

# BELL LABORATORIES RECORD



ACOUSTIC  
TEST CHAMBER

E. H. BEDELL

SOFT SOLDERS

A. H. FALK

RADIO BEACON  
TRANSMITTER

A. A. SKENE

NOVEMBER 1935 Vol. XIV No. 3

# BELL LABORATORIES RECORD

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*Published Monthly by* BELL TELEPHONE LABORATORIES, INC.

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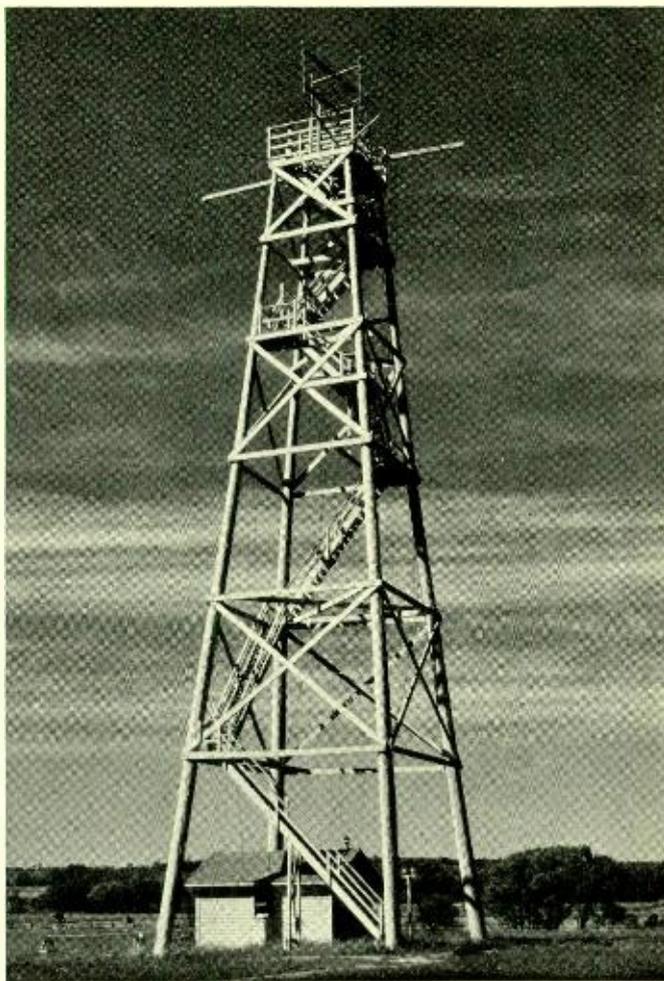
## *In this Issue*

Vacuum Tube for Small Current Measurements . . . . .	74
<i>D. B. Penick</i>	
Acoustical Test Chamber with Cloth Walls . . . . .	79
<i>E. H. Bedell</i>	
Under-Rug Telephone Cordage . . . . .	83
Radio Beacon Transmitter for WOR . . . . .	84
<i>A. A. Skene</i>	
Soft Solders . . . . .	89
<i>A. H. Falk</i>	
Test Car for Marine Radio Telephone Surveys . . . . .	94
<i>G. M. Hafner</i>	
High-Fidelity Ultra-High-Frequency Radio Transmitter . . . . .	99
<i>J. W. Smith</i>	

*Volume 14—Number 3—November, 1935*

CLARKSON COLLEGE OF TECHNOLOGY  
ELECTRICAL ENGINEERING DEPT.

# BELL LABORATORIES RECORD



*Tower for ultra-short-wave experiments at Holmdel*

VOLUME FOURTEEN—NUMBER THREE

*for*

NOVEMBER

*1935*



## Vacuum Tube for Small Current Measurements

By D. B. PENICK  
*Vacuum Tube Development*

SIX electrons per second, flowing in a suitable circuit, can be detected by the D-96475 Vacuum Tube, which compares favorably in performance with the best electrometers—the instrument formerly used almost exclusively for the measurement of small currents. With a sensitive laboratory type of D'Arsonval galvanometer as the indicating instrument these tubes give higher voltage sensitivity, shorter period, about equal capacitance, greater ruggedness and more convenience of operation than the electrometer.

As a tool for scientific research, the low-grid-current tube finds many and varied applications. One of the most common is the measurement of ionization currents produced by alpha particles, neutrons, X-rays, cosmic

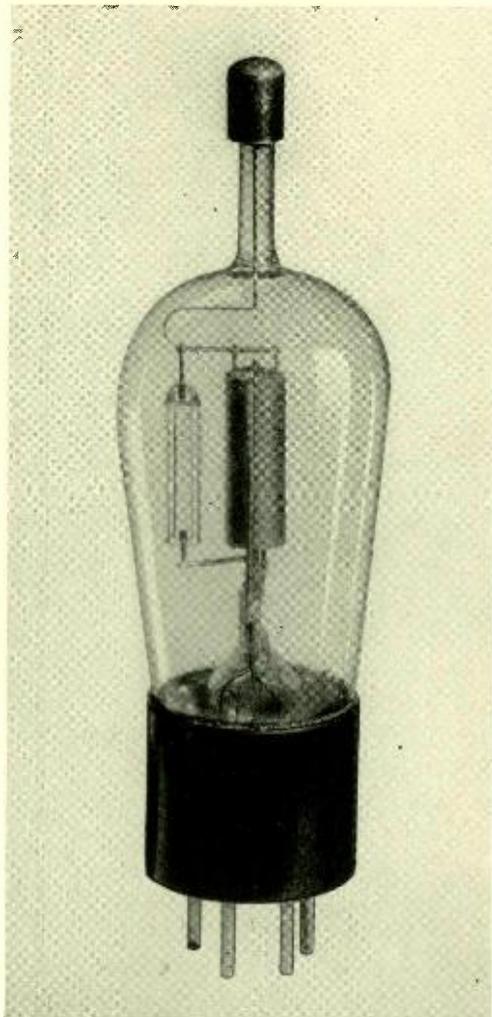
rays, or other manifestations of radiant energy encountered in the study of atomic structure or disintegration. At the other end of the scale of physical magnitudes, this tube finds its place in astronomy, where it is used in the measurement of the minute photoelectric currents of stellar photometry. In biology, it measures the extremely small voltages produced in living tissues, and in industrial chemistry, the hydrogen ion content of solutions. In both of these latter applications the voltages which are measured are produced across glass electrodes, whose resistance is necessarily very high. The indicator used, therefore, must have negligible current consumption to insure accurate measurements and high sensitivity. In these and many other applications,

this type of vacuum tube has proven itself to be an effective substitute for the electrometer.

The minimum charge or voltage which can be measured by either an electrometer or a vacuum tube is determined by the fundamental fluctuations in the deflection of the instrument, due in the case of the electrometer to Brownian motion of the moving element, and in the case of the tube, to shot effect fluctuations of the leakage current to the control grid, augmented in both cases by thermal electromotive force in the circuit. These fluctuations are of about the same magnitude in the tube and the electrometer, and their root-mean-square value is about equal to the effect of a charge of  $10^{-16}$  coulombs, approximately 600 electrons. Thus a deflection equal to the root-mean-square fluctuation would be produced by a current of, say,  $10^{-16}$  ampere flowing for one second, or a current of  $10^{-17}$  ampere flowing for ten seconds, etc. The magnitude of the smallest current which can be detected, then, depends on the length of time which can be allotted for an observation, and on the stability of the apparatus. Under the best conditions that are obtainable it may be as small as  $10^{-18}$  ampere and some experimenters put the limit even lower.

The most essential single characteristic of a vacuum tube for electrometer applications is its low control-grid current. This current must be considerably lower than that of ordinary amplifier tubes which often have control-grid currents as large as  $10^{-8}$  ampere. The possible sources of grid current are numerous and include primary and photoelectric emission of electrons from the grid, positive ions collected by the grid, high-velocity electrons from the filament collected

by the grid, and insulation leakage. Photoelectric emission may be due to stray light, light from the filament, or soft X-rays produced within the tube itself by the bombardment of the plate and other positive elements with electrons from the filament. Positive ions may be produced by the ionization of residual gas molecules in the envelope of the tube by the passage of electron current from the fila-



*Fig. 1—The response of the Western Electric No. D-96475 Vacuum Tube to small currents rivals that of the best electrometers. The tube is six inches by two inches in size*

ment to the positive elements, or they may originate at the filament during the process of emission of electrons. Insulation leakage may occur either through the insulator itself, or through a layer of conducting material contaminating the surface of the insulator.

The reduction of the control-grid current from these various sources may be accomplished by the use of a space-charge grid, by applying low anode voltages, by employing a small filament of low power consumption

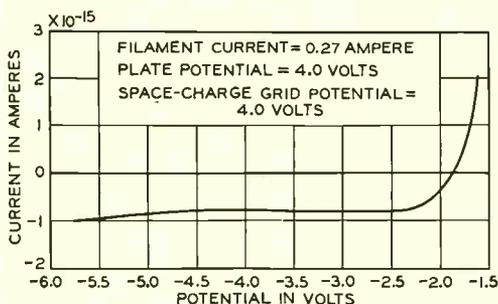


Fig. 2—When the control grid bias is more negative than  $-2.5$  volts, its value has little effect on the grid current. The rapidly rising characteristic for more positive values is due to the positive current of electrons reaching the grid from the filament

operating at a low temperature, by the carbonization or other treatment of the control-grid surface to increase its work function, *i.e.* the work required to liberate electrons from the grid, by the use of insulating material of low conductivity so disposed that the leakage paths between the control grid and the other electrodes are long, of small cross-section, and few in number, and by protecting these insulator surfaces from contamination. The space-charge grid, since it is operated at a positive potential, sets up an opposing field for positive ions

produced at the filament. It also permits operation at low anode voltages with the least sacrifice of amplification, and permits wider physical separation between the control grid and the hot filament, thus reducing primary emission. The low operating voltages result in small ionization of the residual gas in the tube, and also minimize the amplitude and hardness of the X-rays which are produced. The small power consumption of the filament helps to keep the control grid cool, and the low filament temperature results in a minimum amount of light within the tube. Increasing the work function of the control-grid surface has the effect of reducing its primary and photoelectric emission.

These principles of grid current reduction have been applied in the Western Electric No. D-96475 Vacuum Tube, which is shown in Figure 1. In this tube, the filament power consumption is only slightly more than one-quarter watt, and the filament temperature is less than 1000 degrees K. The space-charge grid is a closely wound grid interposed between the cathode and the control-grid. The control-grid is covered with a coating of carbon and is supported by a single glass rod of low conduc-

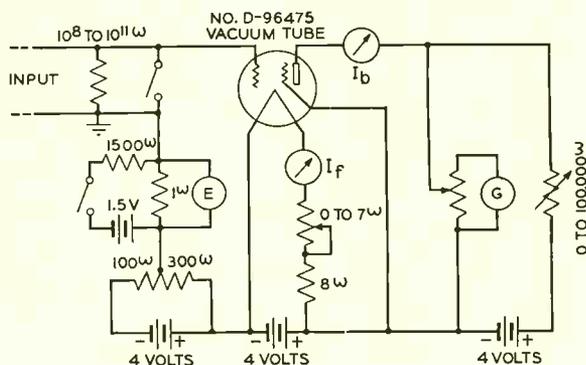


Fig. 3—A very simple circuit is satisfactory for most vacuum tube electrometer applications

tivity, the lower end of which is held by a metal post connected to one of the base pins. This post is intended to be connected to the circuit ground, which should be held at the average potential of the control-grid for minimum leakage. As may be seen from the illustration, a skirt of glass tubing over the support rod trebles the length of the surface leakage path and protects it from contamination by particles evaporated from the metal parts of the tube during manufacture and operation. The control-grid lead is brought out to a cap at the top of the bulb through a neck of small diameter, which affords a minimum surface area for possible leakage. The metal disc which appears in the photograph across the opening of the neck serves to shield its inner surface from contamination. Leakage across the outer surface of the glass may be minimized by washing the bulb thoroughly with alcohol and thereafter preventing the condensation of moisture on it. This may be done by keeping the bulb at a higher temperature than its surroundings, by coating it with ceresin wax, or by keeping it in a dried atmosphere. A grounded guard ring of aquadag or other conductor in contact with the lower part of the bulb is also helpful in reducing this type of leakage.

