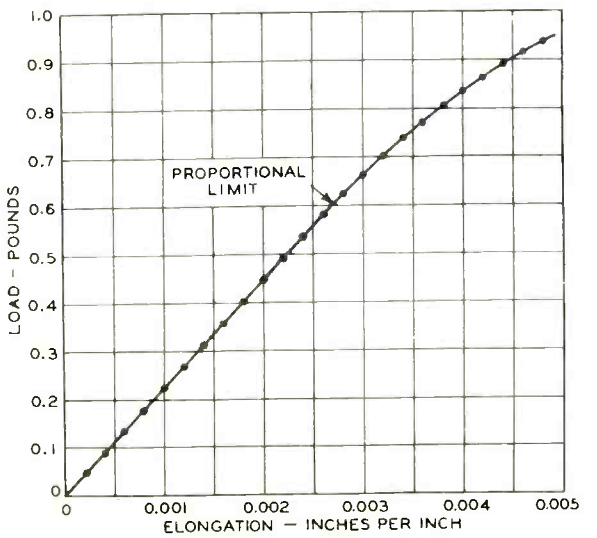


Fig. 1—*Load-elongation curve. The proportional limit is at the point where the straight-line relationship ceases*

crease in length, and then applying and releasing load in increasing amounts until permanent extension in length of the wire is observed after the load has been removed. When the load is great enough to cause a permanent increase in the length of the wire, the elastic limit has been passed.

This method of determining elastic limit, while frequently used, is rendered almost impracticable by the labor and time required to make the test. Through experience it has been established that the proportional limit of the wire, which is more easily determined, is, for practical purposes, equivalent to the elastic limit. To ascertain the proportional limit of filament wire, it is necessary to make accurate measurements of the changes in length as the load is applied. Instead of loading and releasing as is done in the test for elastic limit, a continuously increasing load is used. At predetermined increases in elongation, as the test proceeds, the load is recorded. The elongation, measured by means of the extensometer, with the corresponding load, is then plotted in the manner shown in Figure 1, which represents the load-elongation graph of a sample of .00342 inch diameter filament wire. The proportional limit of this wire was found to be 66,400 pounds per square inch, corresponding to a load of .61 pound and the ultimate tensile strength was 149,000 pounds per square inch, corresponding to a load of 1.39 pounds to break the wire. This represents hard drawn wire. The proportional limit of similar annealed wire is of the order of 21,000 pounds per square inch, corresponding to a load of .193 pound and its ultimate tensile strength 64,000 pounds per square inch corresponding to a load of .588 pound on the wire.

Up to the point indicated by the arrow on this graph, a straight-line relation exists between the elongation and the load, indicating that one is exactly proportional to the other. The proportional limit, therefore, is at the point where the load and the corresponding elongation cease to be proportional.

In the tests undertaken in these Laboratories to find out how much stress might be sustained without causing permanent damage to filament wire, the proportional-limit test has been used. The load is measured by means of a pendulum-type testing machine. As the lower clamp holding the wire is moved down by the operator turning the hand wheel, the pull on the upper clamp causes the pendulum to be inclined proportionately to the load. Testing machines such as this are in general use where the breaking load only of material such as filament wire is to be measured. For the determination of elastic properties, however, an extensometer is used in conjunction with the load-testing machine.

Many types of extensometers are obtainable for measuring elongation, but all of them must be attached directly to the wire. Our investigations showed that the weight of even the lightest of them was sufficient to

