BELL LABORATORIES RECORD

WAVE ANALYSIS
W. KOENIG, JR.
T. G. CASTNER

OUTDOOR TELEPHONE
W. J. THAYER

CONDUIT PLUGS
J. H. GRAY

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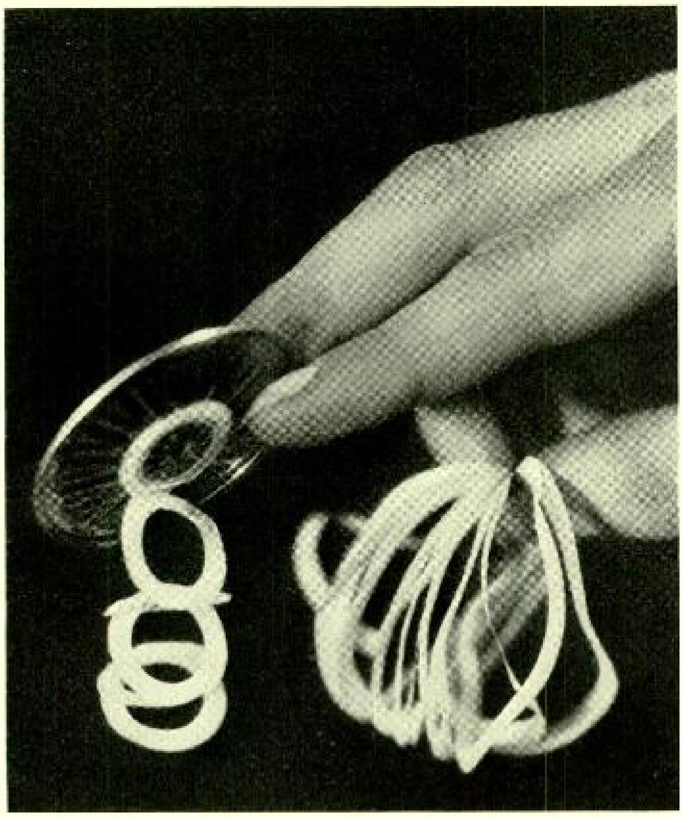

Rings of thin paper are important elements in the handset transmitter. The small ones form an elastic retaining wall for the carbon granules; the larger rings form a cushioning support for the edge of the diaphragm

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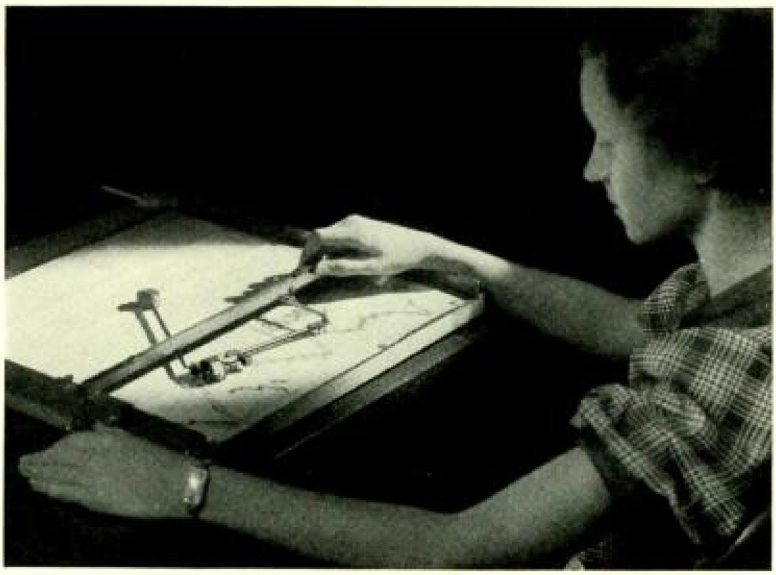


Mechanical Analysis of Waves

By WALTER KOENIG, JR.
Local Transmission Development

ENGINEERS are accustomed to dealing, both in theory and practice, with electrical waves of varying degrees of complexity. The simplest is a pure sine wave such as is produced by a perfect oscillator. A somewhat more complex form is obtained from the output of an electrical generator, which, although intended to be a pure sine wave, usually contains components of frequencies that are integral multiples of the fundamental and with amplitudes depending on the design of the generator. A still more complex form is given by the acoustic wave produced in speech, which has its counterpart in the electric current of a telephone circuit. All such waves can, according to Fourier's Theorem, be represented by a series of simple sinusoidal harmonics of various amplitudes, and any device that is to be able to reproduce these waves correctly must be able to reproduce each of the component waves that its Fourier expression contains.

Unfortunately, the algebraic operations involved in applying Fourier's equations are exceedingly laborious, even for relatively simple waves, and prohibitive for complex ones. As a result many ingenious suggestions have been made for mechanical means of performing these operations. There would, therefore, be little excuse for suggesting a new method unless it possessed very decided advantages. It happens, however, that all previously suggested methods capable of determining a large number of harmonics require a mechanism so complex in design and of such high precision in manufacture that very few have ever been built, and these are too expensive to come into general use.

During studies made in these Laboratories some years ago, it became necessary to analyze a large number of speech sounds. As a result of this necessity, a mechanical wave analyzer was designed which employs a relatively simple and easily constructed arrangement. Its measuring element is an ordinary planimeter, which is attached to the machine when an analysis is to be made. The remaining elements are exceedingly simple, consisting primarily of a drawing board of convenient size to which a graph of the wave to be analyzed may be fastened, a crossbar arranged to move parallel to itself up and down across the board, and a linkage which slides across this bar and holds the pointer of the planimeter. Its operation is also simple since the curve is not followed by the planimeter pointer, but merely touched at a series of predetermined points.

The general Fourier expression for any periodic complex wave is given by the equation:

$$y = a_0 + a_1 \cos\omega + a_2 \cos 2\omega + \ldots\ldots . a_n \cos n\omega + b_1 \sin\omega + b_2 \sin 2\omega + \ldots\ldots . b_n \sin n\omega$$

In this equation $\omega = 2\pi x/\lambda$, where "x" is the distance along the abscissa scale and λ, the length of the fundamental period. If the values of the coefficients $a_1, a_2, -a_n$ and b_1, b_2-b_n are known, the amplitudes of the various harmonics may readily be calculated, since the amplitude of the nth harmonic is $\sqrt{a_n^2+b_n^2}$. The phase angles may also be computed since their tangents are given by a_n/b_n. The method employed in the present analyzer involves the measurement of groups of selected ordinates, a different group for each harmonic. Unlike other methods that have been used, this method is not an approximate one but is theoretically exact.

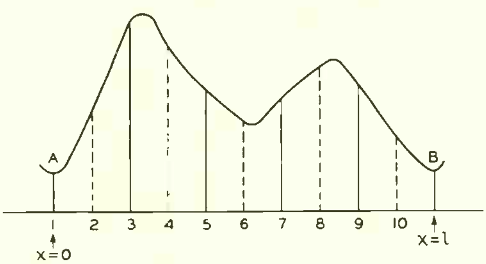


Fig. 1—A simple harmonic wave showing ordinates that are required for determining the 5th harmonic

The wave to be analyzed is represented by a graph or oscillogram. A recurrent section of the curve, representing one wavelength of the fundamental,