The best operating conditions represent a compromise between the desired reduction in grid current and the undesired reduction in voltage sensitivity or transconductance as the anode and space-charge-grid voltages are decreased. Two sets of operating voltages are, therefore, recommended, one for use with galvanometers having sensitivities of  $10^{-9}$  ampere per milli-

meter or better, and one particularly for portable circuits where less sensitive galvanometers must be used. The anode and space-charge-grid voltages are 4 volts for the more sensitive

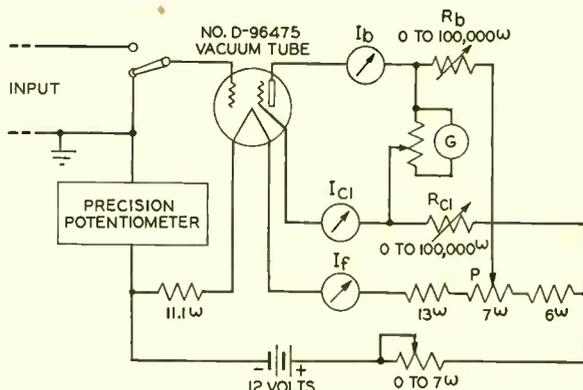


Fig. 4—If a compensated circuit is used, more battery voltage variation can be tolerated

operating condition and 6 volts for the circuit for portable use. In both cases the control-grid voltage is  $-3$  volts. These conditions give for the transconductance 40 and 96 microamperes per volt and for the control-grid currents  $10^{-15}$  and  $10^{-14}$  amperes, respectively. A typical control-grid current characteristic for the more sensitive operating condition is shown in Figure 2.

The operating circuits available for use with the low-grid-current tube are numerous, but for most applications the simplest possible circuit is satisfactory if storage batteries of reasonably high capacity are used to supply the power. An example of a simple type of circuit is shown in Figure 3. The input circuit, of course, must always be adapted to its particular application, but the one shown is typical of circuits which might be used for measuring small currents down to about  $10^{-16}$  ampere. Where instability due to battery voltage fluctuation is encountered, the circuit of Figure 4 is

useful. In this circuit a single 12-volt battery supplies all of the operating power and when the potentiometer,  $P$ , is properly adjusted, the resistances,  $R_b$  and  $R_{ct}$ , always being set to give zero galvanometer current and the proper plate and space-charge-grid voltages, the galvanometer is not sensibly affected by small variations in battery voltage. The input circuit shown here is of the type often used with the glass electrode technique in the measurement of hydrogen

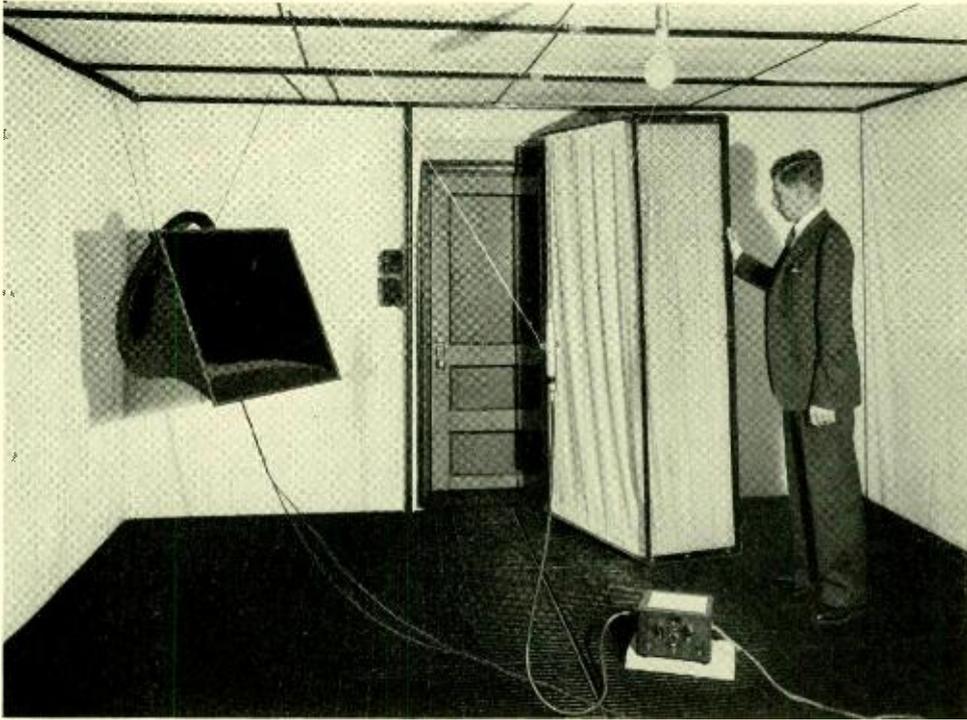
ion concentration in solutions.

In order to obtain satisfactory stability for high sensitivity measurements with any circuit, it is usually necessary to shield the tube from light, from electric and magnetic fields, and from excessive mechanical vibration. If extremely high sensitivity is desired, it may also be necessary to evacuate the enclosure surrounding the tube to reduce ionization of the surrounding air due to cosmic rays and stray radioactive material.



### *Edward C. Wente Honored*

*The first award of the Progress Medal of the Society of Motion Picture Engineers was made to Dr. Edward C. Wente on October 23 at the Washington meeting of the Society. The medal was in recognition of his fundamental contributions and outstanding inventions in motion-picture technology. These include the microphones and light valves which are used by large producers of sound pictures and the loud speakers which reproduce in most of the theaters of this country.*



## Acoustical Test Chamber With Cloth Walls

By E. H. BEDELL  
*Physical Research*

A ROOM whose walls, ceiling and floor are covered with many layers of thin cloth has recently been constructed by the Laboratories for use as an acoustical test chamber. The purpose of the cloth is to absorb the sound which strikes the boundaries of the room and thus to prevent it from being reflected back into the chamber. This reflected sound is frequently very disturbing when making acoustical measurements and its complete elimination is often desired, but this is difficult to effect, particularly for sound of low frequencies.

Experiments recently carried out by the Laboratories have demonstrated that several layers of thin

cloth spaced at distances varying from one-half to three and one-half inches apart constitute a much more effective absorbent of low frequency sound than commercially available acoustic materials. This method of construction also gives almost complete absorption of the high frequencies. It has been found that at least ninety-eight per cent of the incident energy for all frequencies from two hundred to four thousand cycles per second can be absorbed by these layers of cloth, and they are probably equally efficient at higher frequencies, although this has not yet been proved experimentally.

The test chamber which incorporates this new feature was an ordi-



*Fig. 1—Sixteen layers of muslin and thin flannel separated by distances varying from  $\frac{1}{2}$  inch to  $3\frac{1}{2}$  inches are supported against the walls, floor and ceiling of this room on an iron framework. F. E. Engelke is examining the cloth panel which has been attached to the inside of the large door used when apparatus is brought into the room*

nary room about twenty feet long, fourteen feet wide and ten feet high. It had plaster walls over hollow tile and concrete floor and ceiling. Within this room was built a framework of iron pipe separated about one and one-half feet from the walls, ceiling and floor. On this iron structure were suspended sixteen parallel layers of muslin and flannel cloth, separated from each other by different distances in accordance with the pattern shown in Figure 3, thus giving acoustical

absorbing boundaries fifteen inches thick on all surfaces, including ceiling and floor. Each cloth was strung at the ends on one-eighth inch rill rod to permit stretching and to maintain the separation desired between separate layers. These drill rods were supported on the iron framework. Drill rod was also stretched crosswise at frequent intervals to prevent sagging, particularly of the ceiling and floor layers.

The floor construction presented a special problem. This had to be stiff enough to bear the weight of apparatus and operators and at the same time sufficiently open to prevent an appreciable amount of sound being reflected. The difficulty was solved by supporting a steel grating over the cloth layers on the floor. This grating rests on a framework of iron tubing located directly above the top layer of cloth. By making measurements with the grating intact and then removing a number of the sections it was found that it did not add appreciably to the amount of reflected energy present. It is not certain, how-

ever, that this would hold for frequencies where the wavelength approaches the separation of the strips of the grating.

Access to the room was provided without leaving reflecting surfaces by making panels of the same construction as the walls of the room and either mounting them on the inside of the regular doors or on a special structure attached to the iron framework of the walls in front of the door. Both types of construction are shown in the illus-

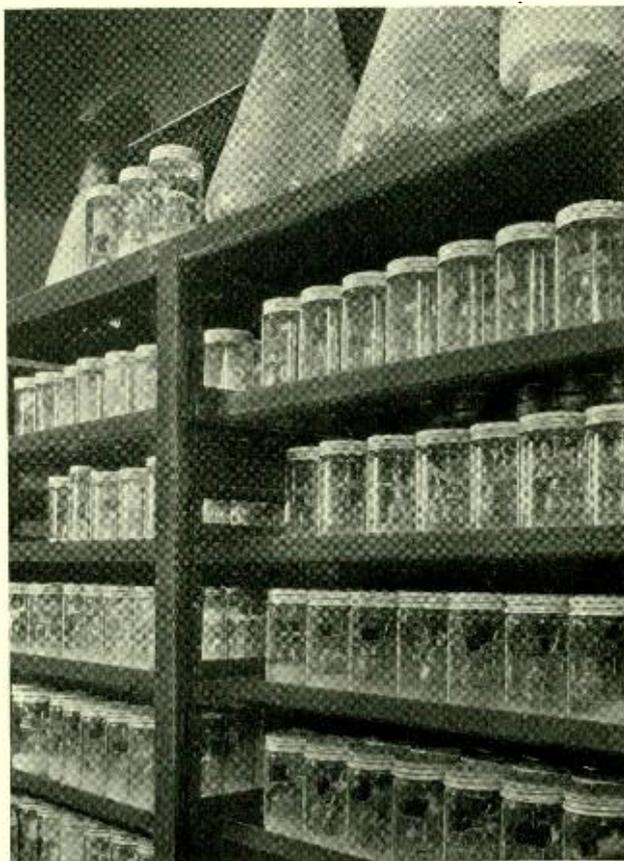


measure the sound intensity, since the direct sound from the source could be eliminated with it by orienting the plane of the diaphragm in the direction of the source.

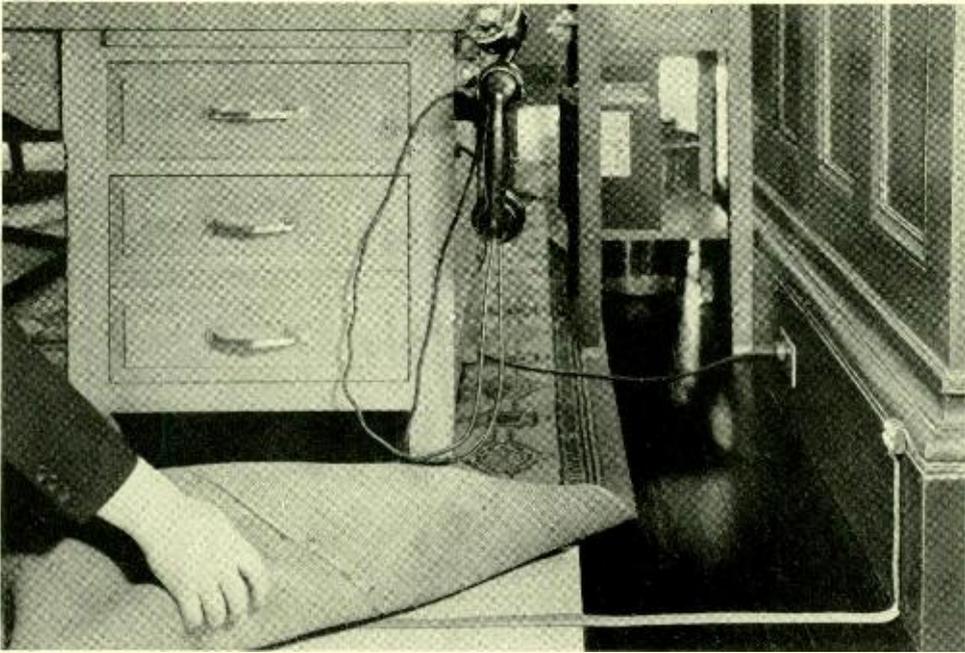
The characteristics of the room thus obtained are indicated in Figure 3. It will be seen that even at one hundred cycles the absorption coefficient is approximately ninety per cent, which is very high. For higher frequencies the absorption coefficient

is even greater, being approximately ninety-eight per cent from two hundred up to 4000 cycles per second.