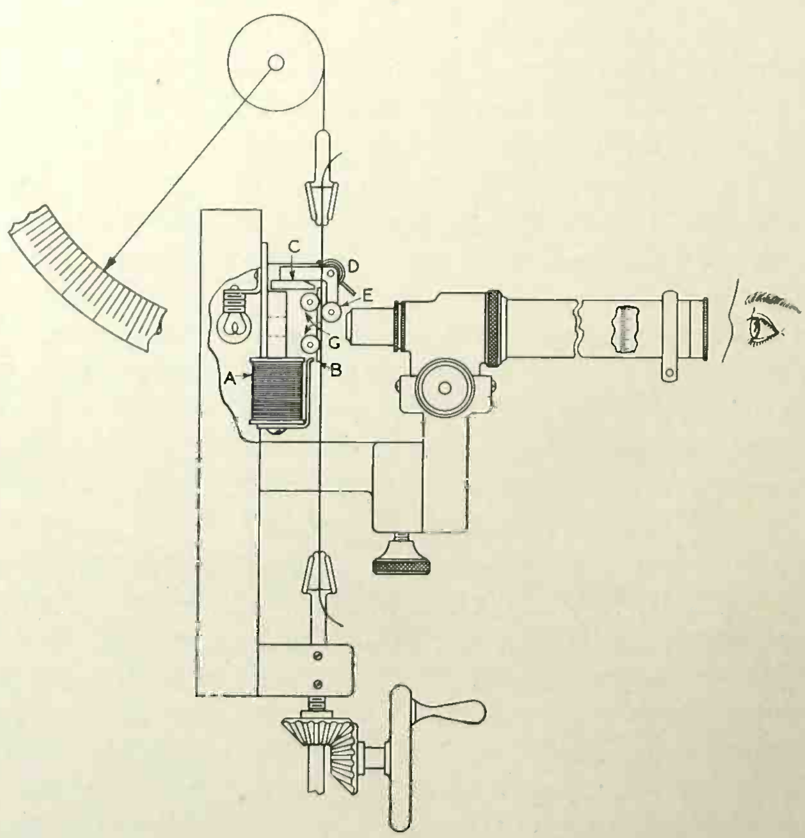


Fig. 2—Schematic diagram of the extensometer. The light passing through the aperture in the follower strip projects the image of the cross hair on the scale in the telescope

stretch the very small wire used for vacuum tube filaments. It was necessary, therefore, to design and build an extensometer to meet our particular needs. Not only was a high degree of sensitivity required but it must be designed so that its weight would not have to be supported by the delicate wire which was under test.

The extensometer that was developed for determining the elastic properties of filament material is shown in Figure 2. It is very sensitive, permitting measurement of elongation to one ten-thousandth of an inch, and its entire weight is supported by the testing machine. The principle on which the instrument operates is the measurement of elongation by observing the change in position of a small strip of metal (B)—called the follower strip—against which the wire is securely held by means of a pressure roller (E). In the follower strip there is a small drilled hole bisected by a cross hair. The cross hair serves the same purpose as a fine line marked on the wire. The main frame of the extensometer is attached to the load-applying screw just under the lower clamp and is carried downward with this clamp as the operator turns the hand wheel.

In making the test a switch on the base of the testing machine is closed, causing a flow of current which energizes the magnet (A). The armature (C) is attracted to the pole of the magnet, drawing down with it an attached lever and causing the pressure roller (E) to be drawn away from the follower strip. At the same time the follower strip is drawn by magnetic attraction tightly against a pair of guide rollers (G). The wire is then secured in the upper and lower clamps and is inserted into the space between the follower strip and pressure roller.