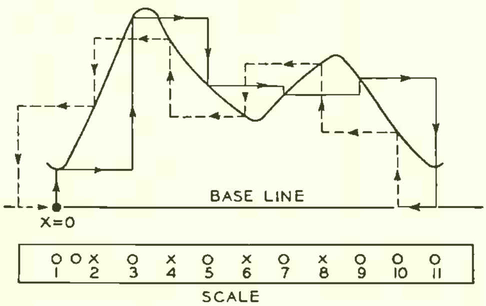


Fig. 2—Method of moving planimeter point in determining the coefficients of the 5th harmonic

is enlarged photographically to a length of twelve inches, and a base line parallel to the time axis of the graph is then laid off in some convenient position — usually at or slightly below the lowest point on the graph. The coefficients for any harmonic such as the nth may be determined without the use of the analyzer by measuring the height of 2n equally spaced ordinates. An example is illustrated in Figure 1, which shows a simple wave where the fundamental wavelength is from A to B—the two nearest recurrent points. The ordinates drawn are those employed for determining the cosine coefficients for

	COSINE COEFFICIENTS			SINE COEFFICIENTS		
n	A_n +	P_n =	a_n	B_n +	Q_n =	b_n
1						
2						
3						
4						
5	230	140	370			
6						
7						
8						
9						
10						
11	$A_n = a_n$ BELOW $n = 10$	NO CORRECTIONS		$B_n = b_n$ BELOW $n = 10$	NO CORRECTIONS	
12						
13						
14						
15			-160			
16						
17						
18						
19						
20						
21						
22						
23						
24						
25			+20			
26						
27						
28						
29						
30						

CORRECTIONS FOR THE FIRST TEN			
COSINES P_n		SINES Q_n	
$P_{10} = -a_{30}$		$Q_{10} = +b_{30}$	
$P_9 = -a_{27}$		$Q_9 = +b_{27}$	
$P_8 = -a_{24}$		$Q_8 = +b_{24}$	
$P_7 = -a_{21}$		$Q_7 = +b_{21}$	
$-a_{18}$ $-a_{30}$ $P_6 =$		$+b_{18}$ $-b_{30}$ $Q_6 =$	
$-a_{15}$ $-a_{25}$ $P_5 =$ 140	+160 -20	$+b_{15}$ $-b_{25}$ $Q_5 =$	
$-a_{12}$ $-a_{20}$ $-a_{28}$ $P_4 =$		$+b_{12}$ $-b_{20}$ $+b_{28}$ $Q_4 =$	
$-a_9$ $-a_{15}$ $-a_{21}$ $-a_{27}$ $P_3 =$		$+b_9$ $-b_{15}$ $+b_{21}$ $-b_{27}$ $Q_3 =$	
$-a_6$ $-a_{10}$ $-a_{14}$ $-a_{18}$ $-a_{22}$ $-a_{26}$ $-a_{30}$ $P_2 =$		$+b_6$ $-b_{10}$ $+b_{14}$ $-b_{18}$ $+b_{22}$ $-b_{26}$ $+b_{30}$ $Q_2 =$	
$-a_3$ $-a_5$ $-a_7$ $-a_{11}$ $-a_{13}$ $-a_{17}$ $-a_{19}$ $-a_{23}$ $-a_{25}$ $-a_{29}$ $+P_3$ $P_1 =$		$+b_3$ $-b_5$ $+b_7$ $+b_{11}$ $-b_{13}$ $-b_{17}$ $+b_{19}$ $+b_{23}$ $-b_{25}$ $-b_{29}$ $-Q_3$ $Q_1 =$	

NOTES:—
A_n, B_n = DIRECT PLANIMETER READINGS
P_n, Q_n = CORRECTIONS DUE TO ODD MULTIPLES
ALL INDICATED ADDITIONS ARE ALGEBRAIC

Fig. 3—One type of form that may be used for tabulating results, showing actual data for the 5th harmonic

Coefficient b_5 is determined in a similar manner only the ten ordinates instead of beginning at $x = 0$, begin at $x = \lambda/4n$, or half way between 1 and 2 of Figure 1. As before the average height of the even-numbered ordinates is subtracted from that of the odd-numbered ordinates. To this difference the sum of the 15th, 35th, etc., coefficients is added and that of the 25th, 45th, etc., subtracted. Here also the general expression for the subscripts of the coefficients is $n(2p+1)$, but in this case they are alternately added and subtracted.

With the mechanical analyzer these groups of ordinates are measured, averaged, and subtracted by the planimeter in one operation. The actual procedure involved for the

the fifth harmonic. Mathematical analysis tells us that the coefficient a_5 is equal to the average height of the ordinates 1, 3, 5, 7, 9 minus the average height of the ordinates, 2, 4, 6, 8, and 10, minus also the coefficients a_{15}, a_{25}, a_{35}, a_{45}, etc. The subscripts of these coefficients are given by the expression $n(2p+1)$ where "p" takes successively all integral values, and "n" is the harmonic being determined. Since the higher frequencies are ordinarily negligible, however, there are not usually many of the higher coefficients that need to be subtracted.

example taken is illustrated in Figure 2. The pointer of the planimeter is first placed on the base line at $x = 0$ and the planimeter dial is set to zero. The pointer is then moved vertically up to the curve and then horizontally to ordinate 3; again vertically up (or down) to the curve, and so on to the curve at the ninth ordinate. From here the pointer is moved horizontally till over $x = \lambda$, or what would correspond to the eleventh ordinate, and then vertically down to the base line. It is then moved back along the base line to the tenth ordinate, then vertically up to the curve, then horizontally to the eighth ordinate and again to the curve and so on. From the curve at the second ordinate, the pointer is moved horizontally to the left a distance of λ/n, then down to the base line and back to $x=0$. In the movements across from left to right to heights of the odd-numbered ordinates are measured and averaged, and in the similar motion from right to left the even-numbered are similarly measured and averaged, and because of the reversal in direction of motion, the latter average is subtracted from the former. The resultant indication on the planimeter dial is proportional to the difference of these two averages.

In the complete analysis of a wave this process is carried out for each harmonic. The calculation and tabulation may be simplified by employing a form as shown on Figure 3. Here in with their proper signs to indicate whether they are to be subtracted from or added to A_n and B_n to yield a_n and b_n. For harmonics above the tenth, the lowest odd multiple harmonic is higher than the thirtieth and can usually be neglected and thus for harmonics above the tenth, A_n is taken equal to a_n. Data for the fifth harmonic have been entered on the forms but the rest has been left blank.

The analyzer, set up for determining the harmonics of a curve, is shown in the illustration at the head of this article, while the essential structural details are shown in Figure 4. The crossbar is mounted with the usual crossed cords to give it a motion parallel to its axis. The arm holding the pointer of the planimeter slides on the crossbar and is moved by pushing the rider, shown near the right end of the crossbar. In making an analysis, therefore, the operator controls the

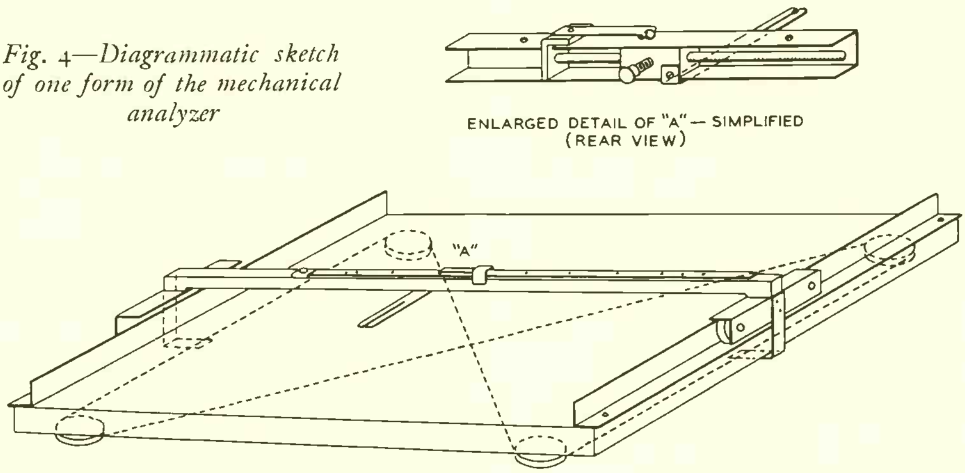


Fig. 4—Diagrammatic sketch of one form of the mechanical analyzer

the columns headed a_n and b_n are placed the coefficients as they are finally evaluated. Under A_n and B_n are placed the differences of the averaged ordinates as determined by the planimeter readings, while under P_n and Q_n are the sums of the coefficients of odd multiple harmonics vertical motion with her left hand and the horizontal with her right, as shown in the illustration at the head of this article. A locking lever controlled by the left hand holds the crossbar of the analyzer in a fixed position while the slider is being moved.