This type of construction has proved satisfactory for many types of acoustical measurements where it is desired to reduce the amount of reflected energy to a minimum. It has been found to be a much more effective sound-absorbing medium, particularly for low frequencies, than any previously devised.

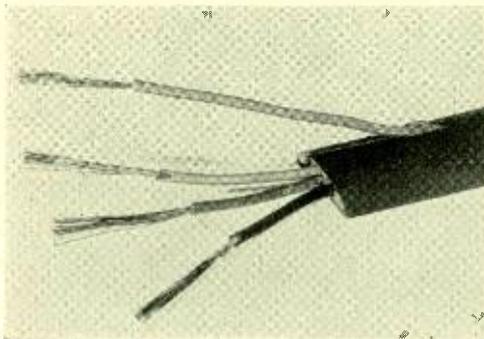


*Testing wood preservatives by rotting treated blocks, using a special technique developed in the Summit Laboratories*



## Under-Rug Telephone Cordage

**T**ELEPHONES are sometimes located where it is necessary to extend the wire under rugs or carpets. The use of standard twisted inside wire formerly employed for this purpose produces a ridge in the rug which is unsightly and causes increased wear. Flat rubber cordage approximately  $\frac{1}{8}$ " in thickness by  $\frac{7}{8}$ " in width has been developed as a substitute for this purpose and is now manufactured by the Western Electric Company. It consists of four conductors of rubber insulated stranded wire



embedded in a strip of brown rubber with beveled edges. Each conductor is provided with a separate rubber insulation so that there will be no danger of crosses between the conductors, when the rubber covering is removed to provide a free length of wire to pass through carpets or to attach at the connecting block. The insulation is of a different color for each conductor to aid in making correct connections.

This cordage is thus used to advantage in situations such as that shown in the illustration.

This cordage is thus used to advantage in situations such as that shown in the illustration.

# A Radio Beacon Transmitter for WOR

By A. A. SKENE

*Radio Development Department*

IT has been the practice for some time for high towers to be painted with alternate bands of either white and orange or yellow and black, and to carry red lights. This has been done to minimize the possibility of their being a hazard to airplanes. When such obstructions are located adjacent to an established airway, the Bureau of Air Commerce has recently required that they be further safeguarded by warning radio bea-

cons, since these are not affected by conditions of poor visibility.

WOR's new broadcasting station\* at Carteret, New Jersey, lies just to the east of the main Philadelphia-Newark airway, and is about eight miles south of the Newark Airport. Although the antenna towers were kept as low as possible because of the proximity of the airway, it was felt desirable to indicate their position in foggy weather by a marker radio beacon. The Newark radio range beacon transmits along the airway a steady 700-cycle tone, which changes to a dash-dot to the west of the airway and to a dot-dash to the east of it. The WOR towers are close to the eastern boundary of the central section of this range beacon and the Western Electric radio beacon recently installed gives warning of the proximity of the tower to anyone flying along the radio range leading to Newark.

The WOR marker beacon has a carrier frequency 1200 cycles above the frequency of the Newark range beacon. This is near enough to the Newark frequency so that when a plane is in the immediate vicinity of the towers the signals will be heard if the pilot has his beacon receiver tuned for Newark. The carrier of the WOR beacon is modu-



*Fig. 1—Front panel of the beacon transmitter*

\*RECORD, April, 1935, p. 232.

lated with 120 cycles interrupted to give a five-dash signal repeated twenty-four times a minute. The antenna of the marker beacon and the power output of the transmitter are so adjusted that a signal is received only when a plane is within about two miles of the towers. A pilot flying north along the airway will be listening to the 700-cycle steady tone of the Newark beacon. As he gets within two miles of the WOR towers the repeated five-dash 120-cycle tone of the marker beacon will come in on his receiver. He will then immediately check his altitude, and if necessary climb to a higher level. Presently the five-dash signal will fade out and he will know that he has passed the towers. The WOR signal will be doubly noticeable; it is not only a five-dash signal, distinctly different from the three possible Newark sig-

nals, but is some  $2\frac{1}{2}$  octaves lower in pitch, the Newark signal being about an octave and a half above middle C, and the WOR signal approximately an octave below.

The beacon transmitter was designed for installation in the transmitter room of WOR. For this reason an effort was made to obtain a front elevation harmonious with the main and stand-by transmitter panels. Its appearance as set up for final test in the Laboratories is shown in Figure 1. This panel now forms part of one of the walls of the transmitter room at WOR, Carteret.

The beacon transmitter is crystal-controlled and operates continuously at a frequency of 339.2 kc. A simplified schematic is shown in Figure 2. The crystal and the four vacuum tubes are visible in the glass front compartment evident in the photograph.

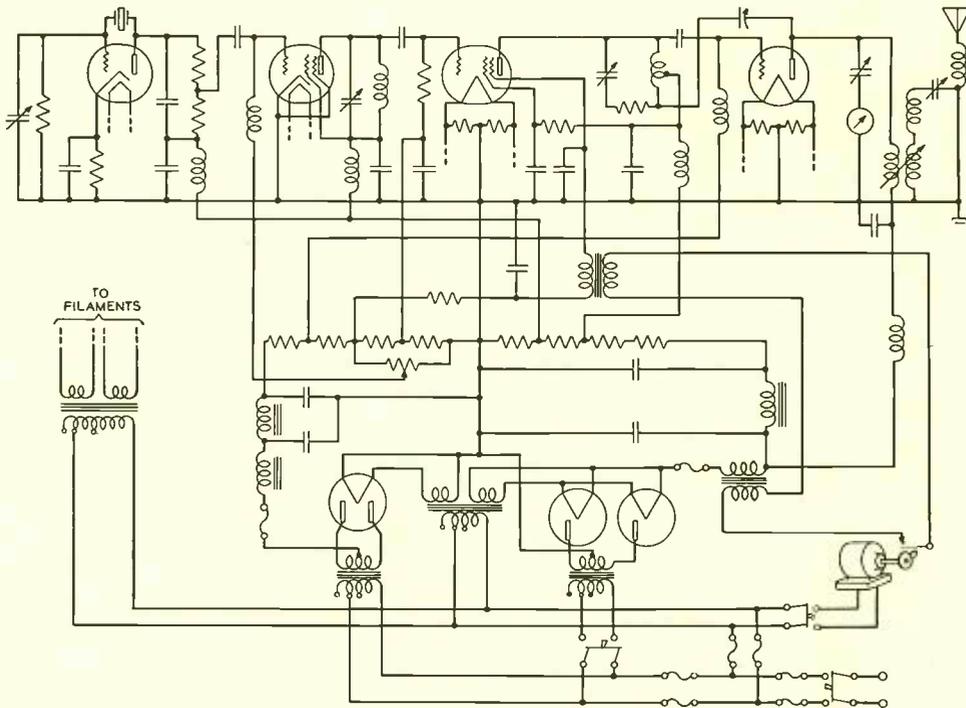
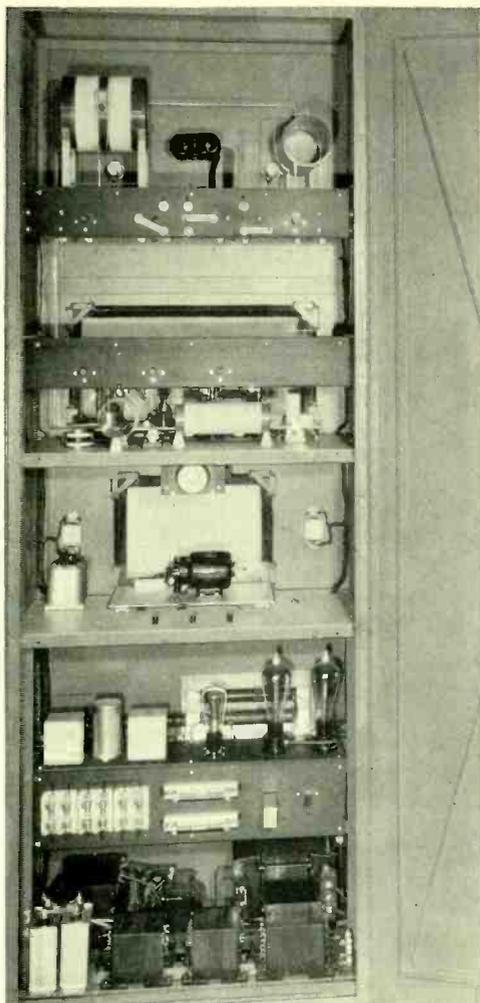


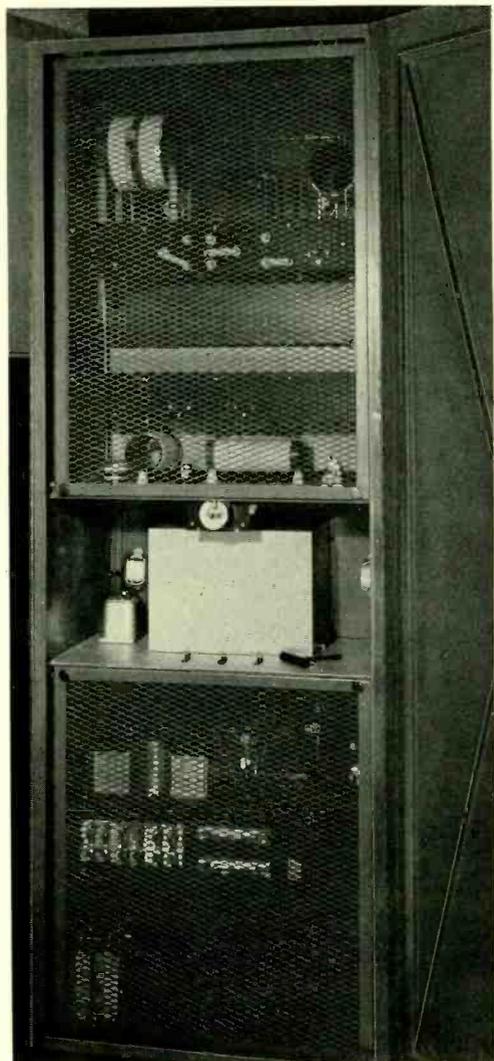
Fig. 2—Simplified schematic of the radio marker beacon at WOR



*Fig. 3—Rear view of the beacon transmitter with protecting screens removed*

From left to right there are the crystal container, an oscillator tube, a buffer amplifier, a modulating amplifier, and a power amplifier. Primary power is taken from the station's 220-volt alternating-current supply. Thermionic and mercury vapor rectifiers, mounted in the lower compartment and evident in Figure 3, supply grid and plate potentials, a single-tube full-wave thermionic rectifier being employed for grid bias and a two-tube full-wave mercury vapor rectifier for

plate potential. The 120-cycle supply used to modulate the carrier is obtained from an auxiliary winding on one of the retard coils of the filter of the plate rectifier. Since this coil is the first element in a filter supplied by a full-wave 60-cycle rectifier, a large 120-cycle voltage is impressed across its terminals, and a few turns of secondary are sufficient for full



*Fig. 4—Rear view of the beacon transmitter with protective screens in place over the high-voltage compartments*

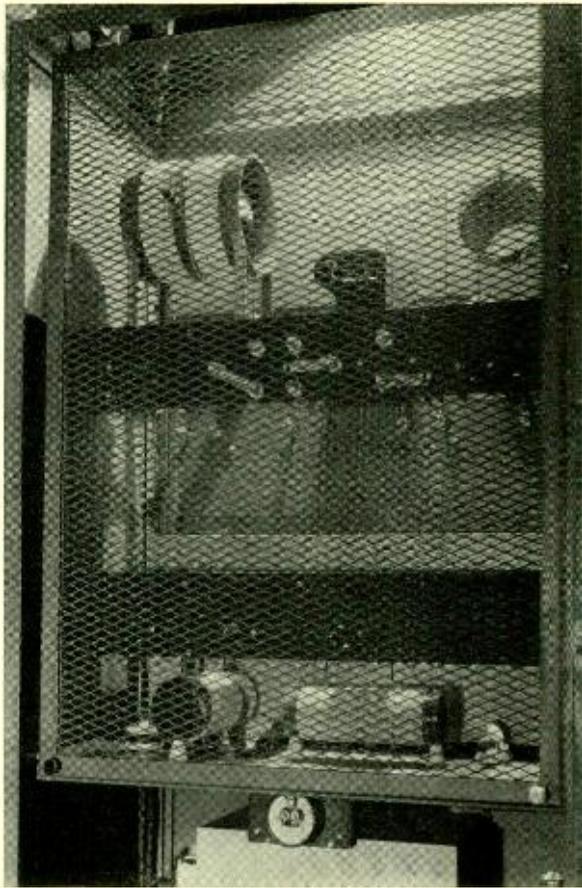
modulation of the transmitter.