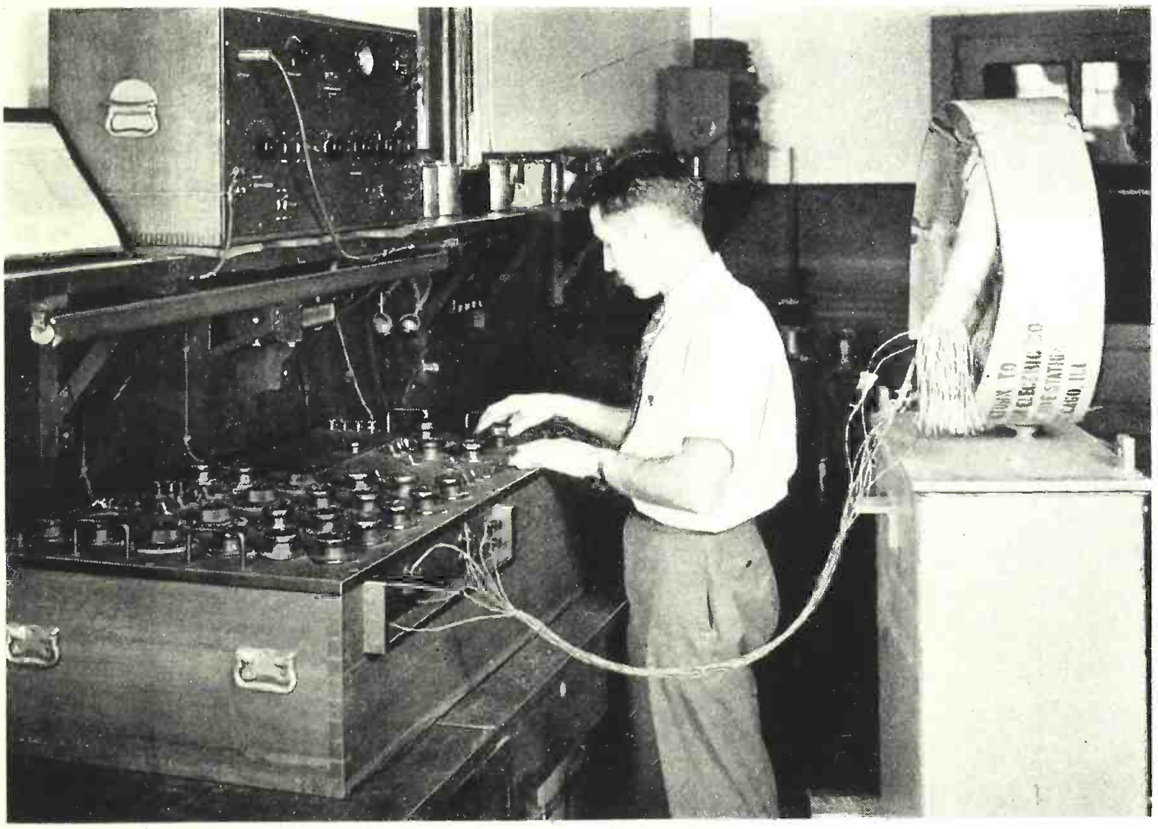
The cross hair in the follower strip is illuminated by a flashlight bulb placed behind it. The image of the cross hair falls approximately on the zero line of the scale in the telescope when the follower strip is drawn against the guide rollers and is centered by energizing the magnet. By means of a vertical screw adjustment of the telescope, the image is made to coincide exactly with the zero line in preparation for the test.

When the circuit through the coil is broken, the pressure roller by spring action (D) presses the wire against the follower strip. As the load is applied, the entire extensometer moves downward, but the rates at the point where the lower clamp grips the wire and at the point where the wire is held in contact with the follower strip are different owing to the stretching of the wire. This difference in the rates of the downward motion causes the follower strip to move on the guide rollers which are carried in jewel bearings to minimize friction. The movement of the image across the scale indicates the amount of stretching between the lower clamp and the point of contact with the follower. Four inches of wire is a convenient test length between these two points.

An unusual feature of this extensometer is that it cannot be damaged when the sample under test breaks. The small follower which is the only moving part may be drawn out of place, or even entirely out of the instrument by the wire breaking, without causing damage. As a consequence measurements of elongation may be carried on, if desired, until the actual breaking point of the wire is reached. In the headpiece the extensometer is shown used with a 2-kg. Schopper testing machine. With this equipment satisfactory tests have been made on filament wire, light valve ribbon, very small (No. 40) copper wire and similar materials. It has been possible to determine the proportional limit of a human hair with this machine. Tests on more delicate materials have indicated that the extensometer is sensitive enough to be used with an even smaller and more sensitive testing machine.

Tests have been made on many samples of filament wire as well as other similar materials by means of the extensometer which has been described. It has proved of great aid in making rapid and accurate measurements and through its use valuable information is being obtained regarding the elastic properties of these materials.

Seated alongside the microphones which are placed in the head of the tailor's dummy, these observers listen to the jingle and thump of a tambourine, and compare transmission through the air and through the microphone system



A Crosstalk Measuring Set of Improved Precision

By J. E. NIELSEN
Transmission Apparatus

CROSSTALK is the term used to designate a disturbance introduced into one telephone circuit by telephone current flowing in another. This disturbance may be introduced by inductance, capacitance, or resistance coupling between the two circuits or by combinations of these three general types of coupling. In loading coils used for quadded cable circuits—and most of the coils made are so used—several circuits are intimately associated with each other, so that conditions are favorable for the production of crosstalk. Considerable effort is expended to keep it down to low values in spite of these conditions, and to facilitate this effort crosstalk measuring sets are required. Recent improvements in loading coils permitting lower crosstalk have made it necessary to provide equipment, for both the Laboratories and the Manufacturing Department, capable of measuring crosstalk of much smaller magnitude and with greater accuracy than have been possible before.