To mark the positions of the various

ordinates at which the planimeter is moved up or down to the curve, perforated strips are provided for fastening to the top of the crossbar, and a ball roller in the end of the slider, dropping into the perforations, acts as a ratchet to indicate when the various ordinates are reached. In general there is one of these perforated strips for each harmonic to be determined, although the number can be halved by utilizing both sides. These strips are held in a fixed position relative to the crossbar by a socket at the left and a dowel pin at the right end, and may readily be changed as desired.

For any harmonic, such as the nth, there are 2n ordinates that must be measured to determine the cosine coefficient and another set of 2n ordinates for the sine coefficient. For both sets the even-numbered ordinates are measured while moving the planimeter in one direction across the board and the odd-numbered, in the other. Thus in each transit across the board only n ordinates are measured. Advantage is taken of this fact to simplify the construction and operation of the analyzer by drilling the holes in the guiding strip a distance λ/n rather than $\lambda/2n$ apart, and thus approximately halving their number. Two additional holes are required, however; one half way between the last two and the other a quarter of the distance from the first to the second. The slider with the ball ratchet that rides on these strips carries a rod to which is clamped the arm carrying the planimeter pointer, an arrangement which allows the position of the pointer to be adjusted.

At the beginning of an analysis, the planimeter pointer is placed at position $x = 0$ and when at this position the ball will be in the first hole. The pointer is then moved up to the curve and then the slider is moved horizontally until the ball drops into the next hole, a distance of λ/n, which brings the pointer to the next odd-numbered ordinate. This process is continued until the ball is in the last hole and the pointer on the base line under the last point. The pointer is then moved to the left until the ball

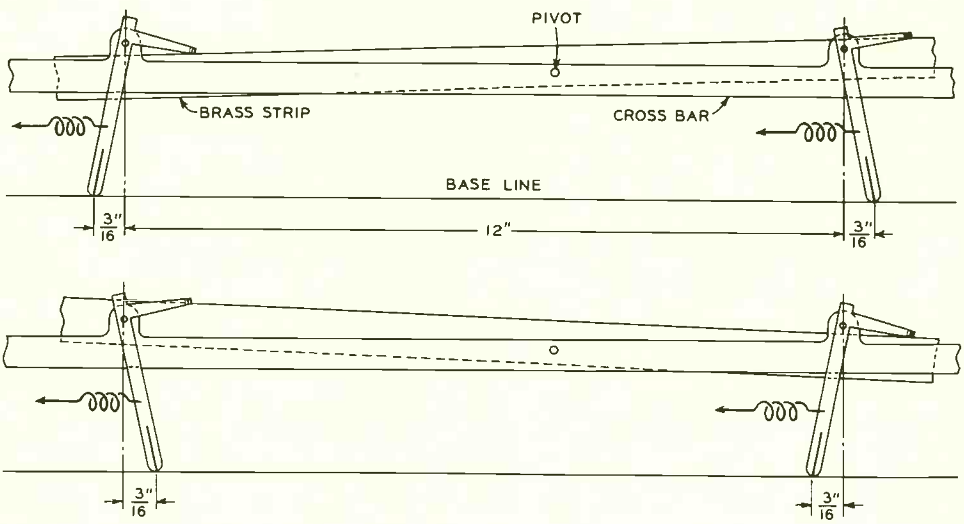


Fig. 5—Diagrammatic representation of adjustment for length of curve—proportions exaggerated to illustrate the principle to better effect

drops into the hole half way between the last two holes. Holding the pointer at this position the slider and the rod are moved back until the ball is again in the last hole. The ball is now in position to guide the pointer to equally spaced ordinates on the return trip, but these ordinates are half way between those measured on the outward journey—thus giving the average of the even-numbered ordinates that are shown in Figure 1.

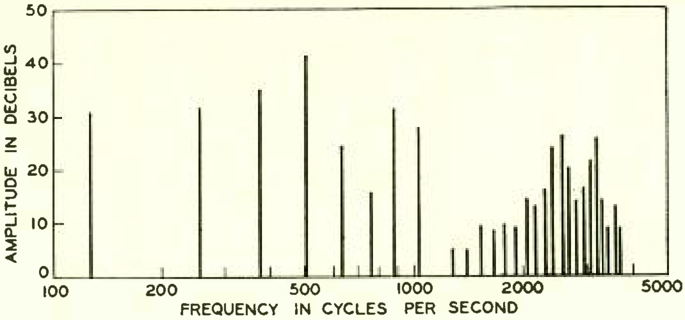


Fig. 6—Harmonic analysis of curve shown in headpiece

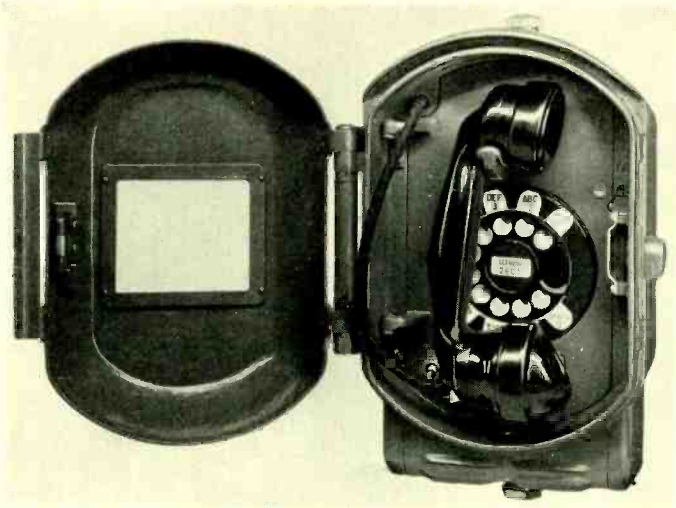
The process is similar for determining the sine coefficient except that the hole quarter way from the first to the second hole is employed to get the correct position for the ordinates. The half way hole at the other end is used the same as for the cosine coefficients.

Another interesting mechanical detail is incorporated because of the difficulty in obtaining a photographic enlargement of the original curve that is exactly twelve inches long. The adjustment provided allows correct measurements to be made of a curve differing in length by as much as ⅜ inch from twelve inches—an adjustment ample to correct for any ordinary inaccuracy in the enlargement. The arm that holds the planimeter is L shaped with the long branch carrying the pointer, and is pivoted at the corner of the L to the slider. A stud at the end of the short branch of the L rides along a flat brass strip pivoted to the crossbar at the middle of the span. This brass strip may be clamped in a slanting position relative to the crossbar in either direction.

The diagram of this construction in Figure 5 illustrates the manner in which it adjusts for small variations in length of the graph. The upper sketch shows the position of the brass strip when the graph is longer than twelve inches and the lower one, when it is shorter than twelve.

With this arrangement the total horizontal distance moved by the planimeter point may be more or less than twelve inches, but whatever the distance, it is divided evenly by the stopping positions of the ball ratchet of the slider.

The results of a harmonic analysis of the curve shown in the headpiece are given in Figure 6, which shows the relative magnitudes of the various harmonics up to the thirtieth. The prominence of the fourth harmonic, indicated in the analysis, is plainly evident from the four peaks of the curve, and the power in the wave is concentrated in the frequency region where the harmonics show the greatest amplitude. The ease with which analyzers of this type can be built, the simplicity of operation, and the large amount of information their use yields make them particularly attractive for a variety of work in acoustic and communication studies.