To obtain the five-dash signal, the 120-cycle supply is interrupted by a cam operated by a small motor. This motor and cam are in another glass-front compartment just below the tubes. Provision is made, through a relay not shown in the schematic, for modulating the transmitter with voice by means of a local microphone. This would make it possible to talk to planes in the vicinity of the station in emergencies, although it is expected that the need for such use will be very rare.

It is not desirable to have the signal from this warning beacon audible more than a few miles from the station. As a result an antenna is provided, meeting specifications of the Bureau of Air Commerce, which gives a large amount of high angle radiation but practically no signal at more than two miles from the transmitter. The antenna is of the single-wire L type only twenty feet above the ground and about 150 feet long. Such an antenna has a very low effective resistance and an extremely high capacitive reactance, so that it is necessary to have an antenna loading coil of high inductance for tuning. The losses in such a coil are necessarily high, and as a result, of the 30 watts output of the transmitter only about 1.5 watts is radiated from the antenna.

Because the resistance of the antenna is so low compared to the impedance of the tuning inductance, it seemed doubtful whether a break in the antenna would produce a noticeable change in the current flowing

to the antenna through the concentric-conductor transmission line. Since continuity of service is of prime importance, particularly during bad weather when the antenna would be most likely to be damaged, an alarm seemed desirable to notify the attendants in the station on failure of the antenna. For this purpose a thermocouple is inductively coupled to the connection running from the loading coil to the antenna, and leads from it are carried back to the winding of a relay in the station. This relay has two contacts, one of which operates on high current and the other on low. It is adjusted so that with normal an-



*Fig. 5—Upper compartment of the beacon transmitter as it appears from the rear*

tenna current neither contact is made, but an appreciable change in antenna current, either an increase or a decrease, will close one of the contacts and sound an alarm in the station.

Access to the apparatus is from the rear through a metal door and inner protective screens over the high-voltage equipment. The arrangement with screens in place is shown in Figure 4, and with screens removed in Figure 3. The screens are equipped

with safety switches which remove all high voltages when they are taken off. The front of the panel was designed primarily to give a pleasing appearance. The glass front compartment housing the interrupter motor and cam is provided with indirect illumination and the tube compartment above it is lighted from the glow of the filaments. With such an unusual arrangement the panel is a point of interest to visitors to the station.



### *Radio Spans Gap in Wire Circuit*

*Western Electric airplane radio apparatus was recently employed to restore telephone service between Miami and Havana, disrupted by the tropical hurricane in early September. This service is normally carried by submarine cable from Key West to Havana and by open-wire lines running along the right-of-way of the Florida East Coast Railway from Miami to Key West. The recent hurricane almost completely destroyed some thirty-six miles of the railroad and with it the telephone pole line. To bridge this gap, two fifty-mile radio links were rapidly provided by using the recently developed 5-watt radio transmitter (19A) and a modification of the 12A receiver. The aircraft radio apparatus has proven itself fully equal to the unusual task imposed upon it, and normal service is now being given over this promptly improvised radio link.*

# I

*Single Crystals of Sodium Chloride. The horizontal lines are one inch apart.*

# II

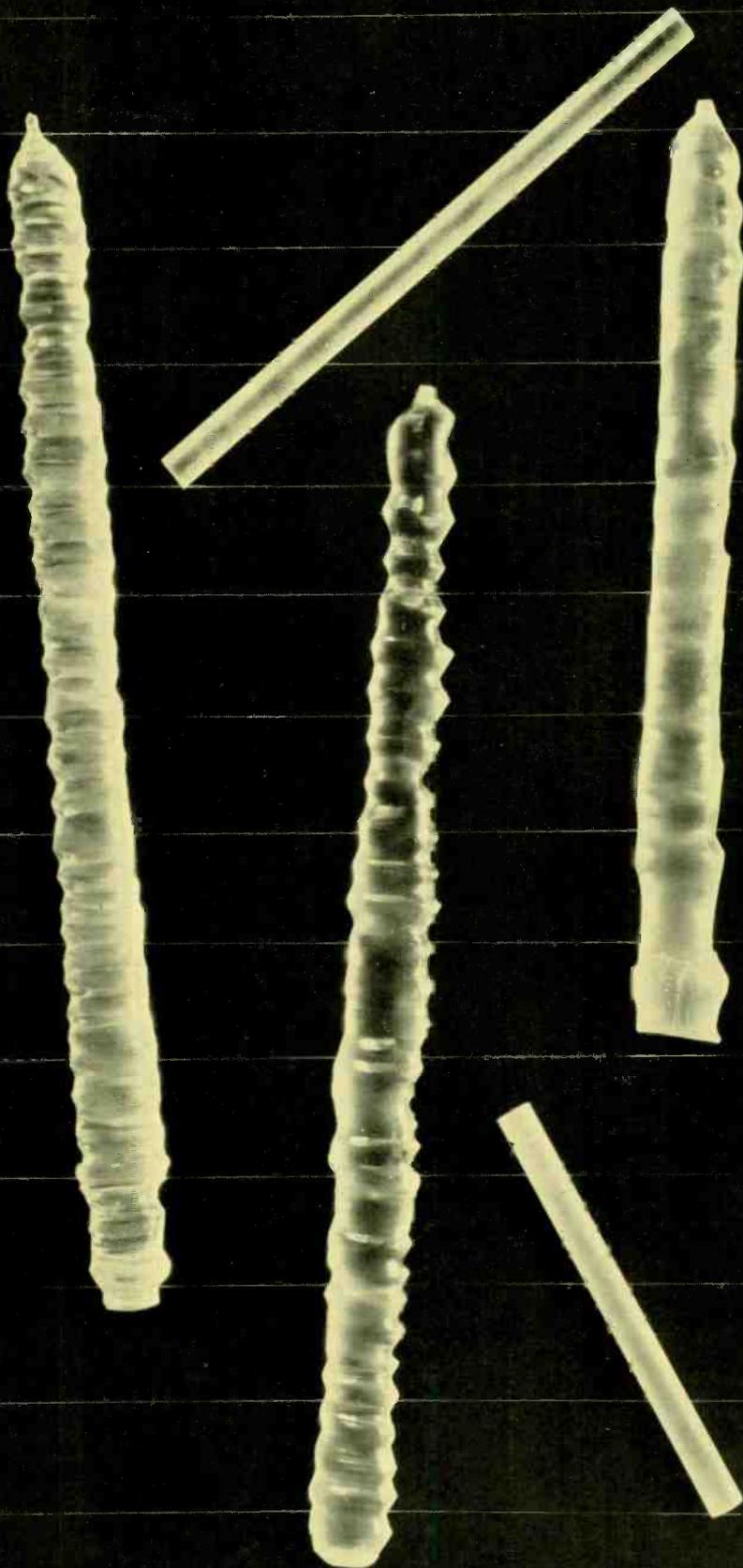
*A new circuit comes into being, in the Local Systems laboratory.*

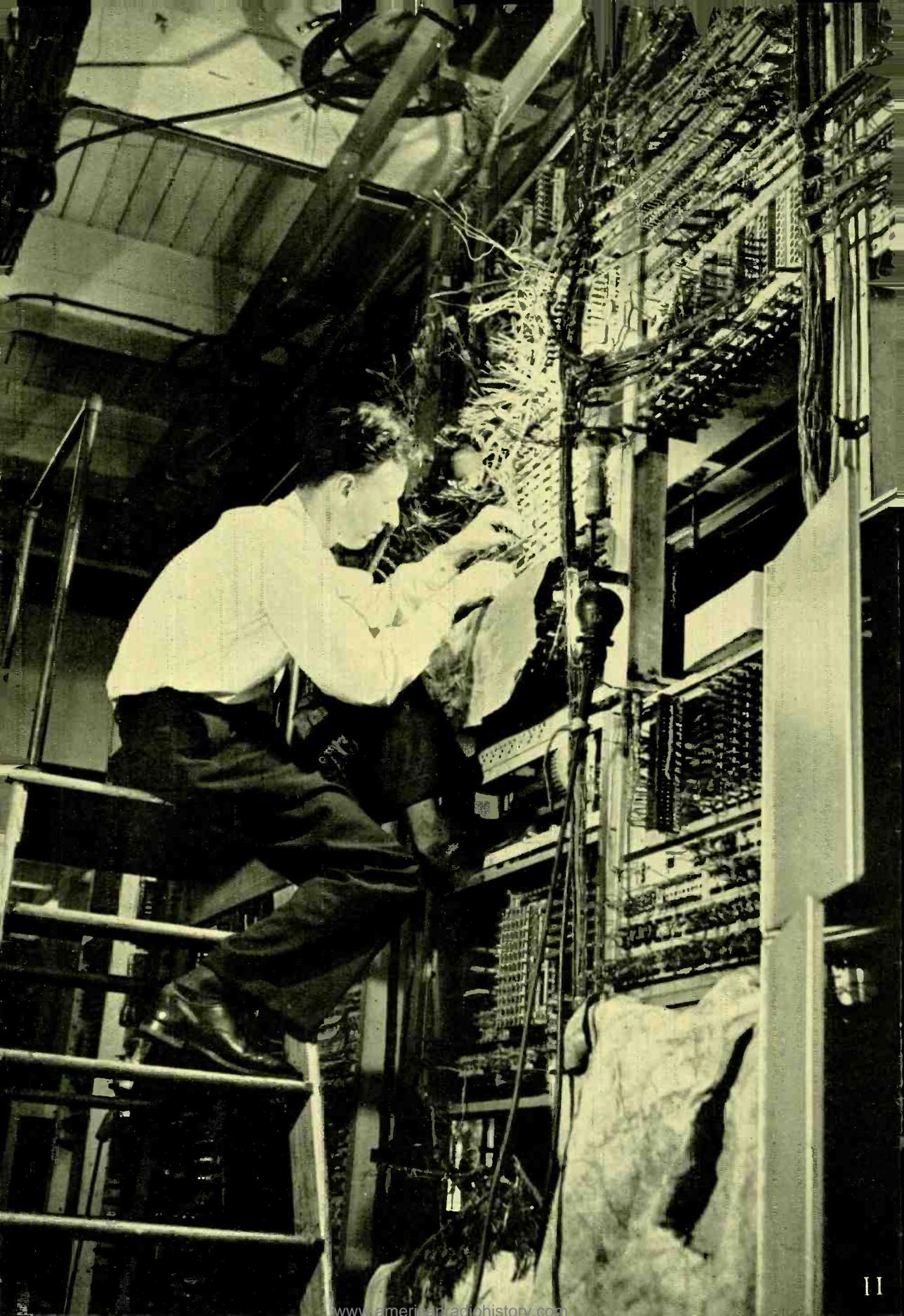
# III

*A familiar operation in the telephone plant.*

# IV

*Squares and Triangles: A radio tower at Whippany.*





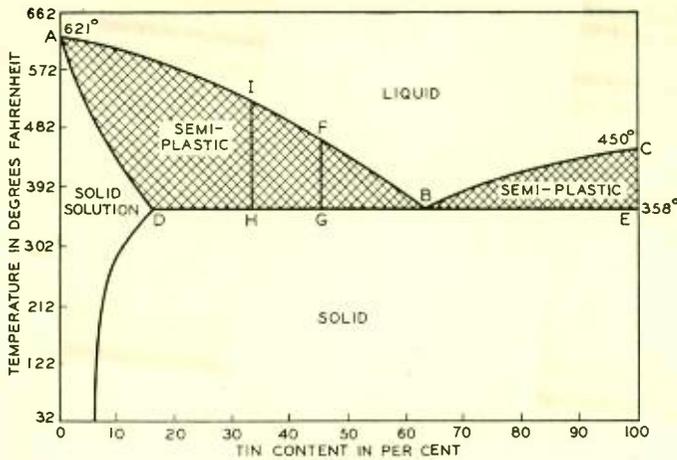


Fig. 1—Temperature ranges within which various alloys of lead and tin are liquid, semi-liquid and solid

ranged in tubular form, is widely used for telephone apparatus, particularly in the field. For untinned wire, which rosin does not clean sufficiently, naphthalene and tetrachloride, the least corrosive of the liquefied fluxes, may be used. Use of this flux is limited because of its high cost, disagreeable odor, and the necessity for careful removal of the excess flux and its decomposition products. The alcohol wash following its use must be done thoroughly and the alcohol changed frequently. For these reasons naphthalene-tetrachloride flux is used only where a more corrosive flux such as soldering salts cannot be thoroughly neutralized by a cyanide or citrate wash and where a non-corrosive rosin flux is not sufficiently active. Table I lists the solder, the fluxes and the neutralizing agent appropriate to typical soldering jobs encountered in the telephone plant.

