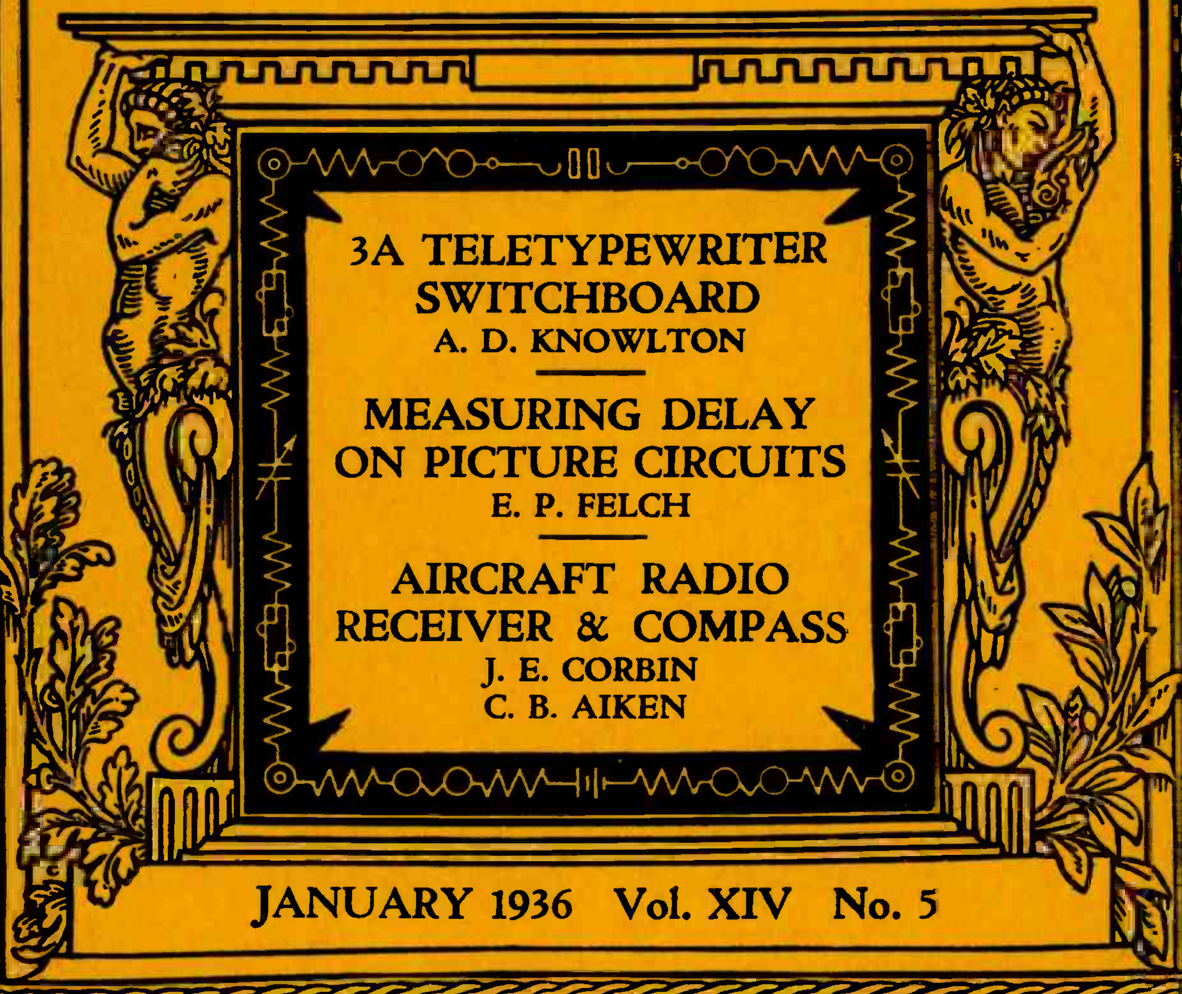
BELL LABORATORIES RECORD



3A TELETYPEWRITER SWITCHBOARD
A. D. KNOWLTON

MEASURING DELAY ON PICTURE CIRCUITS
E. P. FELCH

AIRCRAFT RADIO RECEIVER & COMPASS
J. E. CORBIN
C. B. AIKEN

JANUARY 1936 Vol. XIV No. 5

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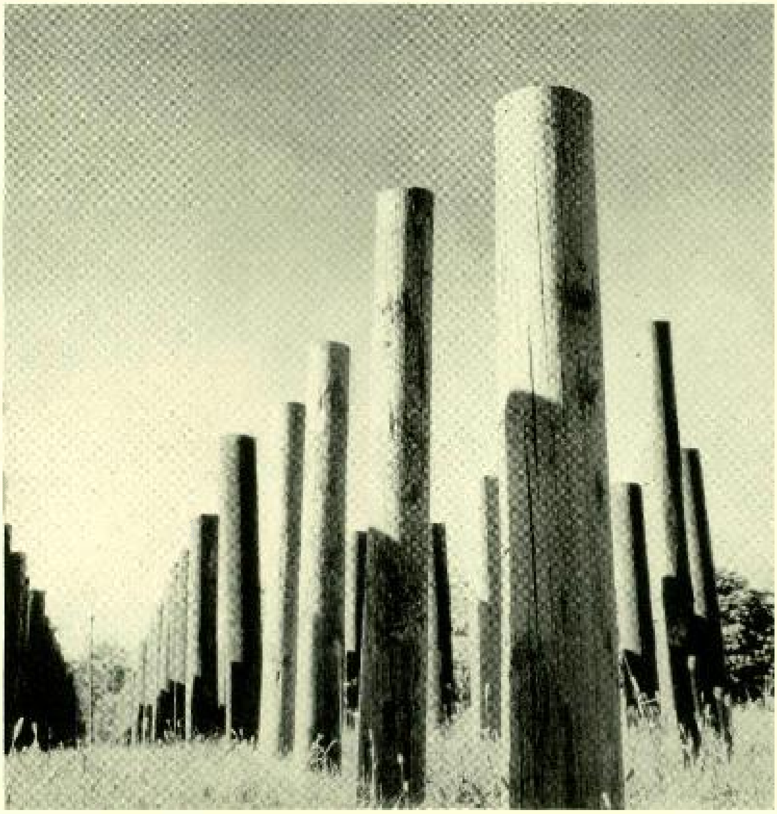

Test Plantation for Telephone Poles at Chester, New Jersey

VOLUME FOURTEEN—NUMBER FIVE

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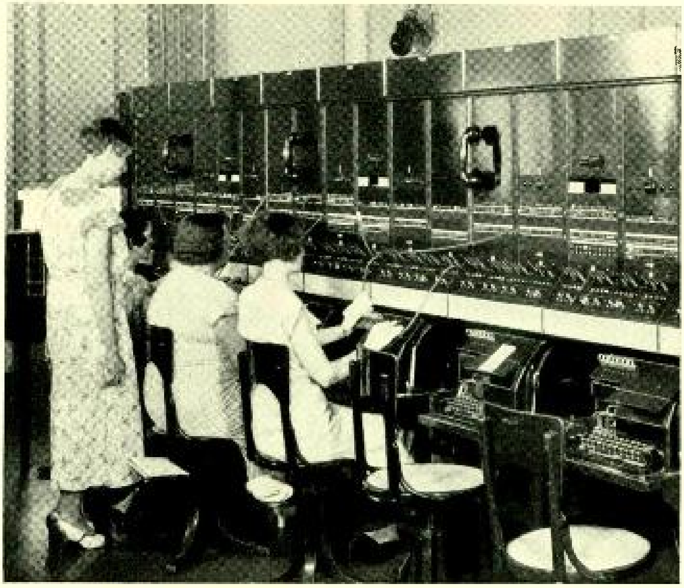

Novel Design Adapts 3A TWX to Wide Range of Conditions

By A. D. KNOWLTON
Equipment Development

EXPERIENCE with the manual telephone switchboard over a period of many years has built up a technique which has been invaluable in the development of switchboards for the nation-wide teletypewriter exchange service.* In the early stages of a new art, however, the expansion of service and the development of new and improved circuits cause fluctuations in factors that in an established art are normally stable. Because of this, it soon became evident that it would be sound economic policy to design the switchboards so that they could be readily adjusted to these changing conditions without major alterations. This, together with the problem of incorporating the teletypewriter in a keyshelf design that would allow efficient use of the multiple, constituted the two major problems in the design of the new No. 3A teletypewriter switchboard for the medium-sized switching areas.

Fundamentally, a manual switchboard consists of a number of subscriber and interoffice lines terminated in multiple jacks before which are placed operators, each having access to all lines, and each furnished with a number of cords for making connections between the lines. The expense of this multiple is an important factor in the initial cost of the switchboard, and it is therefore important that the operators be placed on as close centers as possible up to the point where the operators become crowded, so as to

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*Record, *Jan.*, 1932, *p.* 145.

reduce to a minimum the total length of multiple required for a given number of operators.

It soon became evident that if the teletypewriter were placed at the same level as the cords, the width of the position would greatly exceed the minimum width which past experience had shown to be approximately 22 inches, because additional space along the length of the board would be required for cords and keys to make up for the space occupied by the teletypewriter. Furthermore, with the teletypewriter fixed in the keyshelf, a predetermined number of cords would have to be provided in the original design. Since the number of cords required per operator is determined by the average holding time and the features of the circuits—factors which are in a state of flux in a new art—any future change in these factors would decrease the efficiency of the use of the multiple.

To reduce the width of the position, and at the same time permit the teletypewriter to be associated with any number of cords with little change, the plan was evolved of locating the cord equipment above the teletypewriter and putting the teletypewriter on a separate table, which could be placed anywhere in front of the switchboard. If it were placed in front of a standard keyshelf, the operator would be too far from the multiple for convenient reaching, and so a sloping keyshelf, shown in cross-section in Figure 3, was developed. To keep the sloping section as short as possible, the cords were placed in a single row, instead of putting the calling cords in one row and the answering cords in another as is usually done. The calling and answering end of each cord pair are adjacent, and are differentiated by using a red shell on the calling plug and a black shell on the other.