A Telephone Set for Outdoor Use

By W. J. THAYER
Telephone Apparatus Development

OUT-OF-DOOR telephone service is required to a considerable extent by police and fire departments, at taxicab stations, and by watchmen. For this service there has been available the set shown at the left of Figure 1, which has been extensively used with satisfaction. Within a heavy cast iron box was housed a deskstand transmitter and receiver together with the ringer and accessory apparatus. To obtain certain improved features possible through recent developments, however, as well as a more pleasing appearance, a new set, known as the 300 type, has recently been developed.

One of the differentiating features of the new development, shown in the illustration at the head of this article, is that it employs a handset connected to the set by a waterproof cord. The dial provided has a large external number plate to make the digits and letters more plainly visible.

The semi-oval form, with a long lip for a handle on the outer door which balances the hinge on the opposite side, makes a pleasing appearance. The new set has a cast aluminum housing divided by an inner door into a rear and front compartment. The switchhook projects through the upper part of this inner door and carries the handset, and a dial or apparatus blank is mounted near the center of the door. At the bottom of the door, barely visible behind the transmitter of the handset in the illustration, is a pad holder, placed at an angle for convenience in writing and provided with a spring clip for holding a pad, and on the inside of the door is a metal frame which holds an instruction card. A spring catch holds the outer door shut when the set is not being used. The outer door may be opened by pulling the handle at the right of the set. Associated with the spring catch is a lock which permits locking the set against possible use by unauthorized persons.

Within the rear compartment, shown in Figure 2, is the talking and signaling apparatus, consisting of an induction coil, a condenser, and the ringer, and provision is made for the installation of a relay when auxiliary signals are required. The gongs of the ringer extend through an opening in the bottom of the housing, which is provided with a removable cover with screened louvers to secure maximum audibility and at the same time provide protection against storms. To allow the cover to be readily removed for adjustments of the gongs, only a single screw is employed to fasten it, and the screw is designed to remain in place when the cover is removed—thus eliminating possible loss. When loud ringing telephone bells are used, a switch may be provided below and to the left of the dial, as shown in the illustration at the head of this article, to cut them in or out of the circuit as desired.

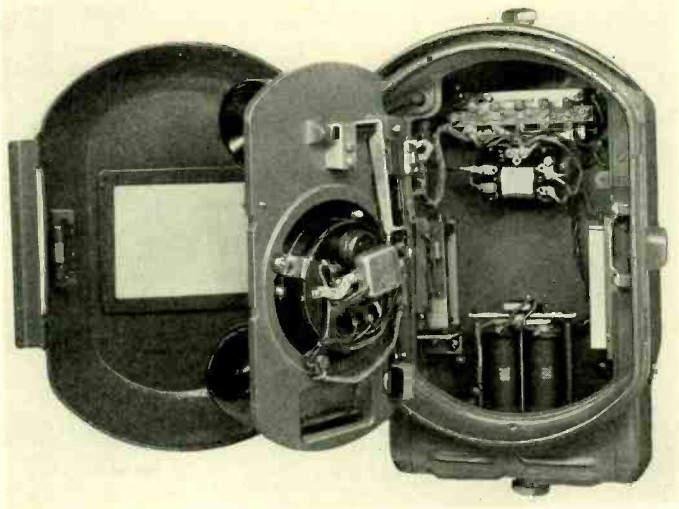


Fig. 2—The screw plugs at the top and bottom of the set block threaded holes left for the conduit through which the connecting wires are carried

The handset employed differs from the more usual type in that the transmitter is protected from the entrance of moisture by a rubber membrane. This construction has previously been described in the Record*, although as applied to an operator's transmitter instead of the usual station handset.

Although the housing is not waterproof in the sense that water could not be forced into it, ample protection is afforded against all usual weather conditions. The outer door, which is of sheet steel

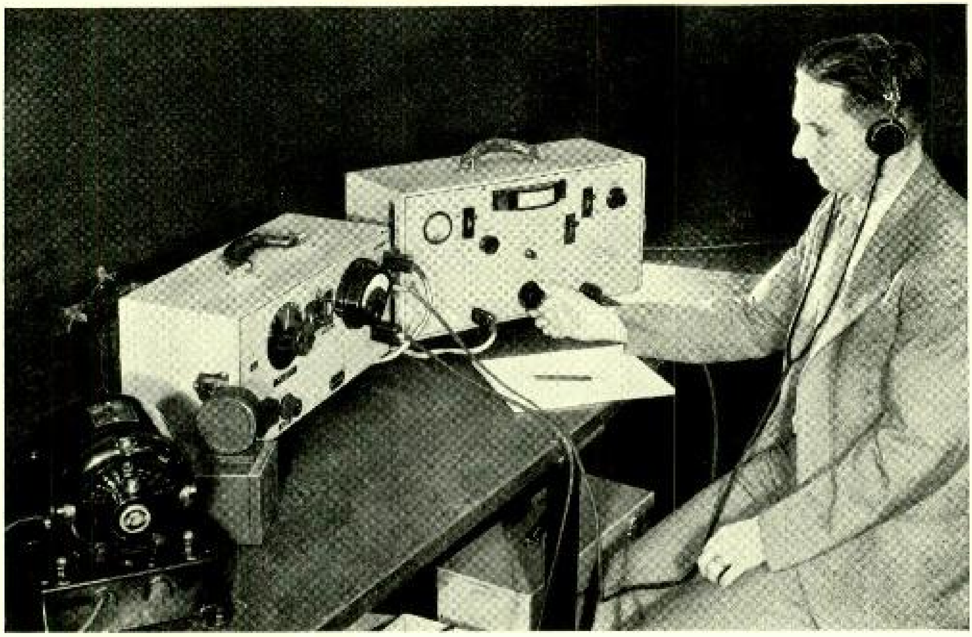
Fig. 1—At the left is the earlier, 530A, type subscriber set, and at the right, the new. A Western Electric nameplate will replace the Bell System nameplate on sets sold to users outside of the Bell System

*Record, *February*, 1932, *p.* 182.

for reasons of strength, fits closely over a projecting flange on the housing which forms a barrier against the entrance of water, and additional protection is provided by a hood—another flange on the housing—projecting over the top of the door. Spring hinges insure that the door cannot be left open, thus exposing the apparatus to storm through carelessness, and a small hole in the bottom of the front part of the housing permits any small amounts of water that may gain entrance to run out without entering the rear compartment. An actual test in which severe rain conditions were simulated by a shower sprayed on the set at a 45-degree angle for fifteen minutes resulted in but a single drop of water entering the front compartment; none was found in the rear compartment.

To make the installation of the set easy, a mounting bracket has been designed with a series of mounting holes which will take care of ordinary conditions encountered in mounting on fences, buildings, etc. This bracket is not a component part of the telephone set, however, but is furnished as a separate piece of apparatus when required. The ease with which this new set may be transported and installed, because of its light weight and small size, as well as its improved equipment, should result in wide use.

H. W. Hermance, in the microchemical laboratory, prepares apparatus for a determination of minute quantities of arsenic



A General-Purpose Frequency Analyzer

By T. G. CASTNER
Wire Transmission Research

SINCE the "Noise Abatement Commission" made its study of the sources of noise in the streets of New York City various other cities and agencies have become interested in noises, their measurement and reduction. Experience has shown the need for a noise analyzer which can readily be transported from place to place. For the New York survey it was necessary to carry around band filters weighing about one hundred pounds, as well as equipment for measuring the total noise, to obtain a somewhat crude form of analysis using only four frequency bands. Much more complete band frequency analyses of speech, music, and noise have been obtained in laboratory setups, but they have required equipment which is decidedly non-portable.