A schematic representation of the four line wires and three loading coils of a phantom group is shown in Figure 1. The three coils, potted in a container which also serves as a shield, comprise a "loading unit." The windings are so connected that those of the side circuit coils add inductance to the side circuits but not to the phantom, while those of the phantom affect only the phantom circuit*.

Crosstalk may exist between two side circuits or between each side circuit and its associated phantom and the two kinds of crosstalk require different measuring arrangements. Side-to-side crosstalk is comparatively simple to measure because it is possible to design the measuring set so that no electrical connection exists between the disturbing and disturbed circuits, while for phantom-to-side measurements it is necessary to have such a connection, which greatly complicates matters.

As was mentioned above, crosstalk may be due to inductance, capacitance, or resistance coupling. There would be no coupling between any two of the three circuits associated in a loading unit, however, if the four windings of the unit were electrically similar. Differences in the electrical constants of the windings result from unavoidable small structural irregularities. It is these differences or "unbalances" which are the basic cause of loading coil crosstalk. These may be resistance, capacitance, self-inductance, or mutual inductance unbalances. They could be measured separately with suitable impedance-unbalance bridges, but since crosstalk depends on the combined effect, and is also affected by the impedance of the loaded cable circuits, it is preferable to provide a measuring circuit that will indicate the combined effects of unbalances under service conditions.

The circuit for measuring crosstalk must therefore provide a disturbing current to be applied either to the phantom circuit or to one of the side circuits of a loading unit, terminating impedances to cause the various components of crosstalk to appear in the magnitudes and phase relations that they would have in the actual cable circuits, and a means of indicating the magnitude of the resulting crosstalk. The circuit for doing this is shown schematically in Figure 2, which illustrates the arrangement for measuring crosstalk in a side circuit produced by current in the phantom. Current is fed into the phantom circuit through four pairs of resistances, the two resistances of each pair being alike to a very high degree of precision. These resistances also act as terminating impedances for the side circuits and as part of the terminating impedance for the phantom circuit.

If pure resistances were used without any reactance anywhere in the circuit it would not be possible to measure correctly the whole crosstalk as it appears in a loaded cable circuit. With terminations that are equal to the cable circuit impedances in both magnitude and phase, all components of crosstalk will appear correctly in magnitude and phase, and this arrangement has therefore been used in the latest shop measuring sets. The termination design problem is relatively simple for the individual shop sets because they are required for testing at a single fixed frequency and it is economically practical for shop use to provide a series of sets that cover the range of service-impedance conditions, each set simulating the impedance of some important type of loaded-cable facility at the specification test frequency. The circuit termination for the Laboratory set is more complicated than the terminations of the shop sets because of the necessity for covering a wide range of impedances at any one of a wide range

*Bell Lab. Record, *March*, 1930, *p*. 309.

of frequencies. For single-frequency measurements at intervals over a frequency band, the correct impedance termination corresponding to any important service-impedance condition at a particular frequency can be approximated by switching simple combinations of fixed resistances and reactances. For precision results in band-frequency measurements, complicated networks having the correct impedance values at all frequencies throughout the band are required, and provision has been made for adding such apparatus externally to the laboratory set when required.

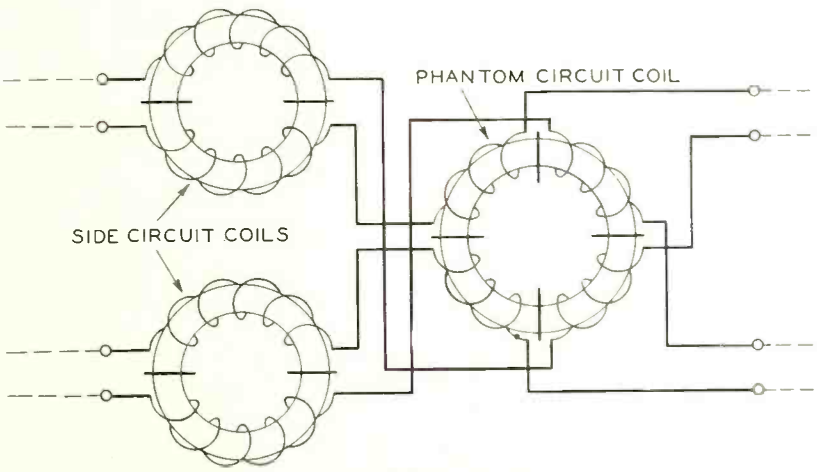


Fig. 1—A loading unit consists of three loading coils: one for each side circuit and one for the phantom