All metallic materials and even many non-metallic materials, such as glass and porcelain, can be soldered if properly prepared. Aluminum is alone among the commonly used metals in offering difficulty be-

cause of the extremely rapid formation of aluminum oxide which is unaffected by the usual fluxing agents. Unless this oxide coating is completely removed it is impossible to obtain a satisfactory soldered joint on aluminum. The best way to remove this coating is to clean the surface with some abrasive such as emery or sandpaper or dissolve it off with some powerful acid such as hydro-

fluoric or nitric acid. Immediately following the removal of this oxide the aluminum surface should be tinned with a solder consisting of zinc or aluminum alloyed with tin. Exhaustive investigations have shown that a solder consisting of zinc and tin, or consisting of zinc, aluminum and tin, is the most satisfactory for this tinning operation. Once tinned, ordinary lead-

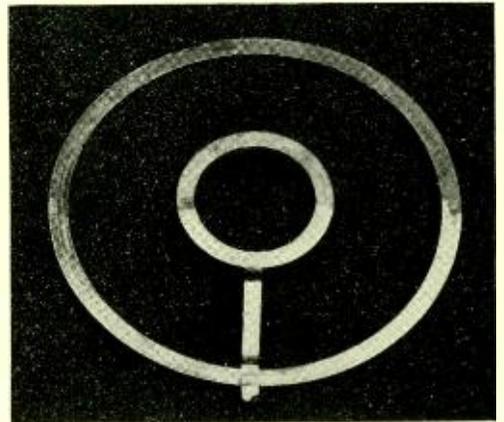
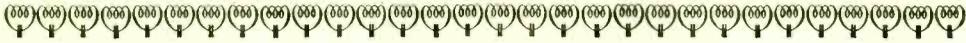


Fig. 2—To counteract the liability to season cracking, the transmitter contact ring in the handset is given a solder dip. This half-dipped ring shows the contrast between the solder (below) and underlying metal (above)



# Soft Solders

By A. H. FALK

*Telephone Apparatus Department*

THE joining of metallic materials by means of another material of lower melting point dates back to the days of the early metal craftsmen. Before the advent of modern machine methods and welding or brazing procedures, metallic parts had to be joined either by riveting or forging operations, or by fastening them with solder, a material of lower melting point. With the coming of the electrical era, the soldered joint became increasingly important, for it afforded a bond of high conductivity, easy to make and economical in space and cost. Today, in the Bell System and in all electrical industries, soldering is widely employed to secure an electrical and mechanical bond.

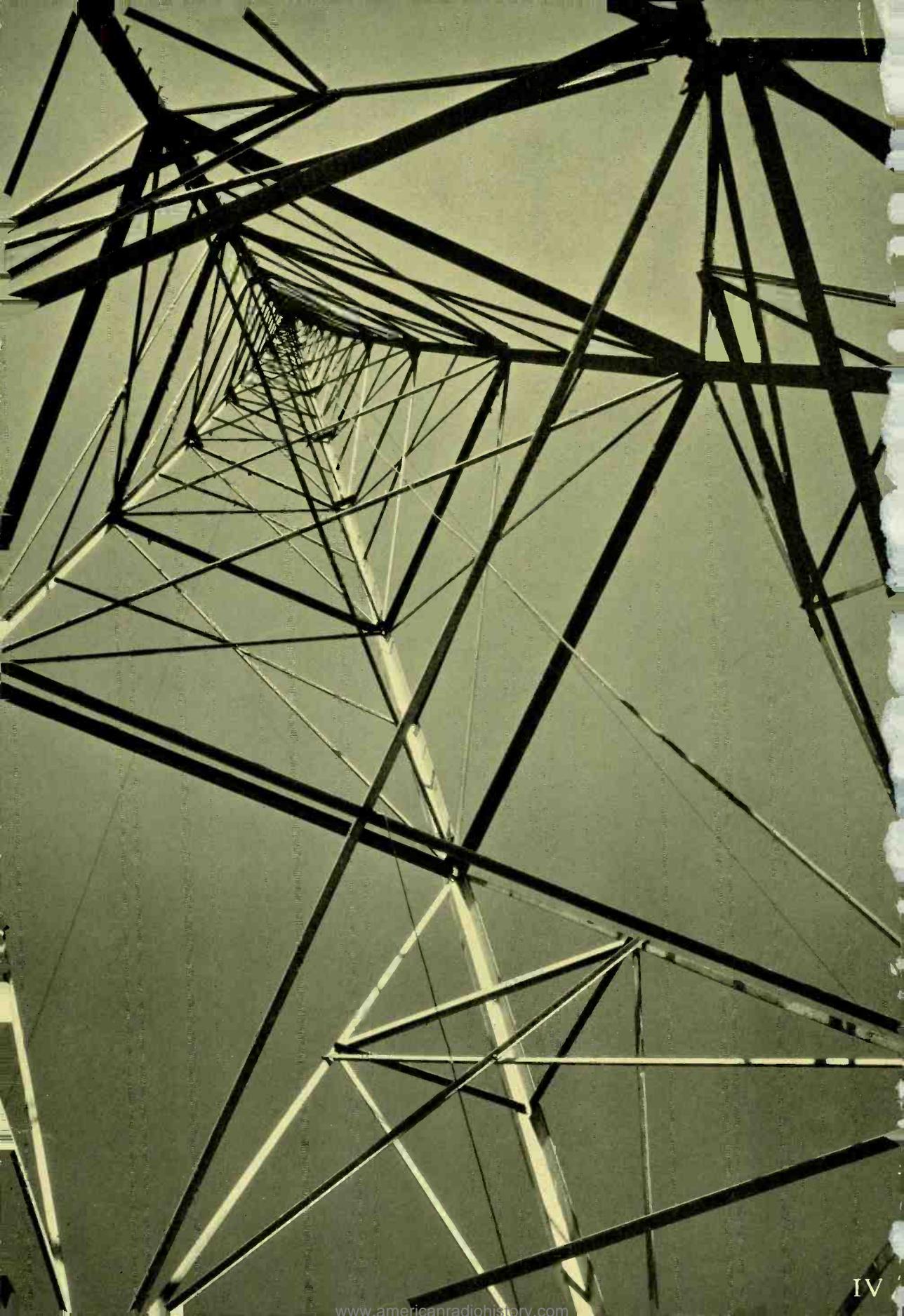
The solders described in this article are called "hand" solders, or soft solders, because of the relative ease with which they can be melted. Wisely chosen many years ago on the basis of prior experience, they still remain excellent solders for their purposes. In recent years, steps have been taken to reduce the cost of the solder by lowering its tin content, and today a solder containing 33 instead of 45 per cent tin is recommended for the great majority of telephone soldering operations. Hard solders, which must be melted with a blow-torch, though widely used in other industries, find comparatively little application in the Bell System.

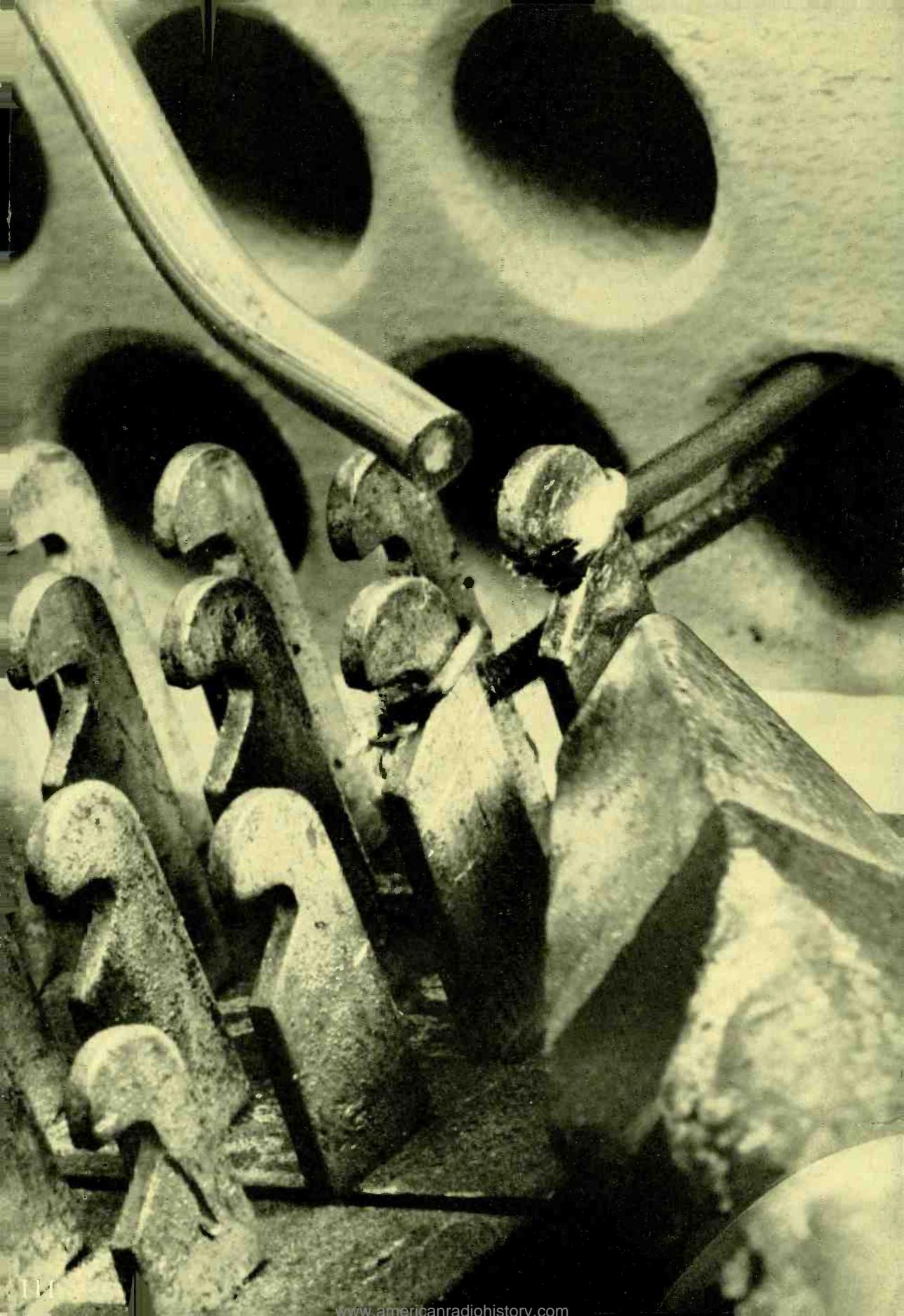
There is no great art in making satisfactory soldered joints; fundamentally, soldering is merely the

alloying of the solder with the surfaces of the parts to be joined. Most metals will alloy, at least to a limited degree, with the lead and tin which comprise the majority of soft solders. Any great difficulty that is experienced in soldering a joint is generally due to an external oxide or sulphide skin over the parts to be joined.