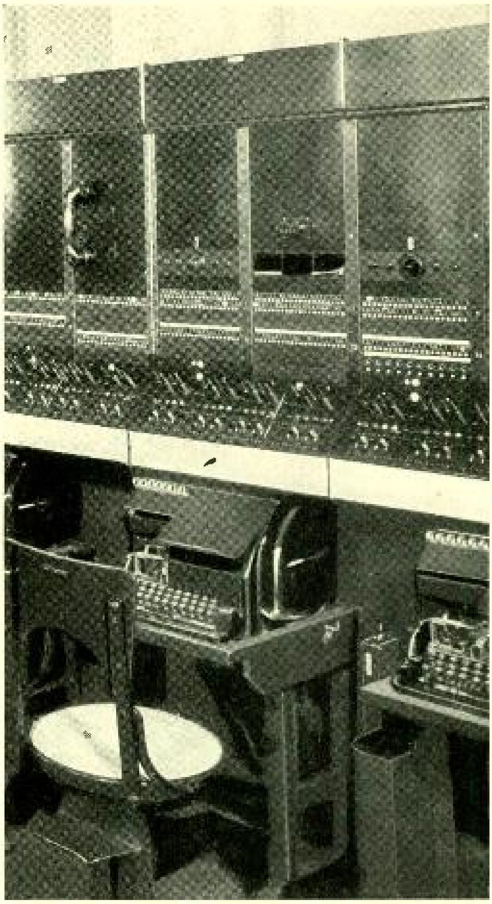


Fig. 1—Handsets are provided on the front of the board for communication with points within the office

The arrangement adopted was the result of experimentation with different models to determine the best design. In this investigation such factors as the ease of handling cords and keys, the sliding action of the cord in returning to the keyshelf, and the efficient location of the teletypewriter with respect to the multiple played important parts. The locating of the cords above the teletypewriter made possible the use of a standard length cord while permitting a 26½-inch instead of a 40-inch operating height for the teletypewriter. This permitted the operators' chairs to be set directly on the floor and eliminated the necessity of a foot rail. With the standard length cord the usual amount of relay equipment could be located in the rear of the section, since the space available is limited ordinarily by the height of the cordshelf.

The depth of the teletypewriter makes it necessary that the back be placed approximately five inches behind the face of the jacks to permit the operator to sit close enough to the jack field for the most efficient operation. The sloping keyshelf provided an arrangement whereby this could be done, the cords passing the teletypewriter over a stainless steel bar.

Each section of switchboard carries two 10¼-inch panels of multiple, and three sections are required for the maximum of 1200 lines for which the board is designed. This gives an overall width of 63 inches for the complete multiple, which is well within an operator's reach. The number of operators required is affected not only by the number of lines, but by the average holding time and the average frequency of calls per line. Since with a new type of service any of these factors may change from time to time, every effort was made to obtain flexibility in the grouping of cords with operators and in varying the number of operating positions. Economic considerations, moreover, make it desirable to supply no more equipment in the way of cord circuits for the switchboard than is immediately needed under existing conditions.

The desired flexibility was secured by an arrangement indicated diagrammatically in Figure 2. The cords and keys are wired to terminal strips, and the cord relay equipment is mounted on units also equipped with terminal strips. These units, which accommodate equipment for ten cord circuits, are mounted in the rear of the switchboard immediately below the terminal strips for the cords, and distributing rings are provided so that any relay equipment can be cross-connected to any cord in the keyshelf, either in the same or in a different section. Each section is provided with a position circuit which is wired to terminal strips and to a multi-contact jack below the front panel of the switchboard where it may be connected to a teletypewriter.

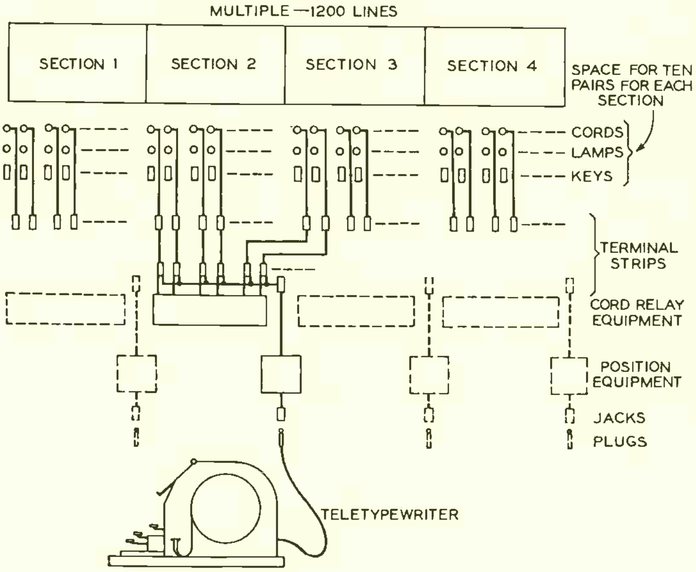


Fig. 2—Schematic of circuit arrangement, showing flexibility obtained by the use of terminal strips and cross-connections

Such an arrangement secures a maximum of flexibility. A sufficient number of sections will be installed originally to accommodate the maximum number of positions that is likely to be needed, but sufficient equipment is installed only for the number of positions and cords needed at the moment. The flexible cross-connection provisions permit the number of cords per operator or the number of positions to be readily changed at any time. No matter how many sections of board are installed, only sufficient relay units need be installed to serve the required number of cords, and the cords employed may be selected from any place along the keyshelf. Each multiple jack has a line lamp associated with it so that incoming calls are indicated at each appearance. This allows any operator to answer any call rather than restricting her to serve a predetermined group of lines.

With such a design, the engineering of various installations is reduced to a very simple process. The number of cords required per operator is determined by the anticipated traffic data. From this information the width of each position is determined. The sum of the positions required to handle the peak load represents the total length of the switchboard and determines the total number of sections required. Cord units are then supplied in the rear of the switchboard to provide for the total number of cords to be equipped. The cords required for each position are then cross-connected to the nearest position circuit. Teletypewriters are moved in front of the various groups of cords and plugged into the jacks for their position circuits. The positions are then ready for operation. Should conditions require a different assignment of cords, the cross-connections may be changed to meet the new requirements, and the teletypewriters moved to new positions along the switchboard.

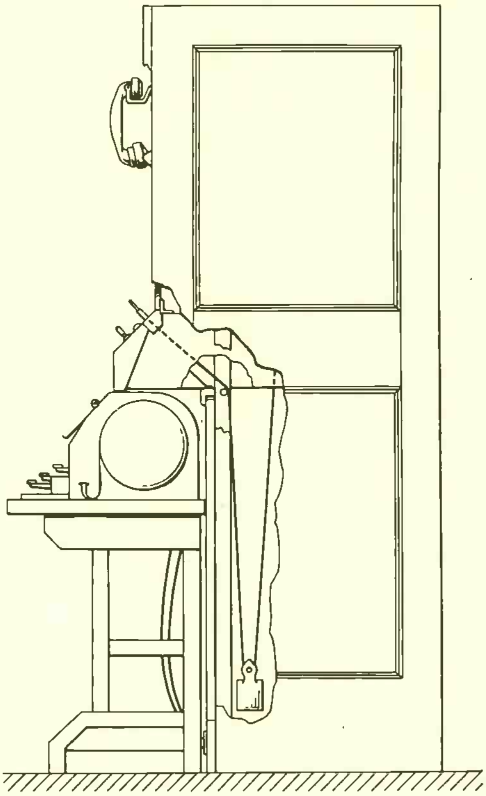
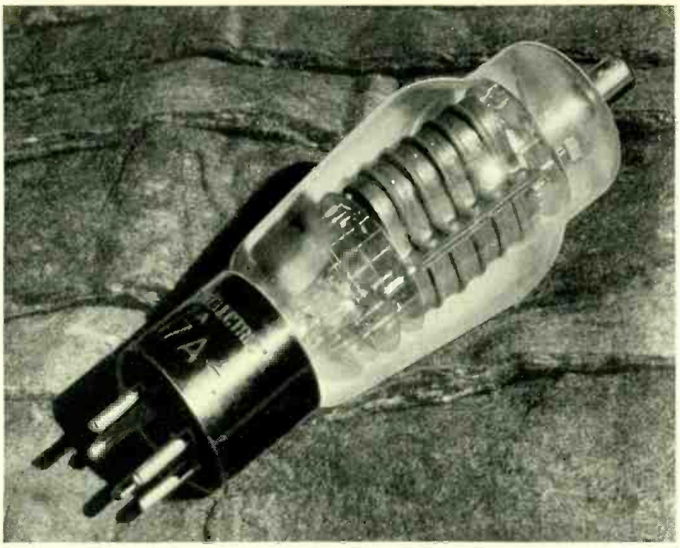


Fig. 3—Cross-section view of the 3A teletypewriter switchboard



The 307A Power Pentode

By E. A. VEAZIE
Vacuum Tube Development

IN the early design of radio-frequency amplifiers the inherent limitations of the three-element vacuum tube introduced many complexities. If reasonable gains were expected, neutralization was necessary to prevent feedback from the output to the input circuit, and the maximum theoretical gain could never be reached because of the losses due to this neutralization. To modulate the output stage of such an amplifier an audio-frequency power level comparable with the radio-frequency power output was required.

As the tube art progressed, four-element tubes were developed in which the outermost grid served as an electrostatic shield between the plate and the control grid. The capacitance between the plate and the control grid was sufficiently reduced by this means to eliminate the need for neutralization. These four-element "screen grid" tubes found wide use as voltage amplifiers at radio frequencies but new difficulties appeared caused by the emission of secondary electrons from both plate and screen grid. If the instantaneous plate voltage dropped below the screen voltage as the plate potential varied, secondary electrons knocked from the plate traveled to the screen. It was therefore necessary to limit the instantaneous plate voltage to values greater than the screen potential to avoid excessive distortion of the signal and the consequent limitation of plate efficiency. Secondary electrons emitted by the screen grid were also a continuous source of trouble, and placed serious limitations on the circuit supplying the screen voltage.

A third grid was added to the screen-grid tube to overcome these limitations, thus producing the pentode. This grid was located between the screen grid and the plate and was originally tied to the cathode within the tube. Its sole function was to prevent the flow of secondary electrons in either direction. Hence it was appropriately called a suppressor grid.

This development satisfactorily overcame the disadvantages of the screen-grid tube while retaining the advantages. These pentodes are characterized by a comparatively high power output at a low plate voltage, and a high gain per stage—thereby effecting economies in plate-voltage supply equipment and in radio-frequency driving power. These two items of themselves would result in a widespread use of this form of tube. On closer examination it is seen that there are still further possibilities contained in this three-grid structure.

If the suppressor grid be disconnected from the cathode, and the radio-frequency output current of the tube be examined as a function of voltages applied to this grid, it will be seen that there is a possibility of using the suppressor for the purposes of modulation. The Western Electric 307A tube, intended for use in mobile transmitters, has been designed to take full advantage of this possibility. Basically this tube is a suppressor grid pentode, but separate leads are provided for each of the three grids, thus permitting the application of any desired voltages to each.

The innermost of these grids, through control of the rate at which electrons leave the cathode, performs functions similar to those of the grid of a triode. The second, or screen grid, is maintained at a fairly high positive potential, and provides the principal accelerating force tending to draw electrons out from the cathode. Because of its open structure, however, practically all the electrons pass through this grid into the space beyond. The suppressor grid plays only a small part in controlling the number of electrons drawn from the cathode, but its potential determines the way in which the total current divides between the screen grid and the plate. When its potential is zero, practically all electrons passing through the screen have sufficient velocity to overcome the retarding effect of the suppressor and continue on to the plate. As the suppressor is carried more and more negative, the fraction of the electrons turned back increases, and consequently the plate current decreases. In fact it is possible to reduce the plate current essentially to zero by making the suppressor grid sufficiently negative.