The crosstalk that is produced in the terminating impedances is evaluated by means of a vacuum tube voltmeter which compares the voltage across the terminating impedances with the input voltage in such a manner that an indication of the crosstalk magnitude is obtained. The part of the measuring set that produces the comparison voltage is called the crosstalk meter. It consists essentially of a slide wire and a resistance network. The comparison voltage is secured by passing the phantom current through the slide wire and from the slide wire in turn passing a known fraction of the current through the resistance network. The vacuum tube voltmeter can be connected across a selected part of the network, and the moving contact on the slide wire is adjusted until this voltage equals that across the terminating impedance of the side circuit. The advantage of using a vacuum tube voltmeter for the measurement of crosstalk is that this type of indicating circuit can be given a high input impedance, and this makes the setting up of the terminating impedances independent of the indicating circuit. Although a voltage-operated device is employed, measurements of current or power may be obtained when the resistances of the crosstalk meter circuit are properly proportioned.

To measure crosstalk the power introduced into the disturbed circuit should be expressed in terms of the power in the disturbing circuit. This ratio of powers may be expressed in decibels, and the crosstalk is then said to be so many decibels down from the disturbing power. Another manner of expressing crosstalk is in crosstalk units. The number of crosstalk units existing between two circuits is defined as one million times the square root of the ratio of the power in the disturbed circuit to that in the disturbing circuit. Thus one crosstalk unit is indicated when the power in the disturbed circuit is only a millionth of a millionth of that in the disturbing circuit. Where the effective resistances of the two circuits are alike the ratio of currents instead of the square root of the power ratio may be taken to express the crosstalk.

The crosstalk measuring set indicates the relative magnitude of the crosstalk current that flows from the loading unit into the impedance that terminates one of its ends. In an actual cable circuit, the crosstalk currents flow from both ends of a loading unit, and the two currents will travel away from the loading unit in opposite directions on the cable. Thus each loading unit causes two kinds of crosstalk, termed "near-end" and "far-end" crosstalk respectively, and they will generally be different due to different combinations of the capacitance and inductance unbalances. The far-end crosstalk is that which travels in the same direction as the energy in the disturbing circuit and the near-end crosstalk that which travels in the opposite direction. For particular types of service the near-end crosstalk may be more important than the far-end crosstalk or vice versa. For this reason certain of the shop sets are designed for measuring far-end crosstalk and the others for measuring near-end crosstalk. In the laboratory set it is necessary to be able to measure both near-end and far-end crosstalk, and suitable switching arrangements make this possible on a non-simultaneous basis.

The circuit shown in Figure 2 is the arrangement for measuring the far-end crosstalk in one of the side cir-