Two types of audio-frequency analysis are commonly of interest in noise abatement work. These are a discrete frequency analysis, in which the measurement of the frequency and amplitude of the important components of a complex wave is made, and a band frequency analysis, in which the energy in arbitrarily chosen frequency bands is measured. To be generally useful, therefore, a portable frequency analyzer should be capable of measuring discrete frequencies as well as the energy over convenient bands. At the start of the investigation of the possibility of developing such an analyzer, no ready means of obtaining the desired characteristics in a single portable instrument were evident. Fortunately, as a result of extensive research on the piezo-

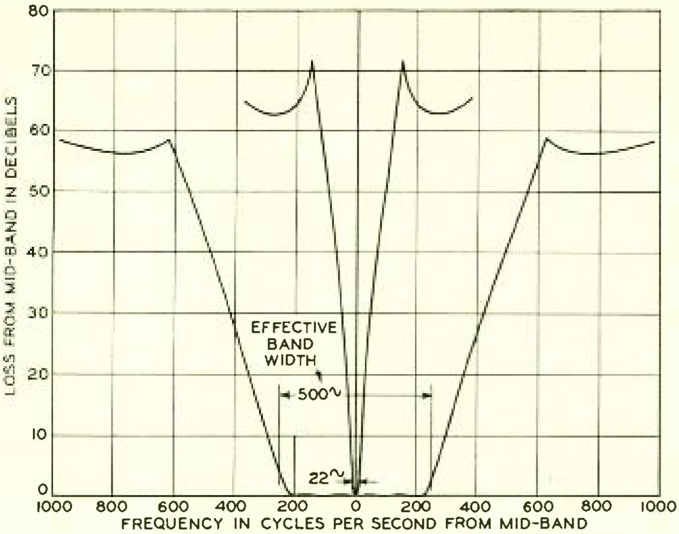


Fig. 1—Characteristics of the two filters employed in the experimental model of the analyzer

electric properties of crystals, a new type of band pass filter, employing quartz crystals as elements, became available in 1930. With this type of filter, band widths ranging from two or three to several thousand cycles can readily be obtained by employing a suitable analyzer circuit and operating frequency.

A model of a frequency-analyzer unit employing filters of this type, was completed early in 1932. It was designed for use with the sound meter*, since in most noise-measuring work a measurement of the total noise is desired as well as an analysis of the noise. This procedure greatly reduced the amount of apparatus required for the analyzer unit and so contributed to its portability. In the headpiece an experimental model of the analyzer unit is shown set up for use with the sound meter for an analysis of the noise of a small motor. As with the sound meter, the battery supply for the analyzer is contained in a separate carrying case.

This model of the analyzer has received a large amount of use in a wide variety of laboratory work during the last two years, and in addition has been employed on a number of noise investigations outside of the Laboratories. In the laboratory, studies have been made of such things as noise in mechanical apparatus, of room noise in typical offices in the Laboratories, of modulation in carbon transmitters, and of sound recording and reproducing. The field work has included such unusual jobs as the analysis of propeller and motor noise on a rigid dirigible and on the Laboratories airplanes; the analysis of noise on the flying deck of an aircraft carrier, in the cab of a moving locomotive, on subway cars, and in the Holland tunnel; and of motor knock in a moving automobile.

Both a 22-cycle and a 500-cycle band are available in the experimental analyzer unit, and may be used in any part of the frequency range from 30 to 9,000 cycles per second. These band widths could readily be changed to other values if desired and the total frequency range could be extended. The 22-cycle band is narrow enough to pick out dominant single frequencies and thus serves for the discrete frequency analysis, while the wider band, which can be shifted to any part of the audible-frequency spectrum, gives the band analysis. The filters have discrimination characteristics as shown in Figure 1.

The operation of the analyzer may

*Record, *May*, 1932, *p.* 334.

be explained by reference to Figure 2, which shows a block schematic of the combination of sound meter, frequency analyzer, and calibrating circuit. The acoustic wave to be analyzed is picked up by the microphone of the sound meter, and passes through the sound meter amplifier and frequency-weighting network into the frequency-analyzer unit. This consists of a modulator, an oscillator which may be varied from 40 to 49.6 kc, the two crystal filters, a demodulator, and a single-stage amplifier. From this amplifier the passed band—now returned to audible frequencies—returns to the sound meter, passing through the two-stage amplifier and rectifier, to the indicating meter.

Crystals have naturally high frequencies of oscillation and the two crystal filters provided have mid-band frequencies of 40 kc. The purpose of the modulator and demodulator is to raise the audible frequencies up to the neighborhood of 40 kc for passage through the filter and then to lower them to their original values for measurement. The modulator is of the balanced rectifier type with the oscillator frequency introduced in the mid-branch. This type was chosen to save space, weight, and battery supply.

The various products of modulation are v, (c ± v), (2c ± v), 3v, etc., where v stands for a band of voice frequencies and c for the oscillator frequency. Since the mid-point of the filters is 40 kc and the oscillator frequency may be from 40 to 49.6 kc, the only one of these products that can pass through the filters is (c-v). At the middle of the passed band, therefore, (c-V) = 40 or by transposition V = c-40, where V is the voice frequency at the middle of the passed band. By varying the value of c from 40 to 49.6 kc, the middle voice frequency passed can thus be made anything from 0 up to 9.6 kc. The effect of changing the oscillator frequency is thus to move the filter along the audible spectrum—making it possible to place the band at any point of the available spectrum. This is indicated

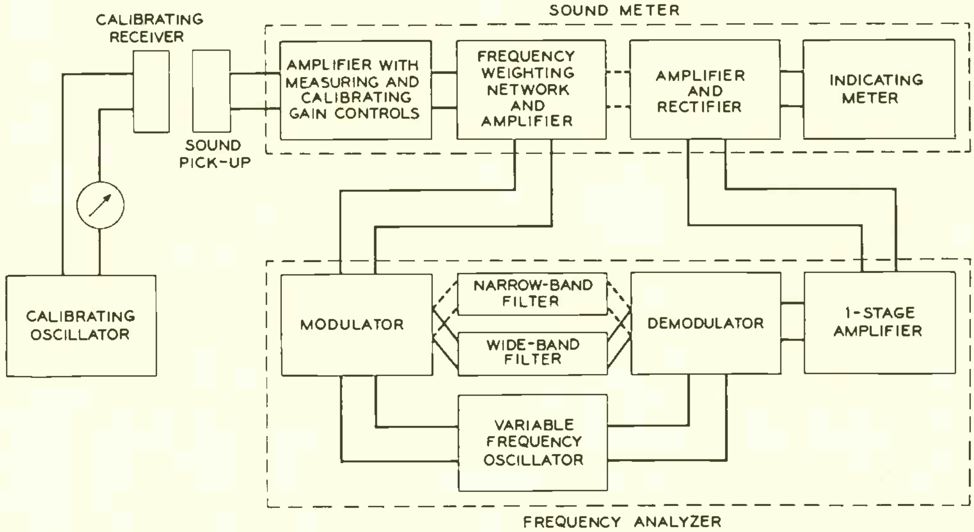


Fig. 2—Block diagram of frequency analyzer showing its inter-connection with the sound meter

graphically in Figure 3 where the voice spectrum is shown below and the possible oscillator frequencies on the scale above it, above which are indicated both the wide and narrow band filters. The values marked along the oscillator scales are those required to bring the band over the section of the voice spectrum that is immediately below it.

The oscillator output voltage is fed into two "buffer" amplifier tubes through properly chosen series and shunt grid resistances. These tubes in turn supply oscillator-frequency energy to the modulator and demodulator. This arrangement greatly decreases the coupling between the modulator and demodulator other than that provided by the filter so that it is possible to realize almost all of the calculated selectivity of the filters that are utilized.