Characteristic curves for the 307A tube are shown in Figures 1 and 2. In Figure 1 the plate current is shown as a function of the plate voltage for several values of control-grid voltage,

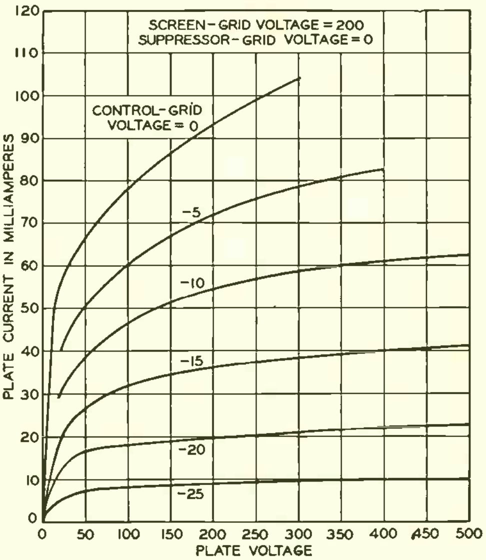


Fig. 1—Static characteristics of 307A tube showing plate current as a function of plate potential—screen-grid potential two hundred volts and suppressor-grid potential zero

the potential of the screen-grid and suppressor-grid being held fixed. The smoothness of these curves in the region where the plate voltage approximately equals the screen-grid voltage indicates the complete effectiveness of the suppressor grid in preventing flow of secondary electrons. The curves of Figure 2 show the plate current as a function of control-grid voltage for several suppressor-grid voltages with plate and screen potentials constant. These curves indicate the parts played by the control and suppressor grids in controlling the current to the plate.

When the tube is used as a modulating amplifier, a radio-frequency input is applied to the control grid. This results in corresponding radio-frequency variations in the plate current. The amplitude of these variations in current and the magnitude of the plate circuit load determine the high-frequency power output of the tube. Under these conditions the amplitude of the current variations is reduced as the voltage on the suppressor grid is made more negative. Thus the high-frequency output power of the tube depends directly on the potential of the suppressor grid.

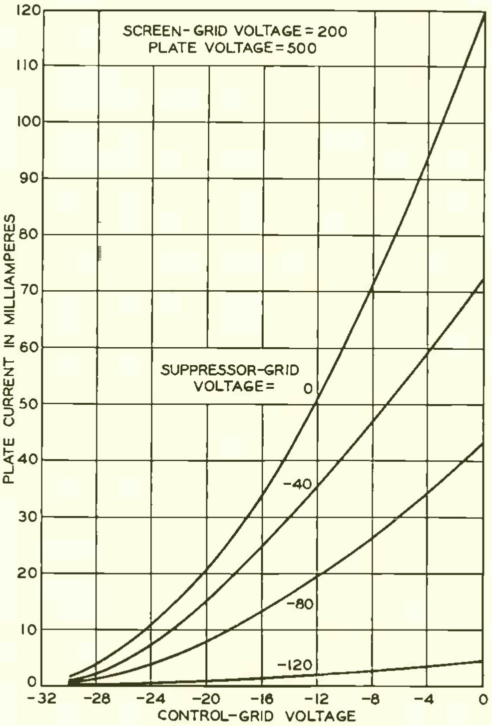


Fig. 2—Relation between plate current and control grid potential of the 307A tube for a plate potential of five hundred volts and a screen-grid potential of two hundred volts

It is this dependence of the high-frequency output on the suppressor potential that makes it possible to use the tube as a modulator. In an ideal amplitude modulator, the high-frequency current in the load is a linear function of the modulating potential. In the pentode this requires careful mechanical design of the grid structures. How close the 307A tube comes to meeting the ideal can well be judged from the curve in Figure 3 which shows the dynamic characteristics for a plate potential of 500 volts.

For radio telephone use, under the conditions for Figure 3, the suppressor might suitably be biased at minus 50 volts. A swing of plus and minus 50 volts from this value causes variation of the load current from approximately double the normal value to practically zero. It is unnecessary to provide a low-frequency power amplifier between the microphone and the modulator tube because a peak voltage of about this amplitude can be obtained directly from a handset with a suitable transformer.

The greatest advantage of the 307A tube over other types lies in the fact that the output may be modulated almost completely by varying the potential of an element which, being continuously negative with respect to the cathode, does not draw space current.

The 307A tube is also suitable for

use as an oscillator. A complete transmitter may be built around two such tubes, with one providing the high-frequency power necessary for driving, and the other serving as a modulator. The relative simplicity of such a circuit, with a minimum number of tubes and associated circuit elements, makes it particularly adapted to transmitters for aircraft, where both small size and light weight are factors of major importance.

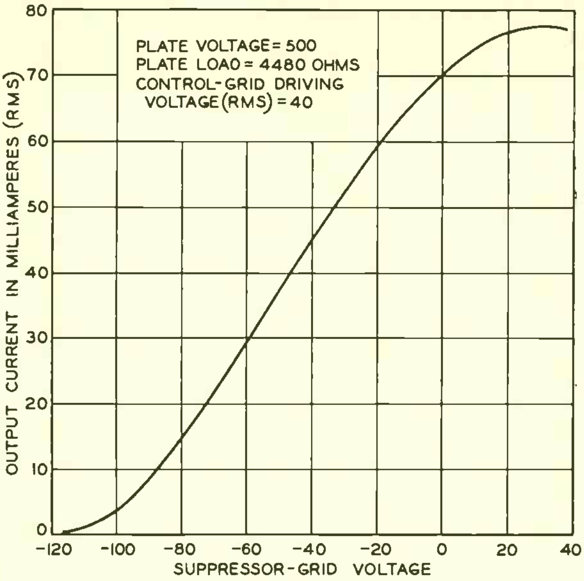
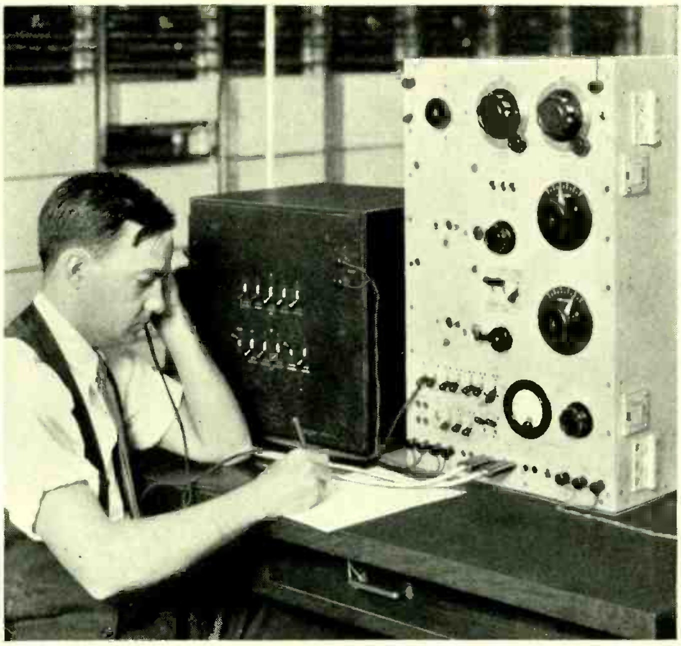


Fig. 3—Dynamic characteristics of 307A tube for a plate potential of 500 volts

The use of a filamentary type of cathode in the 307A tube, rather than an indirectly heated cathode, makes possible important operating economies. Because the cathode used requires only a very few seconds to reach operating temperature, the transmitter may be completely shut down when not in use, but is almost instantly available when needed. Similar transmitter performance could be obtained with equipotential cathode tubes only by maintaining the cathode at close to normal operating temperature during idle periods. Both supply power and useful tube life are thus conserved by use of the filamentary cathode.

* * *

Another installation of harbor-craft radio telephone service has recently been made in the Philadelphia area. This system, which went into operation early last autumn, is operated by the Atlantic Communications Corporation. It is employed chiefly for dispatching tow boats—used in considerable numbers for transporting tankers to and from the refineries along the Schuylkill. It differs from other harbor-craft systems in employing an ultra-high frequency and in incorporating voice-control of the carrier.



Measuring Delay on Picture-Transmission Circuits

By E. P. FELCH
Telephone Apparatus Development

ELECTRIC impulses require a finite time for their transmission over any ordinary circuit, and the time interval from the instant a signal leaves the sending end to the instant it arrives at the receiving end is known as the delay of the circuit. This effect is illustrated by the oscillogram of Figure 1, where the upper graph shows a transmitted pulse of a single frequency, and the lower graph shows the same pulse as received. If the delay were the same for all frequencies, it would have no detrimental effect on transmission, but actually it varies with frequency. As a result some frequencies are delayed more than others. This results in a distortion of the received signal, which is known as delay distortion.

During the development of transmission facilities for the new telephotograph system, it was found that stringent requirements for delay distortion would have to be met, and as a result that delay equalizers would have to be employed. The design of the necessary equalizers could not be carried out, however, until the delay characteristics of typical circuits had been accurately determined. Delay measurements are not new. They were made extensively with a laboratory set in connection with the early telephotography undertaken by the Bell System, and were also made over an 1800-mile stretch of experimental cable circuit arranged to meet the higher standards of the new telephotograph system. It was evident, however, that for many of the measurements that had to be made, more refined apparatus would be required. A new measuring set was consequently developed which employed the arrangement described below. Modifications were also made in the older set, however, which greatly improved its accuracy, and it was used in the final lining-up of the new picture-transmission system, in measurements centering at New York City.

An obvious method of measuring delay would be to transmit a short pulse of constant frequency around a loop, and to record both sent and received signals on the same oscillograph record as in Figure 1. The time between the beginning of the transmitted and received pulses would be the delay. There are two reasons, however, why such a comparatively simple method is not suitable. In the first place it will be noted from Figure 1 that an appreciable time is required for the received signal to build up to its full value. Moreover, the correct time of arrival of the received wave is not the instant when the first disturbance is noted at the receiving end, and there is no way to determine from the graph just what is the correct instant for the beginning of the received signal. Besides this difficulty, it is necessary to measure the delay to ten microseconds, while the oscillograms cannot be read to better than a thousandth of a second.

Distortionless transmission of electrical signals requires the preservation of the shape of the envelope of the signal impulses. This requirement is fulfilled when the "envelope delay," which is defined as the rate of change in phase shift with respect to frequency, is constant over the band of transmitted frequencies. In other words, if B is the phase shift at frequency F, and B' at some slightly higher frequency F', then envelope delay is the value expressed by the quotient $(B'-B)/(F'-F)$ as the difference between F and F' approaches zero.