To dissolve and eliminate this coating, consisting usually of oxides and sulphides of the alloyed metals composing the parts to be joined, various "fluxes" have been developed. For many years a dilute solution of hydrochloric acid has been used. Later came the development of fluxes and solders which were especially adapted for particular purposes. For example, since many telephone apparatus parts cannot be thoroughly washed and all traces of the flux removed after the soldered joint has been made because of the danger of injury to the insulation, the least destructive of fluxes, rosin, must be used.

In making the many soldered joints in telephone apparatus which are in close proximity to coil windings or insulation servings, unusual care must be taken in the choice of fluxes. Ammonium chloride, zinc chloride, and hydrochloric acid are highly destructive of both metals and insulations and cannot be used unless the nature of the apparatus permits thorough removal of the fluxes by neutralization and washing after the soldered joint is made. Consequently rosin fluxed solder, conveniently ar-





tin hand solders may be used for making the joint. In soldering aluminum, however, it must be remembered that all metals or combinations of metals are electrically electropositive to aluminum and consequently are rapidly attacked and disintegrated when exposed to moisture. For this reason soldering of aluminum is not recommended in the Bell System.

Most alloys of lead and tin, indeed all those containing from 16 to 100 per cent of the latter metal, soften at about 358 degrees Fahrenheit as shown by line DBE in Figure 1. In that figure, the line ABC indicates temperatures at which all alloys of lead and tin completely liquefy. In the intermediate temperature range between lines ABC and DBE, which is shown by the cross-hatched area in Figure 1, the solder is semi-plastic, partially liquid and partially solid. This range is important in determining the temperature at which a soldering iron should operate and the speed at which soldering can be done. Thus when used with any particular soldering iron the solder having the greater semi-plastic range will liquefy somewhat slower and will take longer to solidify completely than that having a lower range. For example, the semi-plastic range for the 45 per cent tin—55 per cent lead solder as shown by line FG in Figure 1—is 114 degrees Fahrenheit



*Fig. 3—Millions of soldered contacts are an important element in the Bell System plant*

and the range for the 33 per cent tin—67 per cent lead solder as shown by line HI—is 172 degrees Fahrenheit. It is obvious, therefore, that it will take slightly longer to make a soldered joint using the 33 per cent tin solder than using the 45 per cent tin solder. However, in order to take advantage of the saving in cost of the lower tin content solders, the recent developments in soldering irons have been along lines to increase their efficiency and to operate them at higher temperatures.

Referring to Figure 1, it becomes evident that if two parts to be joined by soldering are to function under operating temperatures in excess of 358 degrees Fahrenheit, it is necessary that a solder having a tin content of

less than 16 per cent be used, because any alloy having a greater tin percentage than 16 per cent will begin to soften or become semi-liquid at this temperature. While soldered joints are not recommended for use at elevated temperatures, because the ultimate tensile strength falls off sharply with elevation of temperature, a lead-tin alloy having a tin content of 4 per cent has been found satisfactory for use under conditions where apparatus must function at temperatures within the semi-liquid range of the ordinary hand solders, and where very little stress is applied on the solder joints.

Compared to the metals being joined, soft or lead-tin solder is inherently weak, having an average ultimate strength of 4000 pounds per square inch at room temperature. Therefore, since the ultimate tensile strength of the solder is low as compared to the metal parts to be joined, the joints must be of sufficient area to bear the stresses to which they are to be subjected and consequently lap joints are preferable to butt joints. At temperatures in excess of room temperature, the ultimate tensile strength begins to fall off rapidly because of the nature of the metals which compose

TABLE I—MATERIALS USED FOR TYPICAL SOLDERING JOBS

<i>Job</i>	<i>Solder</i>	<i>Flux</i>	<i>Neutralizer</i>
General electrical connections in assemblies which cannot be washed.	45% tin—55% lead or 33% tin—67% lead	Rosin.	None.
Running seams on sheet metal (other than lead and its alloys).	45% tin—55% lead or 33% tin—67% lead	Soldering salts. (Ammonium chloride and zinc chloride.) Naphthalene. Tetrachloride.	Cyanide wash, hot water wipe or alcohol wash.
Copper, brass, phosphor bronze, nickel silver, tinned and untinned sheet.	45% tin—55% lead or 33% tin—67% lead	Soldering salts. (Ammonium chloride and zinc chloride.) Naphthalene. Tetrachloride.	Cyanide wash, hot water wipe or alcohol wash.
Galvanized iron sheet.	45% tin—55% lead or 33% tin—67% lead	Soldering salts. (Ammonium chloride and zinc chloride.) Naphthalene. Tetrachloride.	Cyanide wash, hot water wipe or alcohol wash.
Wiping and soldering lead joints.	40% tin—60% lead	Stearic acid.	Burning.
Tinned parts that can be washed after soldering.	45% tin—55% lead or 33% tin—67% lead	Naphthalene. Tetrachloride.	Alcohol wash.
Splicing copper wire where low electrical resistance and high strength are essential.	20% silver, 45% copper, 35% zinc*	Borax.	None.
Repairing brass castings where high strength is essential.	45% silver, 30% copper, 25% zinc*	Borax.	None.

\*These are not what are generally termed soft solders, a torch being required.

the solder alloy, both of which show increased cold-flow, or creep, tendencies with an increase in temperature. Since soft solder, like the lead and tin of which it is composed, offers very little fatigue resistance, it cannot be safely used for a joint which is subjected to fatiguing stresses.

Certain parts made of brass and other alloys are subject to season crack-

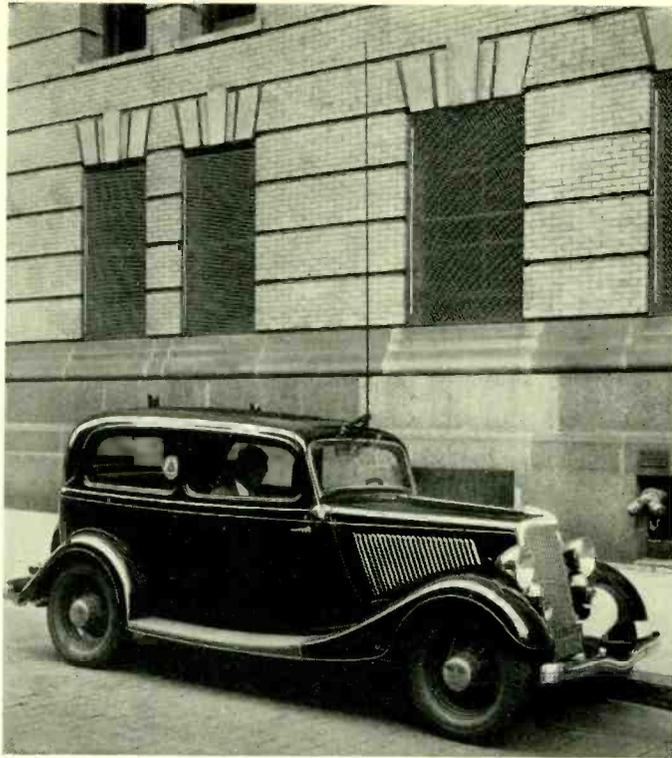
ing.\* It has been found desirable to dip these parts in solder to eliminate the danger of season cracking. The heat of the operation serves to anneal parts, thereby removing any dangerous internal strains. In addition, the use of the solder provides a permanent protective coating to keep the surfaces from contact with the atmosphere.

\*RECORD, October, 1929, p. 77.

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### *A Fugue in Cycles and Bels*

*Electrical transmission, mainly developed in these Laboratories, has had great effects socially and economically, and also upon the profession of music. Upon the art, so far, it has not had much effect. Quietly, however, the technical advances have been laying a basis for a revolutionary change in music itself. For those non-technical readers who take an intelligent interest in what science is doing to and for music, the latest book of John Mills is interesting, informative and not too difficult. After explaining vibration frequency and its relation to musical pitch, Mr. Mills takes the reader through basic notions of the ear, the voice, complex vibrations and the telephone transmitter. Subsequent chapters deal with scales of pitch and loudness, with amplifiers, microphones, loud speakers and with the Laboratories' researches in audition. Other chapters on the power of music, on noise, on overloading and distortion and on auditorium acoustics lead up to the achievement of the reproduction of music in auditory perspective. Tables and graphs at the end of the volume form a useful compendium of information on frequencies, decibels, response curves, energy levels and the like. D. Van Nostrand Company is the publisher.*



## A Test Car for Marine Radio Telephone Surveys

By G. M. HAFNER

*High-Frequency Transmission Development*

**I**N developing radiotelephone communication between ship and shore, various questions arise concerning the effectiveness of the radio transmission. To answer them, field strength measuring apparatus of an easily transported type is required. The best location for a shore station, for example, can be discovered only by making measurements of the fields received from the shipping lanes at points along the shore so as to determine the effects of intervening stretches of land and the type and magnitude of various types of inter-

ference that may exist. Another use of such apparatus is in determining the coverage of a harbor from a proposed shore station site, for which field measurements are made around the shore bounding the intended service area. The determination of the radiated power and directional characteristics of shore station antennas or of ship stations within the harbor requires that the measuring apparatus be brought to appropriate positions with respect to the stations that are under observation.

For some years now measurements

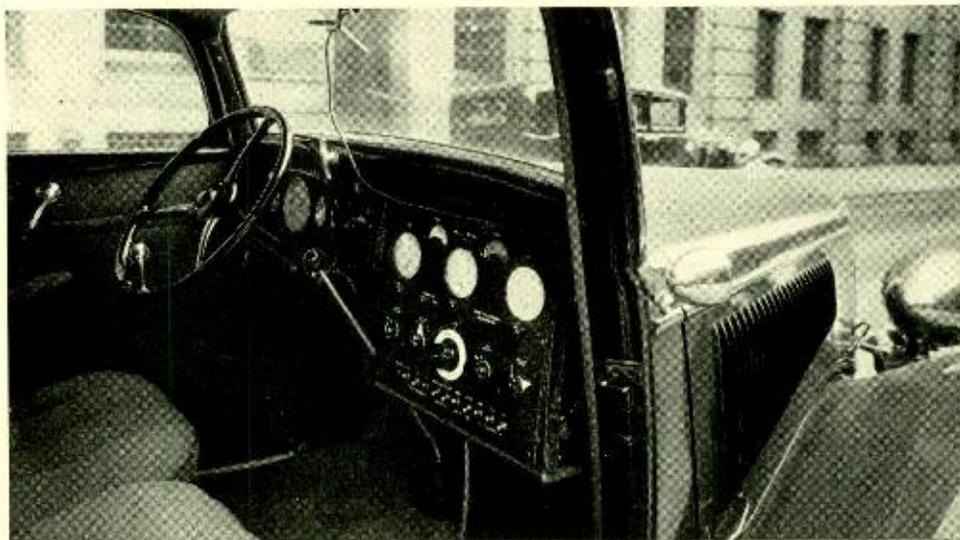
of this kind have been made by means of a truck fitted out with field strength measuring equipment designed primarily for stationary use. Because of the difficulty of moving the set from the truck for calibration purposes and because of restrictions placed on the operation of trucks in many parks and boulevards, it became desirable to provide lighter measuring apparatus which could be conveniently mounted in a small sedan.

With this in view, a small field strength measuring set was built for field test purposes which occupies less than a cubic foot of space and weighs only 25 pounds exclusive of power supply. In spite of its small size, however, the set has many features designed to simplify and improve its operation, and its range has been extended to include the broadcast frequency band.