The wave components selected by the filter are applied to the grid of the second "buffer" amplifier tube which in addition serves to amplify the carrier-frequency energy required for the demodulator. The demodulator is also of the rectifier type. With the band of frequencies passed by the filter, (c-v), and the oscillator frequency c applied to the demodulator, the resultant frequencies appearing across the low-impedance side of the audio-frequency input transformer in the mid-branch of the demodulator are (c-v) $\pm$c, 2(c-v), 2c, etc., of which

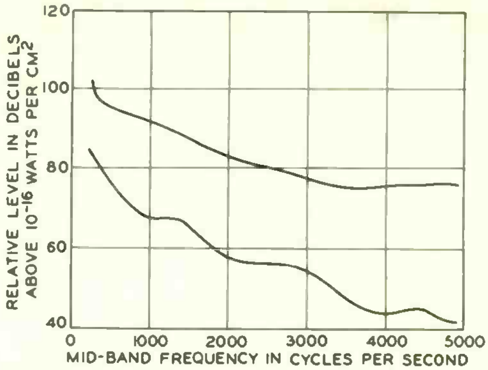


Fig. 4—Typical results obtained by the new frequency analyzer. Above—noise from engines of a dirigible; Below—noise from Laboratories plane

(c-v)-c or v, is the only one having a frequency low enough to be passed by the following audio frequency amplifier. Overall measurements of the sound meter and analyzer at frequencies near 1,000 cycles show the harmonics of v to be at least 50 db down from the fundamental when the modulator is properly balanced.

The measurement of the selected wave components at their original frequencies, which is made possible by the use of demodulation, has the advantage of using the last two stages of amplification in the sound meter with the output rectifier and meter. If demodulation were not employed, this equipment would have to be duplicated, with a corresponding increase in weight. Another advantage of the use of demodulation is that any

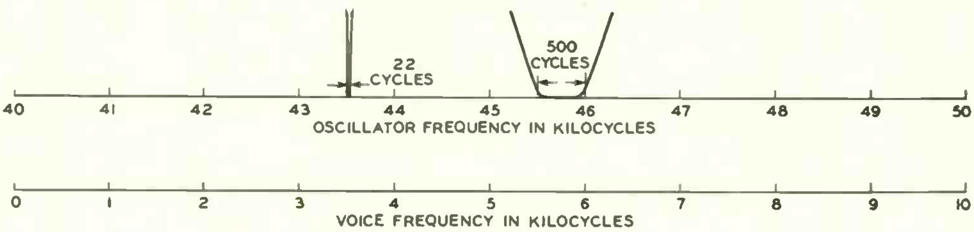


Fig. 3—By varying the oscillator frequency from 40 to 49.6 kc, the mid-point of the filter can in effect be moved to any point of the audible range

carrier frequency leak from the modulator or demodulator, since it results in a zero frequency component in the output of the demodulator, contributes nothing to the reading of the indicating meter. This permits the analysis of lower frequencies without the severe requirement of a very well balanced modulator.

Still another and important advantage of demodulation is that it makes it possible to observe aurally the band of frequencies selected from the audio frequency spectrum. This feature allows the operator to obtain more detailed information on the sound being studied. If, for example, a selected component is varying several db on the indicating meter, monitoring will aid in determining whether the variation is a magnitude change or a frequency change. In addition monitoring aids in the location of weak components among stronger ones. It is often helpful if the observer is able to recognize certain of the passed bands and can associate them with a particular source in the noise.

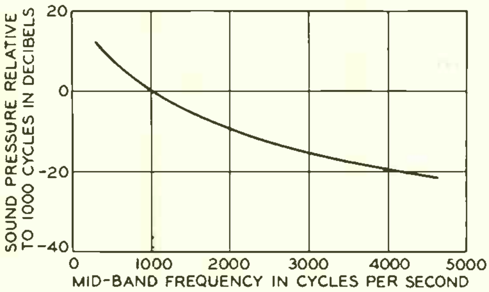


Fig. 5—Room noise in a number of offices

The analyzer includes a single-stage audio-frequency amplifier which is used to make up for the transmission loss in the modulators and filter. Since the narrow-band filter has a somewhat different transmission loss in the pass band than does the wide band, a tapped resistance in the amplifier is changed by one of the same switches used for changing from one filter to the other. The amplifier gain is adjusted so that with either filter in the circuit the overall gain for the analyzer unit as a whole is zero in the filter pass band. The selected components are then read on the indicating meter in the sound-meter output circuit after a suitable adjustment of the sound-meter measuring gain control.

If it is desired to obtain the absolute magnitude of selected components, rather than those resulting from the effect of the frequency-weighting network, the observed values may readily be corrected from the known characteristics of the network. Similar corrections may also be made if desired for the departure from uniformity of the analyzer frequency response characteristic.

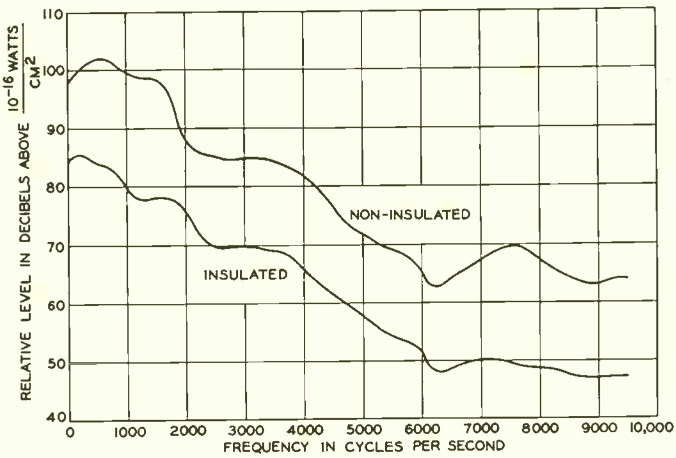


Fig. 6—Analyses of exhaust fan noise showing effect of sound insulation

The calibration of the analyzer for gain is ordinarily made with the assistance of the oscillator in the sound-meter battery box. In the calibration for frequency, the frequency dial is set on zero, using the narrow band, and the meter provided for measuring filament current is switched to measure the direct current in the common branch of the demodulator. The frequency-calibrating condenser is then adjusted to make the reading of this meter a minimum. Under this condition the oscillator frequency is almost the same as the mid-band frequency of the filter since the dip in meter reading is due to the out-of-phase combination of the oscillator-frequency leak from the modulator through the filter with the oscillator frequency supplied to the demodulator. If a more exact check on the frequency calibration is required, an external calibrated audio-frequency oscillator may be applied to the analyzer through the sound meter or other input circuit.

The four 264A Vacuum Tubes used in the analyzer unit obtain their filament power from six standard dry cells and their plate power from four small 22½-volt batteries, all contained in a separate battery box, which weighs approximately 30 pounds. The weight of the experimental analyzer is about 47 pounds.

Typical results that have been obtained by the use of this meter are shown in the following illustrations. In Figure 4, the upper curve gives the energy distribution in 500-cycle bands of the noise from one of the engines of a dirigible, while the lower curve shows results obtained from the Laboratories plane. Both are plotted against an ordinate scale of pressure in db above 10^{-16} watts per square centimeter.

The curve that is given in Figure 5 shows the average of noise measurements in a number of offices at 463 West Street and at 195 Broadway. This curve is plotted in db relative to the sound pressure at 1000 cycles per second, and thus shows the distribution of the measured noise over the frequency spectrum rather than its absolute level.