Practically, in measuring envelope delay, it is not necessary that the difference between F' and F be vanishingly small. Where the two frequencies are separated a finite amount, the quotient of $B'-B/F'-F$ will give the envelope delay for the average of the two frequencies very closely under ordinary conditions, and if the delay in seconds is proportional to the frequency, $B'-B/F'-F$ gives exactly the envelope delay for the average frequency. By taking advantage of this

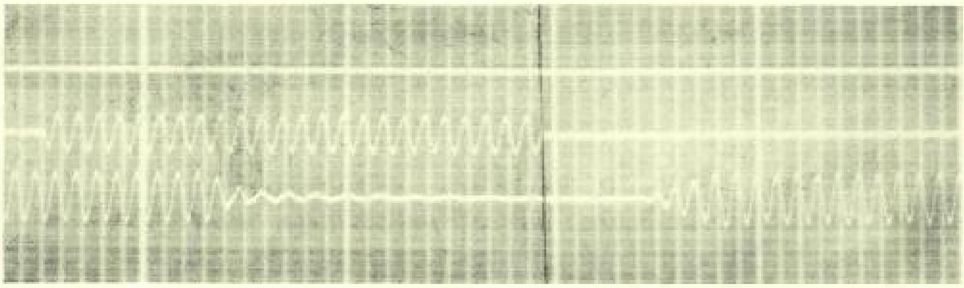


Fig. 1—A signal requires a definite time for its transmission over a circuit, and the time from its start at the sending end (shown in upper track) to its arrival at the receiving end (shown in lower track) is known as the delay of the circuit

relationship it is possible to obtain the delay characteristics of a circuit by measuring the difference in phase shift for two frequencies separated by a small but finite amount.

This could be done either by measuring a phase change for a fixed frequency interval, or by measuring the change in frequency required to produce a definite phase change. The first would require a fixed frequency source and accurate adjustable phase shifters, while the second would require a method of establishing fixed phase intervals, and an adjustable frequency source. The latter system was adopted because it would require only high-stability oscillators, which are comparatively easy to obtain. The phase shift was determined by employing a bridge circuit as shown in Figure 2. The output from an adjustable oscillator is divided, part passing over the line and part through an attenuator which produces no delay. This attenuator is adjusted to give a loss exactly equal to that of the line. The line, however, in addition to the loss it produces, causes a phase shift, so that the currents at the two sides of the bridge are equal in magnitude but differ in phase. The frequency of the oscillator is then adjusted until the phase shift is an even number of cycles. Under these conditions the bridge will balance, and thus a zero reading on the indicator of the bridge shows that the phase shift for the frequency of the oscillator is an even number of cycles.

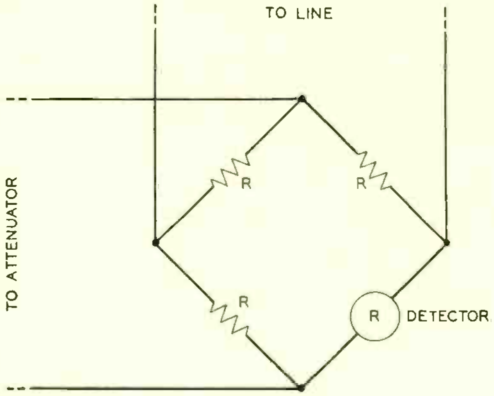


Fig. 2—A bridge circuit was employed to determine when the phase shift in the line amounted to an even number of cycles

With this frequency determined, the frequency of the oscillator is gradually increased. The bridge at once goes out of balance and does not again become balanced until the phase shift has increased by one complete cycle. This second balance point gives another frequency, and the difference between these two frequencies, ΔF, is the frequency change required to produce an increase in phase shift of one cycle.

The phase shift is known accurately because of the high precision with which the balance position of the bridge can be determined. The frequency is measured by combining the two frequencies on a single oscillograph string and measuring the dur-

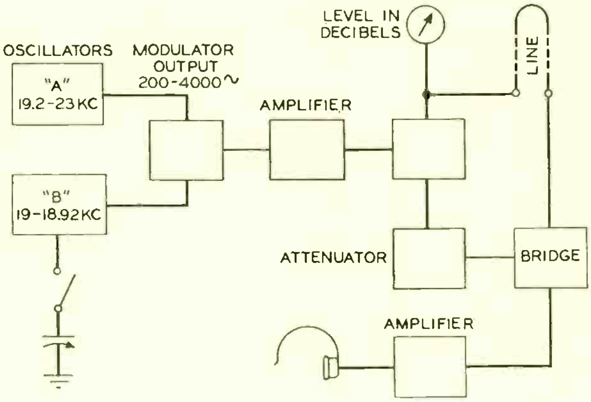


Fig. 3—Simplified schematic of apparatus which is used for measuring envelope delay

ation of the beat-frequency cycle by comparison with hundred-cycle timing lines obtained from an auxiliary frequency standard. By this method ΔF can be determined to about a thousandth of a cycle. The delay measurements were required to about ten microseconds, and a rough calculation showed that to obtain this precision ΔF would have to be about fifty cycles, which corresponds to a delay of about five cycles. For convenience in these measurements, the unit of delay was taken as half-cycles, which were called π-points, since a half cycle corresponds to π radians.

As finally used for measurements, the apparatus was as indicated in Figure 3. Oscillator A determines the frequency at which the particular delay measurement is to be made, while oscillator B gives the frequency interval for which the change in phase shift is to be measured. The outputs of these two oscillators are combined in the modulator, making possible output frequencies from two hundred to four thousand cycles, which more than cover the band width required for telephotography. The rest of the circuit, employed for obtaining a definite value of difference in phase shift, is essentially like that of Figure 2. Oscillator B has associated with it an accurately calibrated air condenser which allows its frequency to be known from the condenser setting.

To illustrate the method of operation, it may be assumed that delay is to be measured at 1200 cycles. Oscillator A might be set to 20.1 kc. and oscillator B to 18.9. The bridge would probably not be in balance at these settings but a slight adjustment of oscillator A would bring it into balance. After this, the frequency of A would be slowly increased until the next balance point was reached. The difference between these two frequencies would give the ΔF for a difference in phase shift of two π-points. Having determined this value, the condenser of oscillator B is set for an increase of about fifty cycles and then adjusted over a small range to secure another balance point on the bridge. This gives two frequencies causing a difference in phase shift of a whole number of π-points. The actual number of π-points is found by dividing twice the difference between the two frequencies, F_2-F_1, by ΔF determined previously, and this number of π-points divided by $2(F_2-F_1)$ gives the envelope delay of a frequency half way between F_2 and F_1.

With such an arrangement readings may be made very rapidly. The work was facilitated by preparing graphs from which the envelope delay could be read directly for a given number of π-points and frequency differences. The apparatus as finally arranged is shown at the right in the photograph at the head of this article. Since the completion of the development tests, the experimental model has been turned over to the Long Lines Department for tests on the system.

Except for very short circuits most of the measurements were made at night because of the rapid fluctuations encountered during the daylight hours due to the effects of temperature on phase angle. Stability was usually obtained about midnight, and from then until daybreak measurements were made continuously.

An Adjustable Precision Standard of Phase Difference

By G. B. ENGELHARDT
Carrier Transmission Research

MEASUREMENTS of phase shift are of major importance in the development of communication systems. In general, any network or piece of apparatus inserted in a circuit produces a phase shift, and it is becoming increasingly important in many recent developments to know its magnitude. A variety of methods are used for making such measurements. These frequently employ calibrated phase shifters operating at a fixed low frequency. For calibrating these phase shifters in the carrier research laboratory, an adjustable standard of phase difference has recently been built. While maintaining a high degree of precision, this standard is simple in construction and quick in operation. The photograph at the head of this article shows the standard being used to calibrate the two 400-cycle phase shifters, shown at the top of the relay rack on the right.

In brief, the apparatus provides two voltages of equal frequency and amplitude which may be given any desired phase difference by shifting the phase of one of the sources. A simplified schematic of the calibrating circuit is shown in Figure 1. The adjustable source is first set to equal level and phase opposition with the reference source as judged by a null indication on the detector. The phase shifting device to be calibrated is then inserted in the circuit of the reference source and adjusted until a null reading is again obtained on the detector. An accompanying change in the setting of the resistance attenuators will generally be required to compensate for the loss of the phase shifting device. This gives the setting of the phase shifting device under test for zero phase shift. Other points may be determined by setting the device to be calibrated to produce varying degrees of phase shift and changing the adjustable source to produce a null reading. The reading of the dial then gives the phase shift of the device.

The constant-frequency sources are two similar alternating-current generators having rigidly coupled rotors. They are mounted behind the front panel of the set as shown at the left in Figure 2. These machines also have d-c. windings which furnish their driving power, and rheostats on the front of the panel—at the right of Figure 2—permit the speed to be set to any desired value. The stator of one of the alternators is rigidly fastened to the base, but that of the other is mounted on ball bearings, so that by means of a worm drive—at the extreme left of Figure 2—it may be rotated around its axis with respect to the fixed stator. Backlash is prevented by a weight attached to the movable stator which preloads the gears in one direction. The slow-speed shaft of the worm drive connects to a large knob and dial on the front of the panel.

The machine utilizes the two-alternator method of obtaining known phase shift. Because of the linear relationship existing between electrical degrees of phase shift of the output and the mechanical degrees of rotation of the stator, the dial may be etched with a linear scale reading directly the electrical phase difference between the output of the two machines. This relationship holds true accurately regardless of irregularities in the machines such as uneven flux distribution or unequally placed slots. The effect of such inequalities is only to introduce other frequencies in the output, but the desired frequency is always present, and all of the other frequencies are eliminated by the use of filters.

The speed of the alternators may be adjusted to give any frequency from fifty to one thousand cycles per second. The frequency is continuously compared with a stand-

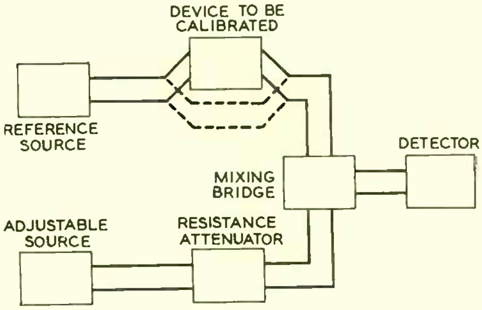


Fig. 1—Simplified schematic of phase shift calibrating circuit

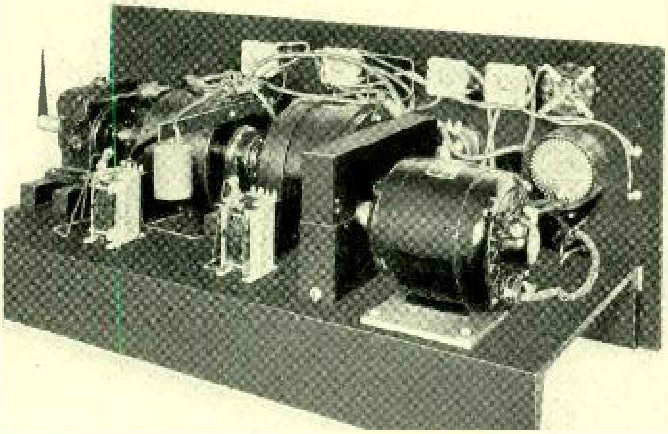


Fig. 2—Rear view of calibrating apparatus

ard frequency of the desired value by a neon tube. This tube is connected between the standard frequency source and the output of one of the alternators. If the frequency of the alternator differs from that of the standard, the phase of the two sources will alternately aid and oppose, causing the lamp to flash on and off. A flashing lamp, therefore, indicates a difference in frequency between the generators and the standard, while a steady lamp which is either lighted or out indicates equality of frequency.