The equipment is mounted directly in the instrument board of the car as shown in Figure 1, so as to be convenient to the observer. A rod antenna

which can be lowered to lie along the top of the car or raised to a vertical position from within the car was also provided as shown in the photograph at the head of this article. Two 6-volt 150-ampere-hour storage batteries, installed under the floor of the car, serve as a power supply. When the car is running, these batteries are kept charged by a generator belted to the engine. All filaments are heated directly from 6 volts, while plate supply is obtained from 200-volt dynamotors run by the storage batteries. A field oscillator, loop antennas, and miscellaneous apparatus such as meters and tools are stored in the back of the car and under the floor.

With former measuring sets, headphones were used for monitoring, which is inconvenient when the monitoring periods are of long duration. With the new set, a small loud speaker is provided for monitoring, but headphones may also be used when a large amount of nearby noise, or other reasons, make them preferable. The



*Fig. 1—The field strength measuring set is mounted in the instrument board of the car in such a way that it may be readily removed*

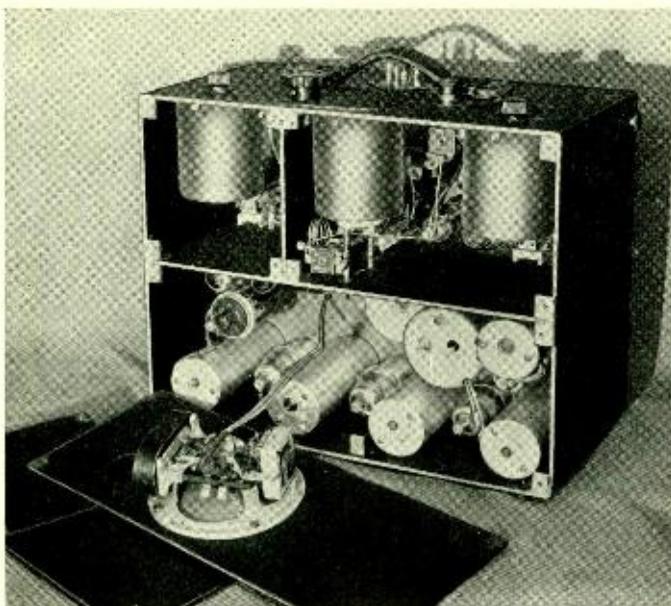


Fig. 2—A view of the set with rear cover laid back. The loud speaker may be seen mounted in the back cover. The knobs on the top are for changing the oscillator coils

loud speaker is mounted in the back of the set as shown in Figure 2. Automatic volume control is also incorporated in the new set, although it cannot be used, of course, during a measurement of field strength.

The arrangement of the controls of the set may be seen in Figure 1. Three vernier dials across the upper part of the front tune the calibrating oscillator, the antenna circuit, and the beating oscillator, respectively. Below, from left to right, are controls for the audio volume, the coarse and fine attenuators, the calibrating oscillator output, and the plate-current rheostat. The output meter, in the upper part of the front on the left, is calibrated directly in db

with a zero center, and enables signals fading over a 15 db range to be measured directly on the meter without continually readjusting the attenuator. A voltmeter, at the upper right of the set, is employed for a variety of purposes. All oscillator coils are contained in the set, and the various ranges are quickly selected by coil switches projecting through the top of the cabinet. The antenna coils are plugged in through an opening in the top. A block schematic of the equipment is shown in Figure 3.

The set is calibrated by the use of a portable field oscillator, which is carried in the car. For this purpose an open space is selected where there will be nothing to cause reflections and absorptions. The portable oscillator is set up, and the measuring set is removed from the car and placed a short

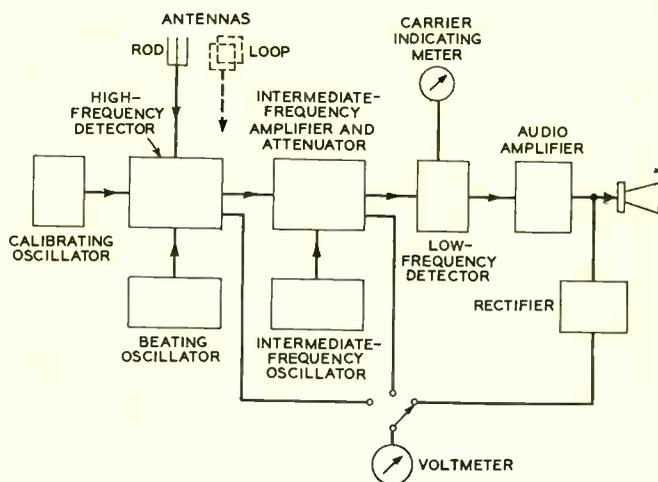


Fig. 3—Block schematic of field strength measuring set

distance—between 500 and 1000 feet—from the oscillator. Both oscillator and measuring set are then tuned to the desired frequency, and the measuring set is connected to a loop antenna. The absolute field strength of the oscillator is then measured. After this, the set is replaced in the car, connected to the vertical antenna, and an attenuator reading taken. The comparison between the absolute field strength and the reading of the attenuator is then used as a calibration for all future measurements as long as the gain of the set remains constant. This gain is measured periodically throughout any series of measurements, and a correction is made if a change is observed.

The results of a field strength survey made in New York harbor are shown in Figure 4, which is typical of such surveys in harbor areas. The contour lines indicate the field strengths in decibels above one microvolt per meter, and after the noise conditions on the boat and at the shore station have been determined, the approximate service range can be estimated.

Noise is measured by employing the field oscillator as a transmitter, and measuring the field strength required to make a signal just understandable over the noise level. The field oscillator is set up in the car, and modulated with a disk record. Its output is carried to a small temporary antenna mounted close to the receiving an-

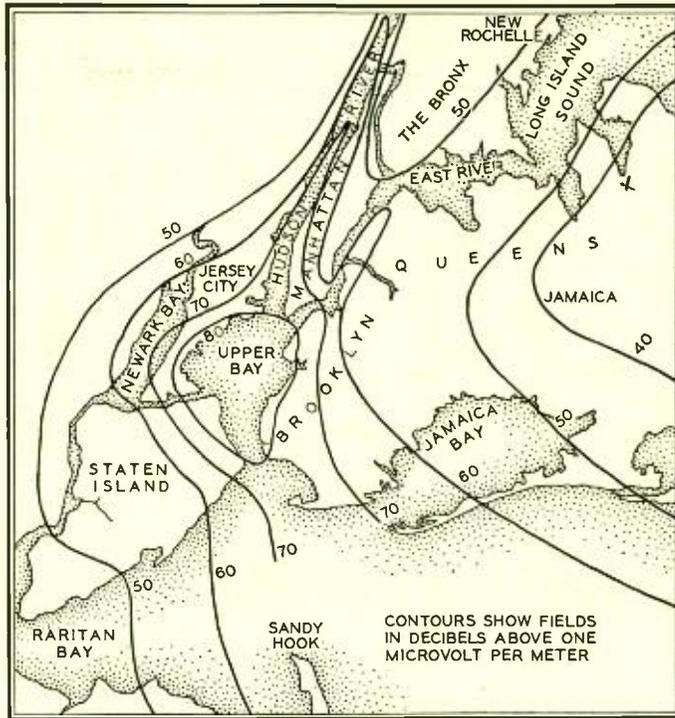


Fig. 4—Field strength survey of New York Harbor and vicinity with the transmitter at St. George, Staten Island

tenna of the car. The program on the record is then monitored while the output of the oscillator is decreased until speech is no longer intelligible over the noise. The output is then raised until the intelligibility of the speech becomes satisfactory. At this point a field strength measurement of the oscillator output is made. This gives the level of the noise in terms of the field strength of a radio telephone signal required to override it.

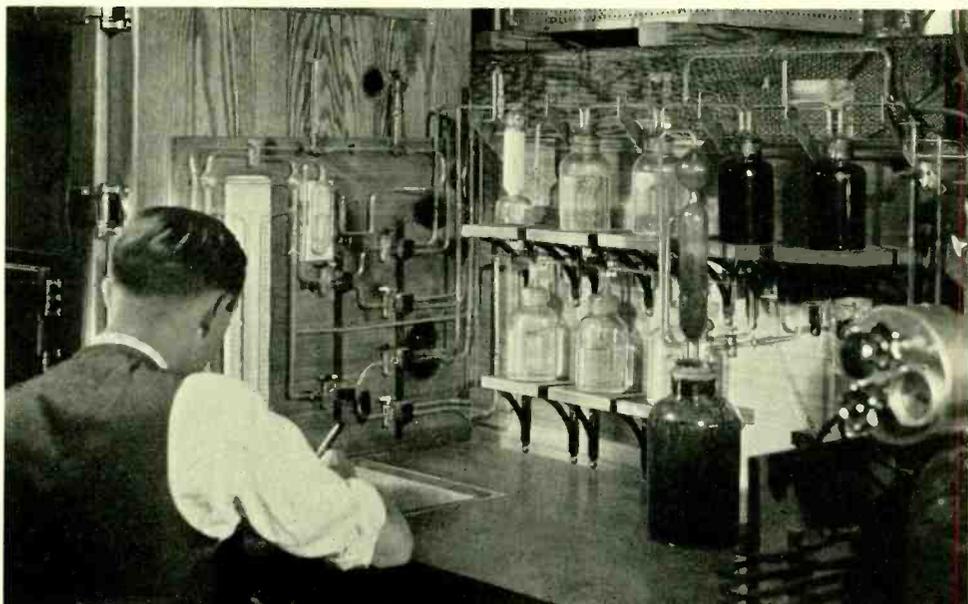
Inasmuch as speech volumes can be measured, the new set also lends itself to the measurement of per cent modulation by a few simple manipulations. This measurement consists essentially of noting how the speech volume with a given carrier output compares with the speech volumes for one hundred per cent modulation.

During the course of tests, two-way

communication between the test car and the station being measured is sometimes desirable. To make this possible a portable low-powered field oscillator-modulator unit is used. Its range, of course, is limited but it has been found to be very useful. A high-level push-button microphone—like those which are used at aircraft ground stations—is employed to modulate

the oscillator and control its carrier.

With this comparatively simple outfit all measurements needed for radio surveys or transmitter tests can be made quickly and satisfactorily. The car is light and fast so that considerable territory may be covered in a day, and every feature of the measuring equipment is designed to simplify and expedite the various measurements.



*Apparatus for purifying gases used in corrosion studies at Summit Laboratories*



## High-Fidelity Radio Transmitter for Ultra-High Frequencies

By J. W. SMITH

**R**IGOROUS requirements covering frequency stability, percentage modulation, and total overall distortion have been placed on broadcast transmitters. Assignments of the ultra-high-frequencies in the United States have, up to the present time, been made only for experimental purposes and requirements as to the performance of radio transmitting equipment operating in this range have not become crystallized. If the fullest advantage is to be taken of the service possibilities of this portion of the radio spectrum, it is to be anticipated that high technical require-

ments will have to be met by the equipment which is employed. The new Western Electric No. 16 type radio transmitter and No. 88 type radio amplifier have been designed with this possibility in view and as a result have characteristics that will meet any requirements likely in the immediate future.

This new ultra-high-frequency apparatus consists of a 50-watt transmitter and a 500-watt amplifier, so that outputs of either 50 or 500 watts are available. The two units, approximately equal in height and width, are shown together at the head of this

article. The combination will operate at any frequency from 30 to 42 megacycles, in which range a number of frequencies have been designated for the operation of general experimental stations in the police, broadcast pick-up, and other services. The transmitter alone has a wider range, extending up to 60 megacycles.

To obtain a high degree of frequency stability, the transmitter is crystal controlled, and maintains its frequency to better than twenty-five thousandths of one per cent. One of the new type crystals is employed which does not require temperature control, thereby eliminating heat-controlling relays, thermostats, and heat chambers.

A simplified schematic of the transmitter circuit is shown in Figure 1. The crystal-controlled oscillator employs a Western Electric 306A vacuum tube, and the second, third or fourth harmonic of the crystal fre-

quency—generated in the plate circuit of this tube—drives another tube of the same type, which acts as an harmonic generator and produces either the second or third harmonic of its input frequency. Immediately following this harmonic generator is a radio-frequency amplifier, employing a 305A tube—and its operating frequency is thus either the 4th, 6th, 8th or 9th harmonic of the crystal frequency. The radio-frequency amplifier drives the modulating amplifier which employs two 305A tubes in a push-pull circuit. Modulation is accomplished by varying the supply voltage to the plates and screen grids with the output of the audio-frequency amplifier.