Figure 6 shows the use of the noise analyzer to determine the effectiveness of sound-proofing on an exhaust fan. The 500-cycle band filter was employed in securing the data. The sound-proofing material produced a loss of between 15 and 20 db throughout the audible range. The great value of this type of study is not only that it gives an indication of the general lowering of noise resulting from insulation, but that it would clearly show if the material were less effective at some frequencies than at others.

I

Apparatus used in the chemical laboratories for micro-distillation.

II

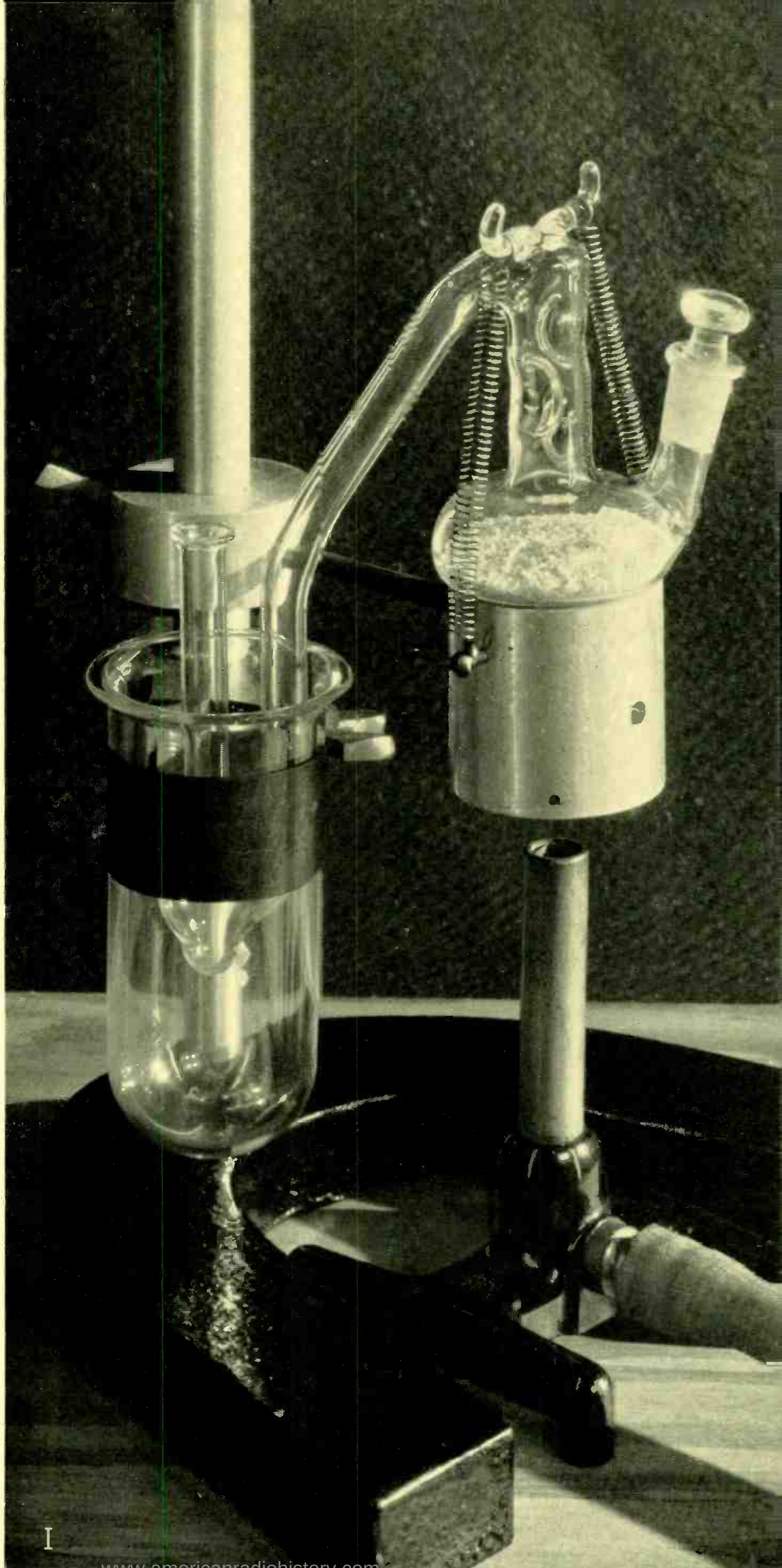
A bay in the Long Lines test room in Cleveland where trials under field conditions have been conducted by Laboratories engineers. The panels in the foreground carry frequency conversion circuits for an experimental service of reference frequency.

III

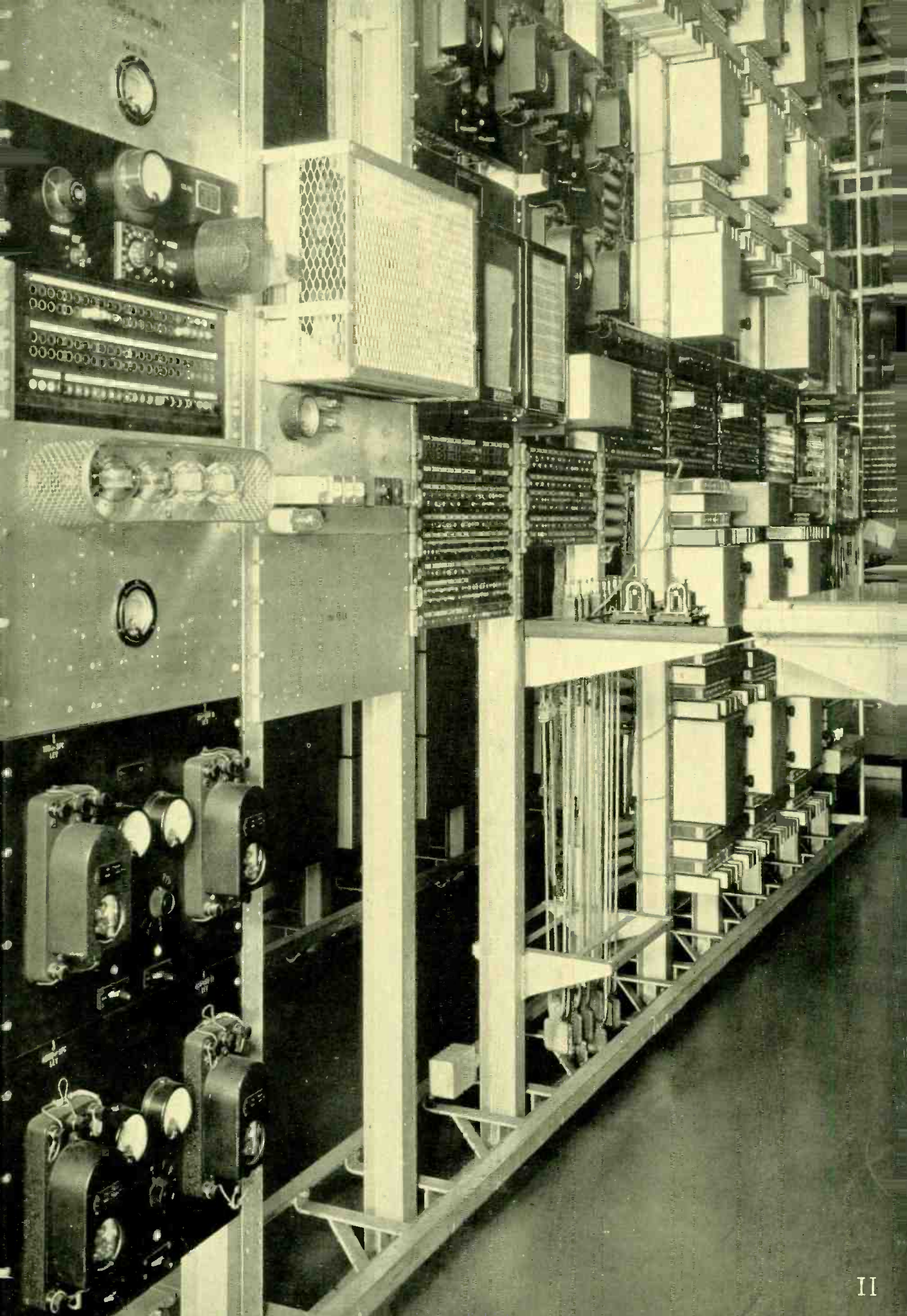
Hundred-watt radio transmitter for police use, designed by the Laboratories for the Western Electric Company.