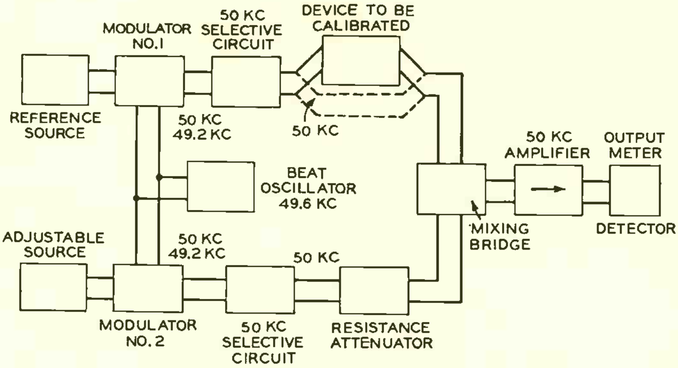
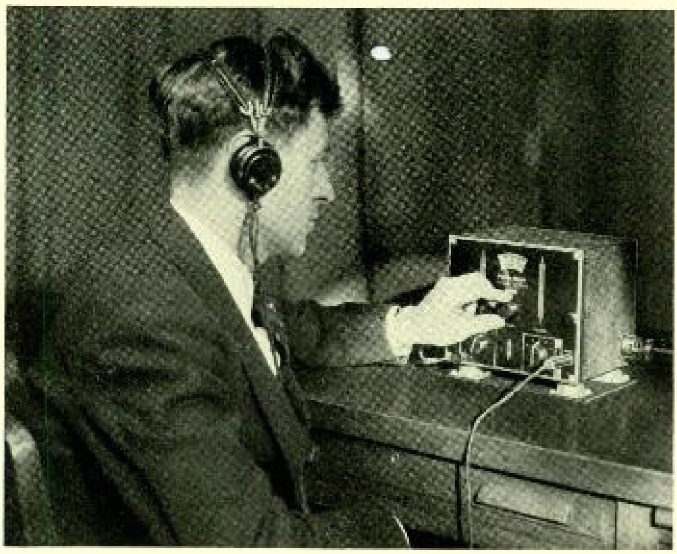


Fig. 3—Circuit arrangement for measuring phase shift at fifty kilocycles

Since four hundred cycles per second is commonly used for calibrating in the carrier research laboratory, provision has been made for procuring high stability at this frequency. This is accomplished by employing a small synchronous motor, which maintains the generators at such a speed that the output is four hundred cycles if the power supply is sixty cycles. Inasmuch as the a-c. supply in New York City is held within very close frequency limits, this gives a fairly accurate output of four hundred cycles. If a frequency other than four hundred cycles is desired, the synchronous motor is disconnected and the alternators are driven at the desired speed by their self-contained direct-current windings.

While the upper frequency of the generators is one thousand cycles, the set may be employed for calibrations at higher frequencies by heterodyning the outputs of the two generators with a common beat oscillator. Such an arrangement for calibrating at fifty kilocycles is shown in Figure 3. Under these conditions, the synchronous motor is used, and thus the output of the two alternators is at four hundred cycles. The common beat oscillator has a frequency of 49.6 kc., which gives a fifty-kc. frequency for the upper sideband; other modulation products are eliminated in the selective circuits, which may either be inserted in the separate branches as shown, or included in the common branch following the mixing bridge. A resistance attenuator, which has a known phase shift at the test frequency, is employed to equalize the amplitude of the outputs at the mixing bridge before the final adjustment for phase shift is made.



A Radio Receiver for the Private Plane

By J. E. CORBIN

Radio Development

THE radio needs of the private plane differ from those of transport and mail planes. In the first place space is generally more limited and weight must be more carefully considered, but besides these physical restrictions the interests and motives of the pilot are different. Commercial pilots fly the same routes day after day, and their chief objective is to reach their terminals safely and on time. The private flyer, on the other hand, generally has a more lenient schedule. While he may fly established air lanes to a large extent, there is usually more freedom to his movements and more of the element of pleasure in his objectives. With a view to meeting these somewhat special needs of the private flyer, the Laboratories have developed a new radio receiver which will receive not only the beacon and weather bands, but the broadcast band as well.

This new receiver, known as the 17A, measures barely 7¾ inches each way and weighs but eleven pounds. It employs only three tubes and may be operated with batteries alone, although in normal use a dynamotor, run from a 12-volt storage battery, will generally be employed to supply 200 volts for the plates. The outside appearance of the receiver is shown in the photograph at the head of this article. There are three controls on the front. The one in the center is for tuning, and the illuminated dial immediately above it has two scales, one for the beacon and weather band from 200 to 400 kc. and the other for the broadcast band from 550 to 1500 kc. The knob at the lower left is a transfer switch to change from one band to the other, and that at the lower right is the volume control. Power connections are made through the multi-contact jack and plug just

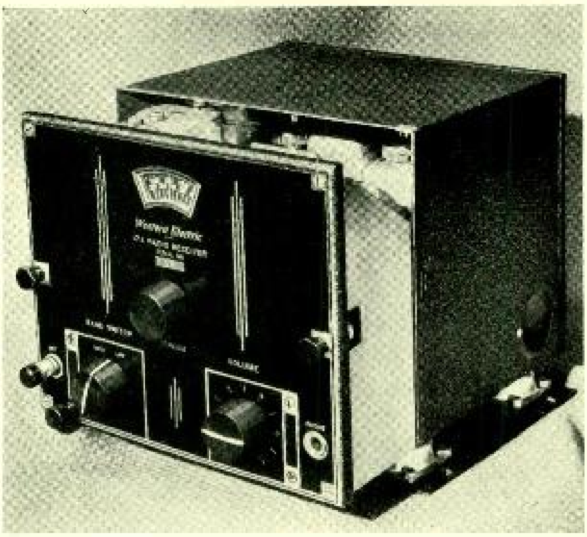


Fig. 1—The 17A radio receiver, showing the metal chassis, the front panel, and the shockproof mounting which protects the apparatus from injury

visible at the rear of the right side.

All apparatus is mounted on a metal chassis, which carries the front panel and is arranged to slide into the outer case as shown in Figure 1. To withdraw the chassis it is necessary only to turn the two small knobs, one on each side of the front. The case, in turn, rests on a shockproof base. It is designed to be mounted close to the pilot where he can manipulate the controls directly. The compact arrangement of the apparatus is indicated in Figure 2 which shows the chassis removed from the case.

The small size of the set is no measure of its performance. The long experience of the Laboratories in designing radio apparatus for all types of service has made it possible to obtain the required selectivity and sensitivity combined with liberal power output and good quality of signal in a very small set. A special feature is the varistor, which serves to reduce the intensity of static crashes exceeding a certain value. This element, completely contained in a cylinder only three quarters of an inch in diameter and a quarter of an inch high, is shunted across the output of the final amplifier through a condenser. At normal operating voltages it has a very high impedance and thus little effect on the output voltage. For voltages above the normal range, however, its resistance drops sharply and essentially short-circuits the output. Its action is instantaneous, and the lowered resistance lasts only for the duration of the high voltage disturbance, which may be only a few milli-seconds. The short-circuiting of the output for

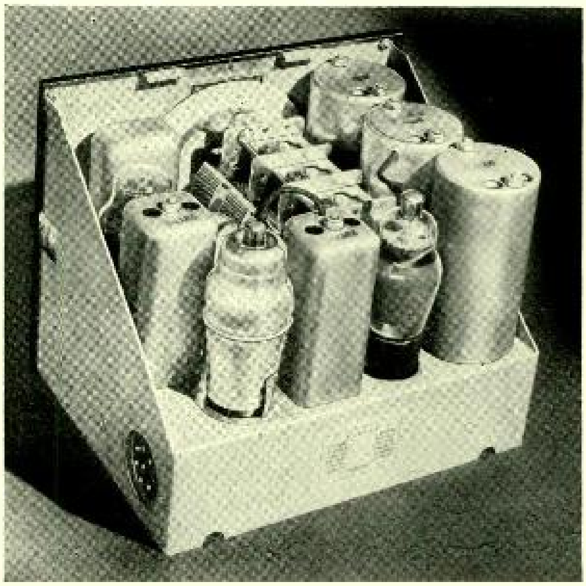


Fig. 2—All wiring and minor circuit elements are mounted on the underside of the chassis—the upper surface carrying only the tubes, condensers, and coils

these very brief periods has little effect on the intelligibility of the signals being received except under very severe conditions.

The receiver employs a superheterodyne circuit as indicated by the simplified schematic of Figure 3. There is first a band-pass preselector. then a converter stage, with one tube combining the function of oscillator and first detector; then an intermediate stage which in one tube unites an intermediate-frequency amplifier, a second detector, and a reflexed stage of audio-frequency amplification; and finally a power output stage which utilizes the third tube and the varistor. The circuit to the right of the preselector remains the same for both beacon and broadcast bands. The action of the transfer switch changes the coils in the preselector and oscillator. The preselector circuit is an important factor in increasing the selectivity of the receiver and in giving a high signal step-up from antenna to grid of the first tube.

The overall "close up" selectivity of the receiver is shown in Figure 4. The selective action of the preselector has been made to provide adequate suppression of image frequencies and to reduce interfering signals of this character to so low a value that cross-talk in the tubes is negligible. The width of the voice band is about 2000 cycles. In the interest of high selectivity for beacon signals spaced only 6 kc. apart, the voice band must be kept moderately narrow, but it has been made wide enough to give good intelligibility. The sensitivity, shown in Figure 5, is very uniform over the bands and is higher than is obtained with many four and five tube sets. Signal strengths as low as 15 microvolts per meter may be readily picked

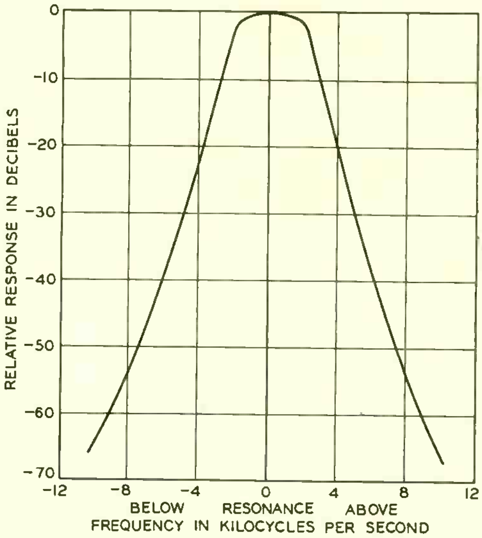


Fig. 4—Overall selectivity of the beacon and weather band of the 17A receiver

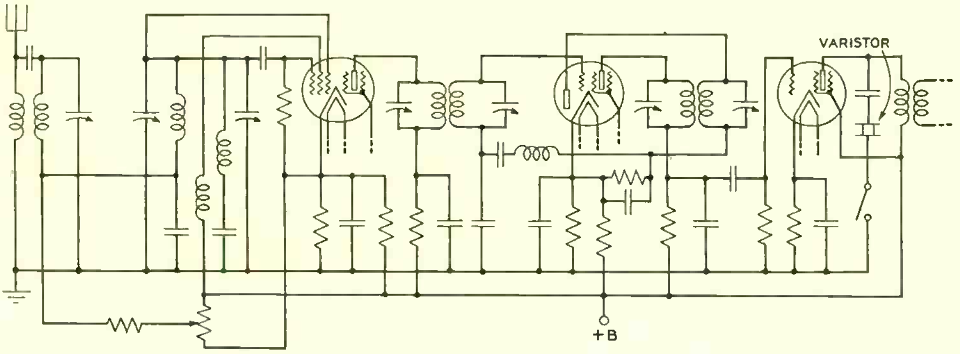


Fig. 3—Simplified schematic of the 17A radio receiver

up with this radio receiver using an antenna of the usual aircraft type.