The audio-frequency amplifier employs three stages of transformer-coupled amplification. The first stage serves as a voltage amplifier and is coupled to a push-pull stage, which acts as a driver for the power amplifier—also a push-pull circuit. Approx-

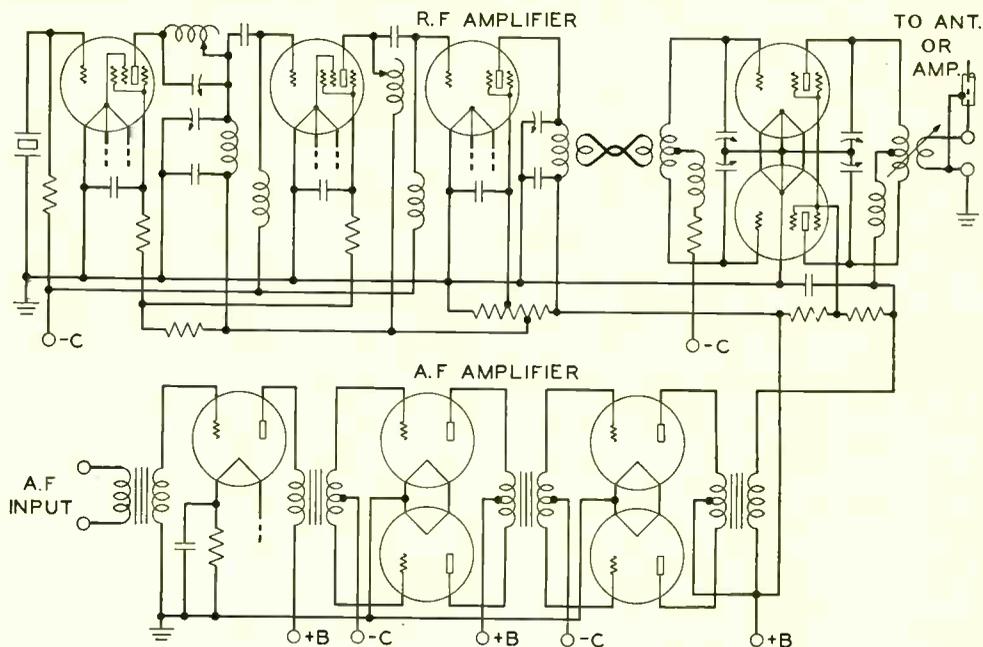


Fig. 1—Simplified schematic of the 16 type ultra-high-frequency radio transmitter

imately 65 watts of audio-frequency power is necessary at 100 per cent modulation. This amount of power is obtained with 800 volts on the plate, which was taken as a desirable limit for the operating voltage. The grids of the audio power amplifier are driven only slightly positive, thus insuring a very low overall distortion. The input necessary for 100 per cent modulation is 20 db below six milliwatts which is easily obtainable directly from a single-button carbon microphone.

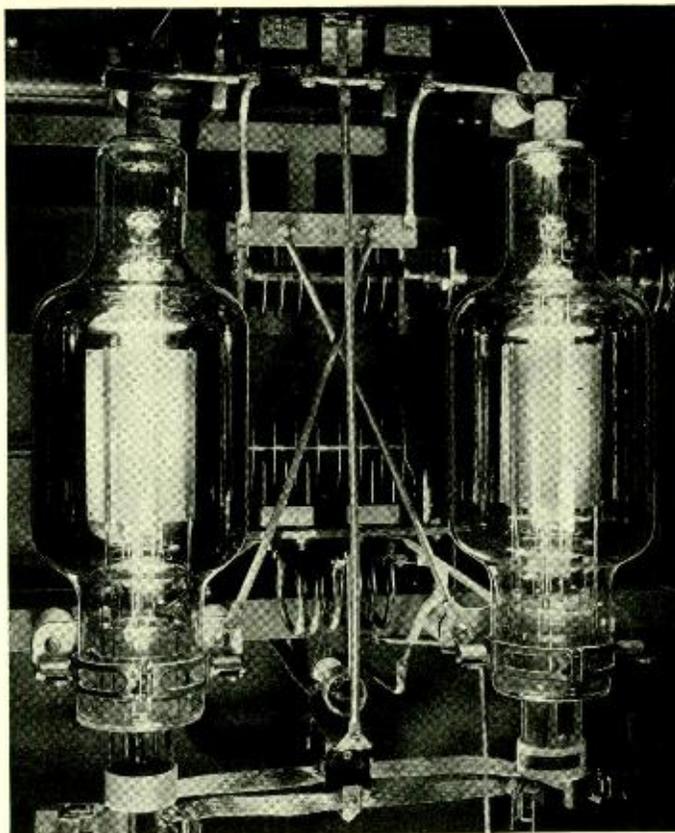
The 88 type amplifier is a single-stage push-pull amplifier employing the 251A tubes already described in the RECORD.\* The tuned output circuits

of both the transmitter and the amplifier are designed to couple to either an open-wire transmission line or a single concentric conductor to feed radio-frequency power to the antenna. To reduce possible harmonic radiation from the antenna, a  $\frac{1}{4}$  wavelength short-circuited section of concentric transmission line is shunted across the output terminals. At the fundamental frequency this shunt has a very high impedance and so has no effect, but at even harmonics it acts as a short-circuit and thus prevents the even harmonics from reaching the antenna. All of the harmonics above the second are satisfactorily reduced

in amplitude by the output circuits of the radio transmitter.

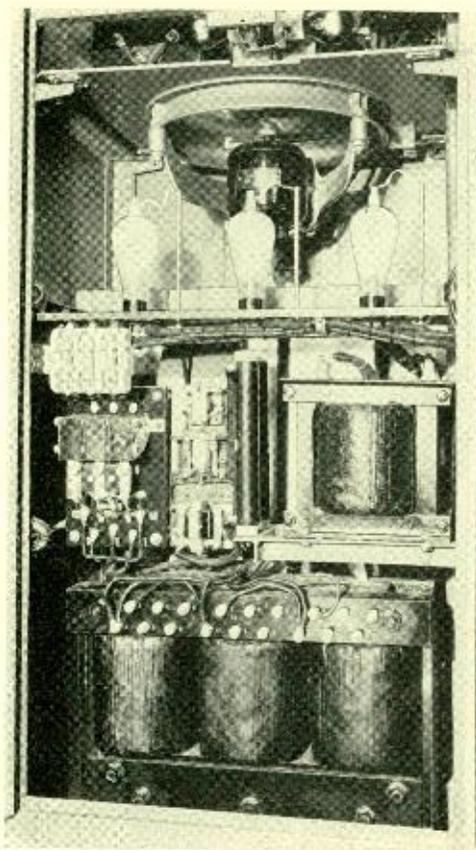
Both the transmitter and amplifier units have their own mercury-vapor rectifiers for plate supply. For the transmitter, a single-phase full-wave rectifier delivering 800 volts is provided, and for the amplifier a three-phase rectifier delivering 2500 volts. In the transmitter unit there is in addition a 265-volt single-phase rectifier, which supplies grid bias for both transmitter and amplifier. All these rectifiers employ Western Electric 249B mercury-vapor tubes.

Apparatus for the radio transmitter is mounted on six panels which form the front of a steel cabinet seven feet



*Fig. 2—Upper section of 88 type amplifier showing power tubes, coils, and tuning condensers*

\*RECORD, October, 1932, p. 30.



*Fig. 3—In the lower section of the amplifier is the mercury vapor rectifier providing the 2500-volt plate supply*

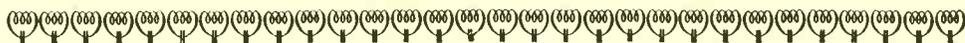
high, two feet wide, and a foot and a half deep. Access to the circuits is through a full height door covering the rear of the cabinet. An exhaust fan at the top of the door and a spun-

glass air filter at the bottom provide an adequate supply of clean air to maintain the apparatus at satisfactory operating temperatures.

The 88 type amplifier is mounted in a cabinet divided into an upper and lower section, each with double doors on the front. The lower section includes the power supply equipment and the upper section, the two power tubes with their tuned input and output circuits. The doors of this upper section have glass panels, while those of the lower section are solid. A fan is installed in the partition between the two sections, which draws air from the lower part of the cabinet through an air filter, and exhausts it through the top. All doors on both cabinets are equipped with safety switches which disconnect the high voltage when the doors are opened.

The unit type of construction of the 16 type transmitter makes it possible to adapt the equipment to several types of communication. The first installation of the 16 type transmitter and 88 type amplifier was for one-way police broadcasts in the city of Newark;\* a photograph of this installation is shown at the head of this article. The first two-way installation of the 16 type transmitter was in Evansville, Indiana; and other installations have since been made.

\*RECORD, June, 1935, p. 290.



## Contributors to This Issue

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E. H. BEDELL has been engaged in studies relating to the absorption and transmission of sound and allied subjects in the field of acoustics since he joined the Acoustical Research Department of the Laboratories in 1925. He was graduated from Drury College in 1924 with the degree of B.S. and spent the following year doing graduate work at the University of Missouri. The acoustical test chamber described in the current RECORD, an outgrowth of his work, is an important contribution to experimental acoustics since it shows how rooms with high absorbing power for low frequencies can be constructed.

D. B. PENICK has been working on special problems pertaining to the operation of vacuum tubes in high quality circuits, and especially on the reduction of noise, since he came to the Laboratories in 1923. This work led to the development of the electrometer tube which was originally designed for use by members of the Laboratories Staff in other experimental problems. It soon appeared, however, that there was a demand for a tube of these characteristics by outside research workers

which has required their production in increasing quantity. Mr. Penick received his B.S. degree in Electrical Engineering from the University of Texas in 1923 and a B.A. from the same institution the following year. In 1927 he received an M.A. from Columbia University.

J. W. SMITH graduated from the University of Illinois in 1924 with the B.S. degree in Electrical Engineering, and at once joined the Technical Staff of the Laboratories. Here, with the Radio Development Department, his work was first concerned chiefly with the development and installation of the 50-kw. broadcast transmitter. Since 1933, he has been engaged in the development of ultra-high-frequency radio transmitters, both of the telephone and telegraph type, such as are used for police and other similar services.

FOLLOWING SERVICE in the U. S. Army during 1918 and 1919, A. A. Skene received the degree of B.S. in Electrical Engineering from Pennsylvania State College in 1920. He at once joined the Engineering Department of the Western Electric Company, where he was engaged



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*D. B. Penick*



*J. W. Smith*



*A. A. Skene*



*G. M. Hafner*



*A. H. Falk*

in apparatus design and radio development until 1923. He then spent some six years with the Union Switch and Signal Company, concerned with the engineering of railway signalling and automatic train control systems and equipment. In 1930 he joined the Technical Staff of the Laboratories, where he has been occupied in the design and development of radio broadcasting transmitters and associated apparatus.

AFTER SEVERAL years of active radio work outside the Bell System, G. M. Hafner joined the Development and Research Department of the American Telephone and Telegraph Company in 1927. Here for three years he worked on the development of the first short-wave transatlantic radio-telephone link. In 1930 he transferred to the ship-to-shore group where he worked chiefly on radio transmission surveys. Since his transfer to the

Laboratories last year, he has continued his transmission survey work as applied to ship-to-shore radio-telephony.

FOLLOWING HIS graduation by Tufts College in 1920, A. H. Falk entered the Laboratories where his first work was in the Systems Development Department. After further study at Tufts, he received his master degree in chemistry, and returned to the Laboratories in December, 1922. For the next year he was concerned with a variety of special problems, and in 1924 he became a member of the group which designed loading coil cases. A method of coil assembly was described by Mr. Falk in the BELL LABORATORIES RECORD for February, 1926.

During the last seven years Mr. Falk has been a member of the Metallic Materials group, where he has carried on studies of contacts, solders and a great variety of other materials.