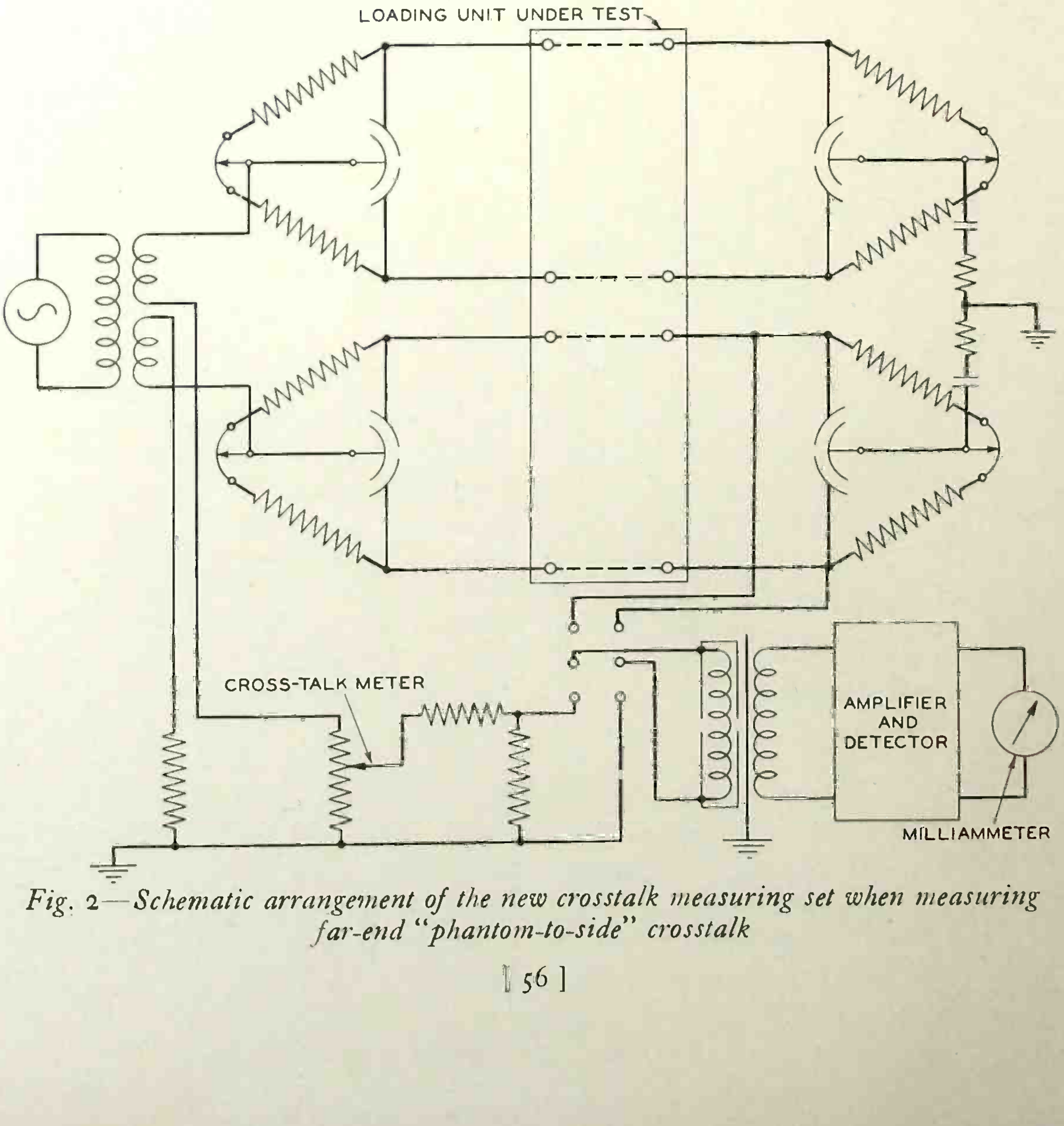


Fig. 2—Schematic arrangement of the new crosstalk measuring set when measuring far-end "phantom-to-side" crosstalk

cuits due to the phantom circuit current. The laboratory measuring set is capable, however, of measuring the crosstalk in the other side circuit also, and of measuring the crosstalk between the side circuits. Near-end as well as the far-end crosstalk can be measured in all three cases. It is possible, furthermore, to make measurements over a wide frequency range, from 200 to 10,000 cycles for phantom-to-side measurements and from 200 to 50,000 cycles for side to side measurements. An elaborate switching and shielding system had to be developed to do these various things, and to cover the required range of impedances in the circuit terminations. The wiring had to be balanced for capacitance to ground to one tenth of a micro-microfarad.

One of the difficulties encountered was the correct measurement of the voltage across the terminating impedance of the loading units. Since the amplifier of the vacuum tube voltmeter must be connected to circuits that are unbalanced to ground as well as to those that are balanced, it is necessary to have a transformer in its input circuit. This transformer is placed under rather severe conditions because it is subjected to the simultaneous action of two voltages. Across the primary terminals there is the crosstalk voltage being measured, and in addition there is a potential to ground on the winding as a whole, which is the potential in the phantom circuit. This latter voltage, which is many times greater than the crosstalk voltage, causes a current to flow to ground through the capacitance between the primary winding and the ground shield. In flowing to ground this current flows through part of the primary winding and thereby sets up a voltage in the secondary. When a single shielded transformer is employed the voltage thus produced in the secondary is comparable in magnitude with that due to the crosstalk it is desired to measure when this crosstalk is of the order of 50 units, and below 50 units the undesired voltage may be greater than the crosstalk voltage. Although it might be possible to determine the magnitude of the unwanted voltage, it would not be possible to determine its phase. Since a large voltage is thus added to the measured voltage in an unknown phase relation, large and uncorrectable errors result. To reduce these errors to inappreciable amounts, the primary winding of the transformer has been provided with shields connected to each terminal as shown in the illustration. These shields prevent the capacitance current from flowing through the winding and setting up the unwanted voltage in the secondary. Although double shielded transformers are not new, this transformer has to meet requirements in regard to impedance, direct capacitance between windings, and conductance unbalance between the two inner shields and the outer shield, that are far more severe than those of ordinary bridge transformers.