Although this receiver was developed primarily for the private flyer, it also serves admirably as an emergency receiver for commercial planes, because it may be completely battery operated with small current drain. The filaments are normally arranged for connection to a twelve-volt battery, but a series resistance is in the circuit, and if the battery connection is made inside the resistance, full heater current may be obtained from a six-volt supply. A ninety-volt B battery may be used under these conditions for plate voltage. While the set is designed for a normal supply of two hundred volts, operation on the lower voltage does not seriously impair the sensitivity or power output. The peak output at full voltage is one watt, and since sixty milliwatts is adequate for headset reception there is an ample reserve of power for these emergency conditions.

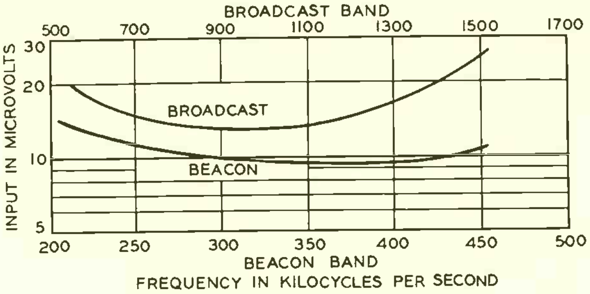
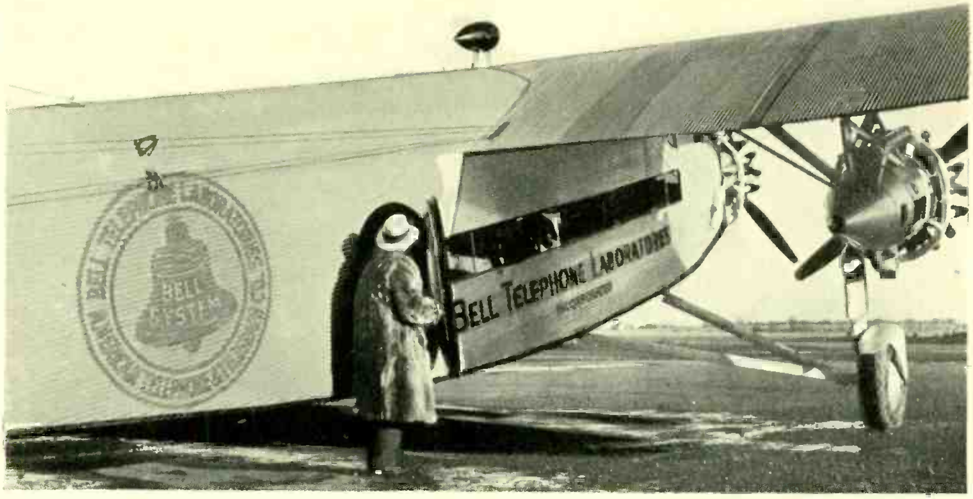


Fig. 5—Sensitivity curves of both beacon and broadcast bands of the 17A radio receiver



A Radio Compass for Aircraft

By C. B. AIKEN
Radio Development

VESSELS at sea have long used radio compasses to determine the direction of shore stations or of other vessels. Careful operation is required to secure accurate bearings, however, and the apparatus itself is rather heavy and bulky, so that such compasses have been employed only to a very limited extent by aircraft. Recently, however, Bell Laboratories made available an easily operated radio compass for use primarily with Western Electric marine radio telephone equipment.* Recognizing the possibilities of wider usefulness for this very effective visual-indicator instrument, they have incorporated some of the basic principles in a smaller and lighter weight set for use as a radio compass for aircraft. It consists of a loop assembly and a compass control unit, and is designed for use in conjunction with the 17A radio receiver.*

This receiver is a sensitive three-tube set housed in a small metal cabinet measuring about eight inches each way. It can receive either the broadcast band, from 550 to 1500 kc., or the beacon and weather band, from 200 to 400 kc., and thus when used with the compass equipment may serve the double duty of giving entertainment and assisting in the navigation of the ship. A small switch on the front of the cabinet makes the change from one band to the other.

This new radio compass includes two loops, a compass control unit, similar in size to the 17A receiver, an output filter unit, and an indicating meter for installation on the instrument panel. The control unit has three tuning ranges, which with the two

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*Record, *June*, 1935, *p.* 300.

*Record, *p.* 161 *of this issue.*

loops permit the pilot to obtain bearings on any of the beacon or airway weather stations as well as on any broadcast stations. He may use the apparatus to determine the direction of appropriate station, and thus ascertain his own position by cross bearings, or he may use it as a "homing" device to fly directly toward a station. The circuit arrangement permits him to listen to a broadcast program at the same time he is determining a bearing on the station from which the signal is being received.

The loop system, which is mounted in a streamlined housing to reduce wind resistance, is designed for mounting either above or below the fuselage, and is connected to the compass control unit through a shielded cable. A hand wheel inside the cabin is employed to turn the loop, and a dial indicates the angle the loop makes with the axis of the plane. As with other radio compasses, the principle involved is that a loop antenna gives maximum output when the radio waves are traveling in the plane of the loop, and minimum when they are perpendicular to the loop.

A loop by itself determines only the line of direction. Thus it might, for example, indicate that the waves were traveling in a north and south line, but would not determine whether they were coming from the north or south. To determine the "sense" of the direction, as it is called, a non-directional antenna is required in addition to the loop. For this purpose the regular antenna of the plane may be used, or a short simple antenna may be substituted.

Extensive training is not required for the operation of the compass. A two-position key, furnished as part of the equipment and mounted over the antenna binding post of the 17A receiver, is used to connect the receiver either to the non-directional antenna or to the compass control unit. In taking a bearing, this key is first thrown to the antenna position and the station on which a bearing is to be taken is tuned in on the receiver as usual. The key is then thrown to the compass position, and the tuning knob on the compass control unit turned until a maximum signal is heard. The position of the meter pointer then indicates whether the loop is at right angles to the direction of the station, or, if not, indicates the direction in which the hand wheel should be turned. A low-frequency potential, used to operate the indicating meter, is superimposed on the signal from the loop antenna by the compass circuit, and gives a low-pitched tone signal which is heard at all times except when the loop is at right angles to the direction of arrival of the radio waves. This tone serves as an auxiliary indication of the position of the loop relative to the direction of the incoming radio waves.

To obtain a bearing, the hand wheel of the loop is turned in the direction from the needle toward mid-scale until the pointer of the meter comes to zero. The superimposed tone disappears at the same time, and the angle of the radio station with respect to the axis of the ship can be read directly from the dial above the hand wheel. As long as the loop is properly oriented with respect to the radio station the program will be heard without any superimposed tone, but as soon as the loop is off the bearing, the tone will come in. When the compass is used as a homing device, the dial on the hand wheel is set at zero and the plane turned until the meter pointer comes to zero and the tone disappears, when the plane will be flying directly toward the radio station. As soon as the plane deviates from this direction the meter will be deflected and the tone will be heard. If when turning the hand wheel the pointer moves in the opposite direction, the hand wheel is turned further in the same direction. This will cause the pointer first to move still farther from zero and then finally return to zero, when the true bearing may be read from the scale. Because of the visual indicator, continuous monitoring with head phones is not necessary to the operation of the compass.

One of the major advantages of this type of compass is the visual indication made possible by the use of a non-directional antenna and a loop pick-up in combination. During rainstorms, however, the straight antenna may introduce considerably more static than is effective in the loop alone. To make it possible to eliminate this, there is a two-position switch on the compass control unit, which permits two methods of determining a bearing. In one position of the switch, the operation is a visual function as just described. With the switch in the other position, the non-directional antenna is not employed and the superimposed potential for the operation of the meter is also omitted. With this latter method, the direction of the radio station is indicated aurally only by the disappearance of the signal when the loop is at right angles to it. When the compass is being used as a "homing" device under these conditions the loop may be turned away from the "null" for short intervals to hear weather announcements or broadcast programs. The only advantage of this alternative method, which does not employ the non-directional antenna, is that in the presence of certain types of static, reception on the loop alone is sometimes quieter, and the course may be flown and messages received with less interference than might be effective on the visual indicator option. For the most part, however, the very definite advantages of the right and left visual indicator (as compared with the "null" signal in headphones) and of the continuous "sense" indication (as compared with the 180 degree ambiguity of the loop collector by itself) are expected to be of such importance that the alternative method will be resorted to only infrequently.

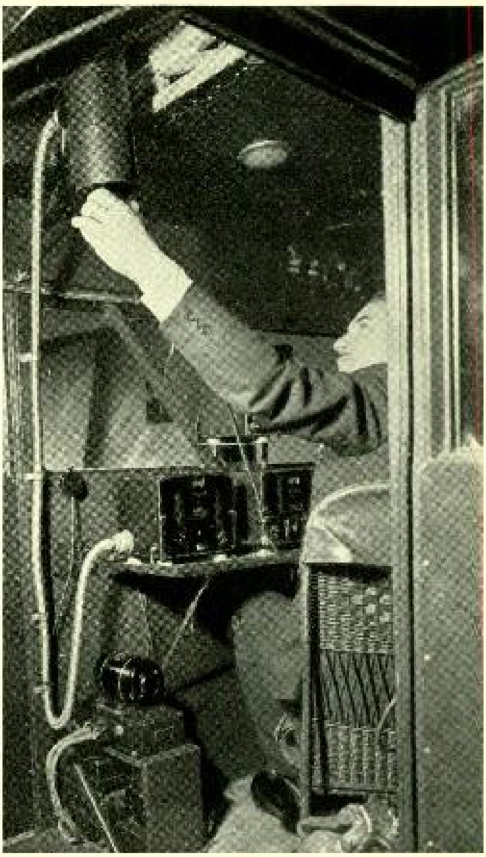
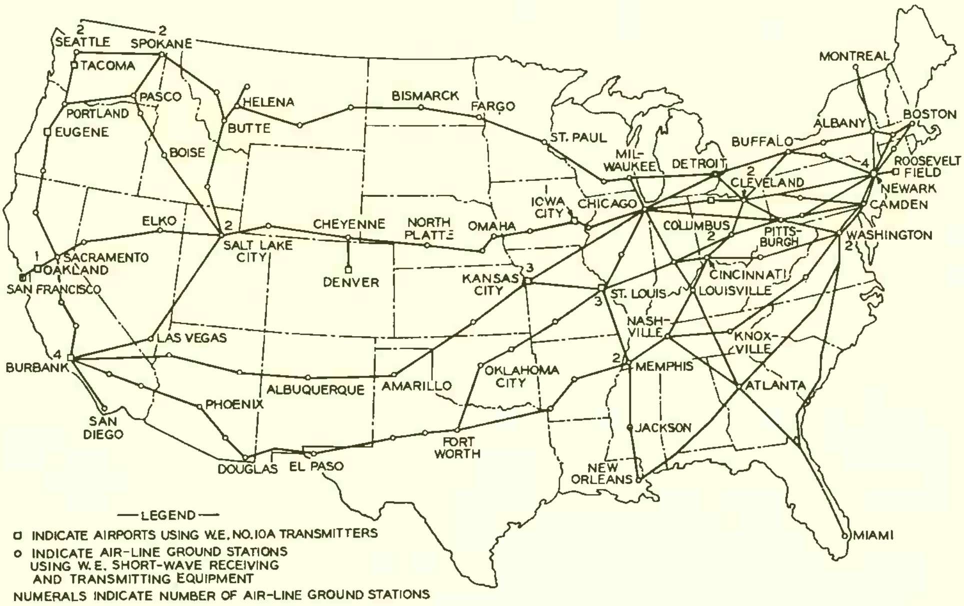


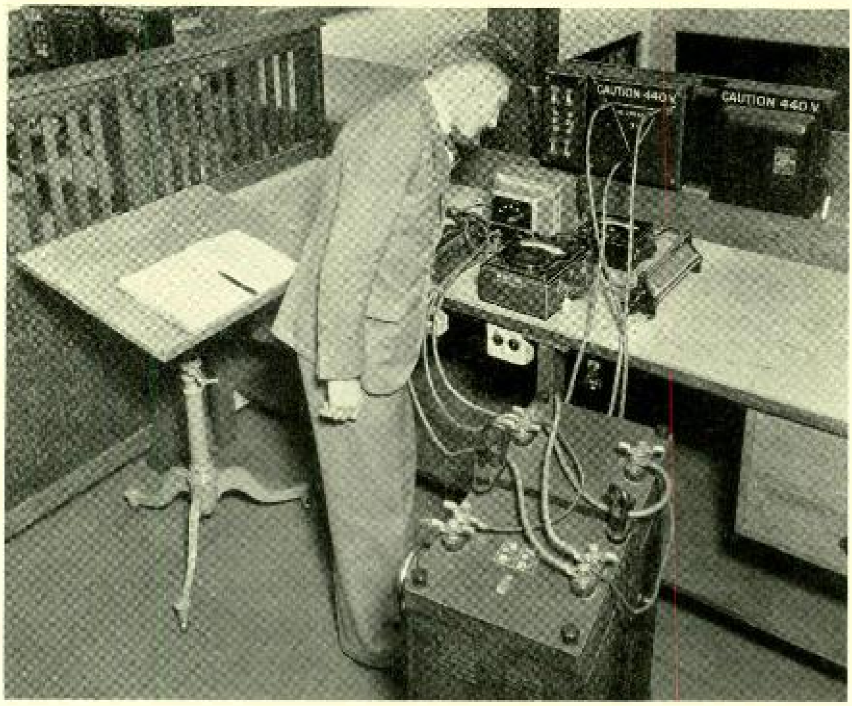
Fig. 1—Capt. A. R. Brooks demonstrates the use of the new radio compass in the Laboratories' Fairchild plane

Several models of this radio compass have been built and are being tried out experimentally. Such an installation in the Laboratories' Fairchild plane is shown in Figure 1. Here the compass unit is at the left and the 17A receiver—similar to it in size and appearance—is at the right. Below is the power supply unit, and above is the control wheel of the loop. In the photograph at the head of this article the loop antenna in its streamlined housing can be seen installed on the Laboratories' Ford plane.



The rapid extension of commercial air lines in recent years is to a very large extent a tribute to the skill, ingenuity, and far-sightedness of American airplane designers. Even the finest type of modern plane, however, would not alone provide adequate safety in long flights. Ready and reliable communication between plane and ground is essential; and this need is being met by the rapidly increasing use of radio communication. In this field the Western Electric Company has taken a leading part.

The widespread use of radio apparatus designed by the Laboratories is partially indicated by the map which shows the location of airport and air-line ground stations that employ Western Electric equipment. It does not indicate, however, the extensive use of Western Electric apparatus in the planes themselves, where radio serves for two-way communication with the ground, and for the reception of weather reports and beacon signals.



Transformer Testing Laboratory

By R. W. DeMONTE
Transmission Apparatus Development

TRANSFORMERS and retardation coils have been used in telephone circuits for several decades, and extensive investigations have been made in the Laboratories of their design and performance at voice and carrier frequencies. There were few uses for power transformers in apparatus developed by the Laboratories, however, until the introduction of the electronic rectifier and the heater-type vacuum tube enabled communication apparatus to draw its energy directly from alternating-current mains. With this change in the method of supplying power the situation has rapidly altered; small power transformers are now required in large numbers for these and other purposes, as well as retardation coils for the filters which suppress the ripple in the output of the rectifiers.

The development of these transformers and retardation coils requires laboratory facilities for verifying design, for determining behavior under load conditions, and for a variety of miscellaneous tests. To provide more adequately for these needs, floor space was recently made available in the West Street building. Part of it is utilized for power-supply apparatus and for a work bench for making miscellaneous mechanical adjustments, but the major part of the space is divided into eight laboratory compartments as indicated in perspective plan shown in Figure 2. They vary in

Fig. 1—The transformer with its control panel, at the right of the main switchboard, is enclosed as a matter of safety

size from 38 to 110 square feet, and to some extent these areas are arranged with certain specific tests in view.

The six compartments in the north end of the room are shown in Figure 3, and the other two are similar in general arrangement and equipment. Each is surrounded with a five-foot fence with a gate in the corridor side, and each has a laboratory bench covered with transite to reduce the fire hazard, and a writing stand for the engineer's notebook. The floors are covered with rubber matting, and as an additional precaution safety buttons are installed in each compartment by which the entire power supply of the laboratory may be immediately interrupted. Power panels and outlet boxes are also provided in each compartment to make the various types of power supplies readily available to the engineers.

The main switchboard for the transformer laboratory is shown in Figure 1, and in Figure 4 is given a simplified schematic diagram indicating the various types of power available and how they are secured. The main source of supply is a three-phase, 220-volt, 60-cycle circuit feeding through the main circuit breaker, which may be tripped by the safety switches in

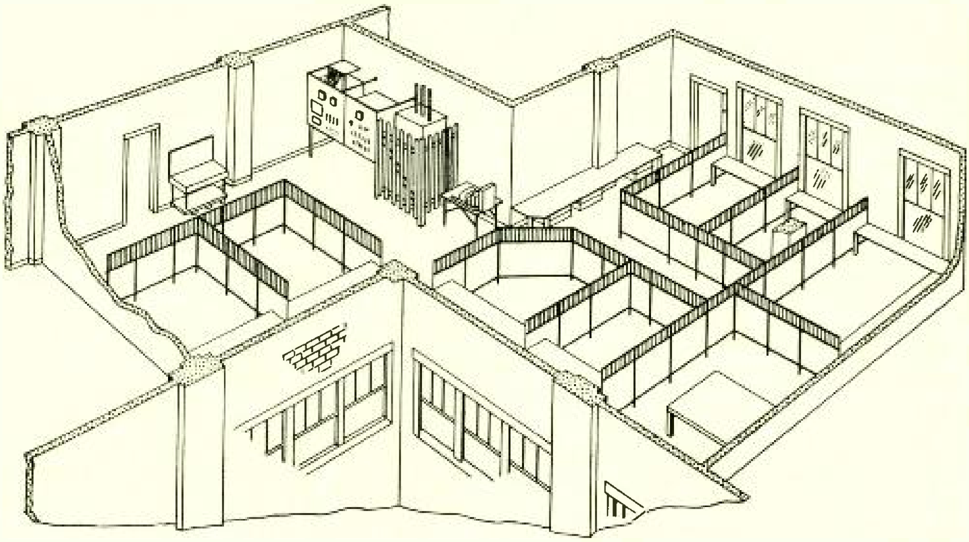


Fig. 2—Perspective plan of the power-transformer laboratory

Fig. 3—The compartments are similar in having a bench, writing stand, and outlet boxes for power supply, but vary in size and in their special equipment

the individual compartments. Two circuits are connected to the laboratory side of this circuit breaker: one running to the primary of a three-phase transformer having secondary voltages of 110, 220 and 440 volts, and the other to a three-phase motor that drives a 125-volt d-c generator. One connection from this generator provides the 125-volt d-c supply to the laboratory, and another supplies an adjustable-speed motor directly connected to three 300-volt single-phase alternators. The motor is adjustable over a two-to-one speed range, and over this range the frequency of the three generators varies from 25 to 50, 50 to 100 and 100 to 200 cycles respectively. Besides these main supplies, there is a small motor-generator furnishing eight hundred cycles at one hundred volts, and a 150-volt battery.

The transformer control panel is shown in Figure 5. Besides the main switch and various fuses, it carries switches for changing the taps to obtain any of the three available voltages. Connections from the secondary of this transformer run to main

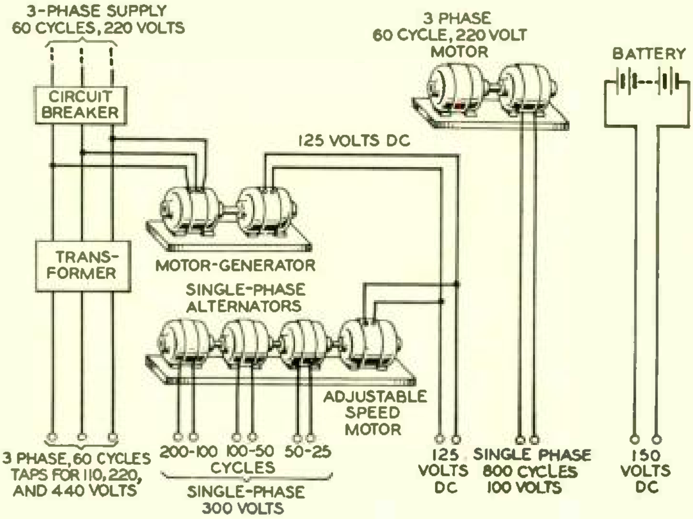


Fig. 4—Simplified schematic diagram of power supply

switches and three-phase outlet boxes in four of the compartments. The two switchboard panels at the left of the transformer enclosure, Figure 1, control the two main motor-generator sets, and provide patching jacks whereby any of the various supplies can be connected to any of the laboratory compartments. Two two-wire circuit jacks are located in each compartment and are given the same circuit numbers as the corresponding jacks at the main board. The various power supplies at the main board also appear in jacks so that they can be connected to any of the laboratory circuits by means of patching cords.