Crosstalk between different loading units is very small compared with phantom-to-side and side-to-side cross talk within loading units. No regular measurement of it is therefore required, and in the few cases where it is necessary to measure it, this can be done with the measuring set just described in the arrangement for side-to-side measurements, possibly with the aid of some external resistance boxes and condensers.

The set will measure as low as one crosstalk unit, which corresponds to a power level in the disturbed circuit

120 db below that in the disturbing circuit. To obtain a reasonable accuracy when such great sensitivity is required, the circuit elements common to the phantom and its side circuits must be adjusted to a very high degree of equality. To obtain an accuracy of 1 db in the measurement of crosstalk that is 120 db down, the balance of the measuring set must be adjusted so that the crosstalk arising within the measuring set itself is 140 db down. This, for example, means that when the resistance component of the side circuit impedance is 800 ohms, the two 400 ohm resistances must not differ by more than .00025 ohm. Such a balance can not be maintained permanently but must be established every time a series of measurements are made. Slide wires and condensers have been provided for this purpose, the latter to balance the phase angles of the resistances.

A scale model, constructed by W. C. F. Farnell, Curator of the Historical Museum, to show the spaces which will be occupied by the Bell System exhibit at A Century of Progress, the international exposition to be held at Chicago in 1933

Contributors to this Issue

H. E. Mendenhall received the B.S. degree from Whitman College in 1921, then went to California Institute of Technology to receive the Ph.D. degree in 1927. After a year as instructor in physics and electrical engineering at the University of Utah, he came to the vacuum-tube research laboratory at West Street. He has been especially concerned with the development of vacuum tubes for transmission at high frequencies and powers.

A. W. Kishpaugh graduated from the University of North Dakota in 1912. After two years each with the General Electric Company and the Utah Power & Light Co., he joined the research department of the Western Electric Company. Here he was employed on radio receiving problems and on the development of radio equipment for the Army and Navy, particularly for use on aircraft. Later he was engaged in the development of apparatus and systems for the commercial applications of radio telephony and more recently in the development of broadcasting equipment. At present he is in the Apparatus Development Department in charge of broadcasting and transoceanic radio development.

H. Baillard received an A.B. from Columbia University in 1923, and the degree of Chemical Engineer, from Columbia's School of Engineering, in 1925. The following year he joined the Technical Staff of Bell Telephone Laboratories where, with the Chemical Department, he engaged in studies of electroplating and corrosion, enameled wire, and miscellaneous organic materials. In 1928 he transferred to the Outside Plant Department. Here in addition to certain staff work he has worked on paint problems, and more recently on cable joining and maintenance.

After three years at the University of Pittsburgh and subsequent study at the Carnegie Technical Night School, C. H. Marshall spent a year in the Experimental Department of the Westinghouse Air Brake Company, and the following thirteen years with the Westinghouse Electric and Manufacturing Company. With the latter company he was for

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several years in charge of the Physical and Mechanical Testing Laboratory where he was responsible not only for the testing work but for the establishment of standards and testing methods. In 1928 he joined the Technical Staff of Bell Laboratories where he was associated with the materials organization. Here he was connected with the development and use of copper wire, condenser foils, lead cable sheath alloys, die castings and other metallic materials, as well as with the development of special electrical and mechanical devices required for the testing work such as the extensometer described in this issue of the RECORD.

J. E. NIELSEN graduated from the Royal Technical College in Copenhagen, Denmark, in 1924 with the degree of B.S. in Electrical Engineering. He came to this country shortly afterward and did miscellaneous radio work until, in 1926, he joined the Technical Staff of the Laboratories. Here, with the Apparatus Development Department, he has been engaged in the development of equipment for measuring attenuation and crosstalk.

C. H. Marshall

J. E. Nielsen

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