In the various tests carried on there is frequently needed a wider voltage range than is available from the main supply sources. This is secured by portable apparatus in the compartments. In Figure 6, for example, is a test set-up using a single-phase induction regulator, which gives a smooth control of voltage over a wide range. A three-phase induction regulator is also available, and is shown in use in the photograph at the head of this article. Besides this method of obtaining different voltages, various forms of commercial transformers, arranged to give voltage variation by taps in one form or another, are employed.

Power transformers and retardation coils are frequently required to operate at voltages where the insulation of the windings and the formation of corona become important.

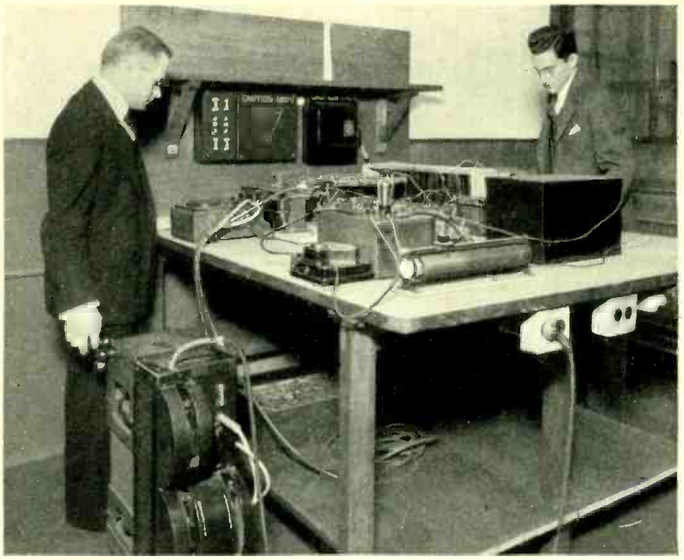


Fig. 6—C. A. Brigham and B. E. Stevens making peak voltage measurements on a rectifier circuit

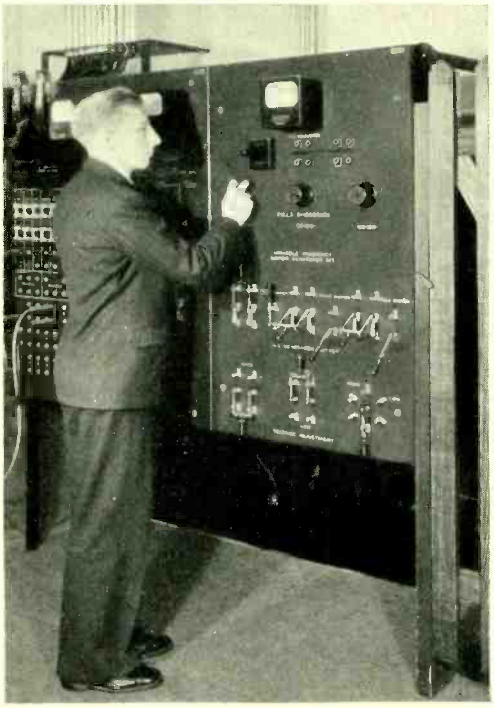


Fig. 5—The transformer panel carries switches for selecting 110, 220, or 440 volts as well as the main switch shown being operated by L. E. Milarta

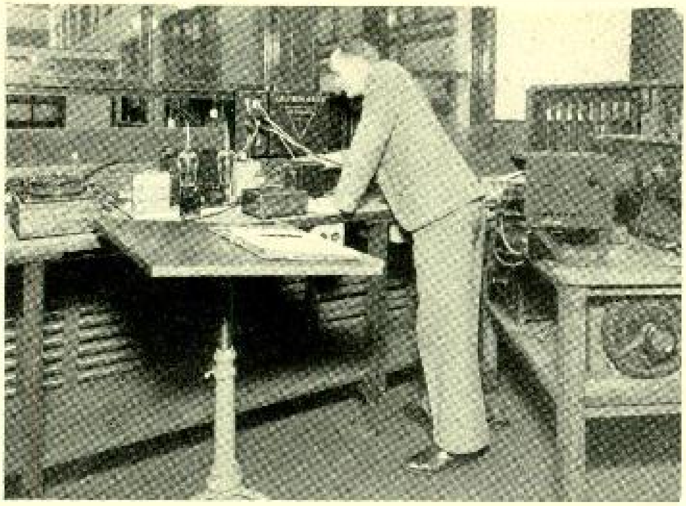


Fig. 7—E. E. Aldrich testing a grid-controlled rectifier with a three-element oscillograph (at the extreme right)

One of the compartments is provided with special facilities for corona studies, with a circuit that provides voltages up to 15,000 volts. This circuit may also be employed for making dielectric strength tests on coils and insulating materials. With power transformers, however, the failure of insulation may occur between turns, and dielectric strength tests between winding and ground are of little value in determining weakness of this type. An induced voltage test circuit is provided in one of the compartments for this type of test, as shown in Figure 8. Voltages at 180 cycles and up to 2500 volts are made available by this circuit. The effects of current and voltage wave shape may also be of considerable importance, and a three-element oscillograph, shown at the extreme right in Figure 7, is available for studies of this nature.

Retardation coils for ripple suppression are required to operate both with an a-c potential across their winding, and with a direct current passing through the coil. The inductance of the coil depends on both, and to aid in the design of such coils a superimposed inductance bridge* has been provided, which will measure inductance with as much as 2200 volts a-c across the winding and 12 amperes d-c flowing through it.

The behavior of coils and transformers at elevated temperatures is frequently a matter of considerable importance, and an electric oven has therefore been provided in which temperatures are available up to 265 degrees Fahrenheit. The oven is equipped with thermostatic control, which allows the temperature

Fig. 8—J. P. Whistler operating the induced voltage testing set

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*Record, *December*, 1935, *p.* 131.

to be held constant at any temperature within its operating range. This oven is also used for special studies of insulating and potting compounds.

With the laboratory facilities available, transformers and retardation coils at all usual ratings may be satisfactorily developed and tested. Usual procedure, after a coil or transformer has been developed, is to have a model built in the Model Shop. Complete tests simulating the actual circuit conditions are made on the model to verify the design. Tool-made samples are also tested in the transformer laboratory as a further check on the operating characteristics of each design. Due to the continuously increasing demand for small coils in all types of apparatus, laboratory studies are always in progress seeking means of improving the quality and increasing the life of transformers and coils, as well as of reducing their cost.

A Pattern of Cycles and Bels

"A special blue ribbon goes to John Mills' 'A Fugue in Cycles and Bels,' a most unusual book on music. For here a radio and telephonic engineer, whose witty and lucid pen has already pleased us with 'Letters of a Radio Engineer to His Son' and 'Signals and Speech in Electrical Communication,' tells us the rôle which electricity plays in music today, and is bound increasingly to play tomorrow. He weaves cycles (units of vibration frequency which determine pitch) and bels (units of acoustical power or loudness) into a pattern which explains the whole electrical study of sound. Technical, but deeply fascinating.

"Just consider this example of the range and sensitivity of the listening ear—that if a person speaks normally into your ear at a distance of half an inch, you receive 10,000,000,000 times more acoustical power than the ear needs to detect a sound. There's a moral there somewhere."

—Theodore Hall, "No End of Books," Washington Post.

Contributors to This Issue

Upon receiving the B.A. degree from the University of Oregon in 1927, E. A. Veazie joined the Technical Staff of the Laboratories. Here, with the Vacuum Tube Development group, he has been engaged principally in the design of multi-grid tubes for both low and high frequency uses.

C. B. Aiken received a B.S. degree from Tulane University in 1923. He then went to Harvard and received an M.S. in Electrical Communication Engineering in 1924 and an M.A. in Physics the following year. After two years with Mason, Slichter and Hay of Madison, Wisconsin, engaged in geophysical exploration, he joined the Laboratories in 1928. Here he was occupied with work on aircraft radio receivers and special measuring equipment. In 1930 he was made supervisor in charge of broadcast radio receiver development—a position he held at the time the radio compass was developed.

C. B. Aiken

A. D. Knowlton received the B.S. degree from Haverford College in 1920, and in the fall joined the Technical Staff of the Laboratories. He was first associated with the Equipment group where he did engineering work for the first dial installations in New York City. Later he transferred to the Manual Switchboard group and was engaged in the design of call indicator equipment and other manual switchboard developments. In 1931 he transferred to the telegraph group where he worked largely on teletypewriter switchboards. He is now supervisor of the group developing telegraph and teletypewriter equipment.

George B. Engelhardt graduated from Cornell Uni-

E. A. Veazie

A. D. Knowlton

G. B. Engelhardt

R. W. DeMonte

J. E. Corbin

E. P. Felch

versity in 1930 with the E.E. degree. Shortly after he joined the Technical Staff of the Laboratories, associating himself with the Carrier Transmission Research group. Here he has been concerned chiefly in developing measuring apparatus for use at very high frequencies, such as are proposed for transmission over coaxial structures. Measurement of phase shift at these frequencies has been one of his major studies.

R. W. DeMonte joined the Transmission Apparatus group of the Laboratories in 1920. During the next five years he took the course for Technical Assistants at the Laboratories, and also studied at Cooper Union, receiving the B.S. degree in Mechanical Engineering in 1925. During this period and for the next year he was engaged chiefly in the design of filters and networks. In 1926, and for the following three years, he turned to the design of audio-frequency coils. Since 1929 he has been in charge of the design of transformers and coils used in regulators and rectifiers.

J. E. Corbin received the degree of B.S. in Electrical Engineering from Pennsylvania State College in 1930 and immediately joined the technical staff of the Laboratories. Here as a member of the radio development group he has engaged in the design of radio-frequency distribution systems, and of radio receivers for broadcasting stations and aircraft.

E. P. Felch graduated from Dartmouth College in 1929 with the A.B. degree in Physics, and at once joined the Technical Staff of the Laboratories. Following a brief training period with the Western Electric Installation Department he entered the Trial Installation group in the Systems Development Department. Transferring in 1930 to the Electrical Measurements group of the Apparatus Development Department, he has since been engaged in the development of carrier and radio-frequency oscillators, detectors, and phase-measuring equipment. In connection with the telephotograph project during 1934, he was active in the design of delay measuring apparatus and spent some time in the field giving instructions in the technique of delay measurement.