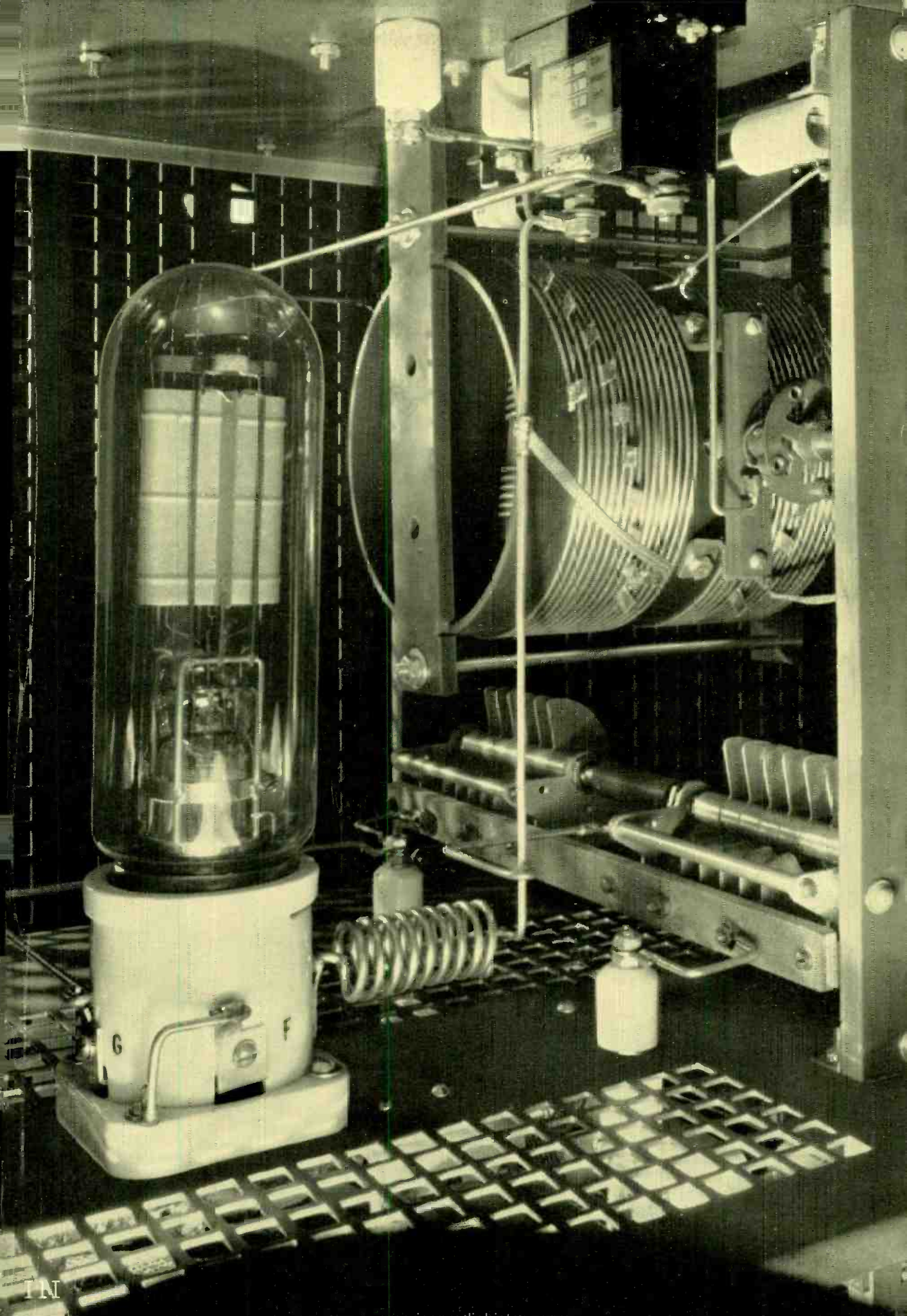
IV

Experimental tube used to study electrical breakdown in high vacuum.



I

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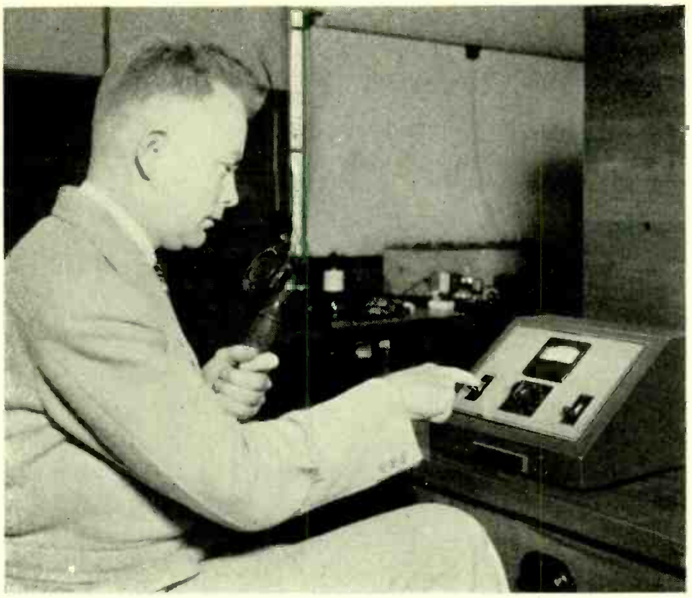


A Small Radio Transmitter for Police Duty

By F. E. NIMMCKE
Radio Development

THE effectiveness of police radio communication systems in the apprehension of criminals can be judged by the widespread popularity that such systems have gained. To cover their extensive service area, the larger cities usually install several transmitters each rated at the maximum authorized power of 500 watts. Western Electric 500-watt transmitters have been giving excellent service in New York, Chicago, and other large cities of the country. For the smaller communities, a centrally located transmitter of moderate power output will generally be adequate to cover the local area. To meet their needs, the Laboratories has recently developed an efficient and inexpensive 100-watt transmitter which makes small demands on space and is simple to operate. Its usefulness is not limited to the smaller urban areas, however, since many large cities may be most effectively covered by a number of small transmitters each covering a portion of the total area.

The range of a transmitter of this size depends both on its location and on its frequency. In general the coverage is somewhat greater in the middle west than along the two coasts. Representative ranges are shown in Figure 1. Modern sensitive receivers for police work require approximately 0.5 millivolt per meter for a satisfactory signal, and the curves show that signals of this strength will be obtained at distances from six to twenty miles.

The new transmitter may be adjusted to any carrier frequency between 1500 and 3000 kc, and can be operated at 50 watts to meet the requirements of the Federal Communications Commission for communities with a population of 100,000 or under, or at 100 watts for communities of population between 100,000 and 200,000. It consists of the radio transmitter itself, shown in Figure 2, and a control unit shown in the illustration at the head of this article. No external batteries, rotating machinery, or speech input equipment are required. The power needed, approximately 1000 watts, is all taken from a 50- to 60-cycle single-phase source at 110 volts.

The transmitter may be installed in any dry, well-ventilated room. It does not need to be in the same room as the dispatching officer nor where the antenna lead enters the building. Power from the transmitter to the antenna is efficiently transmitted over a concentric transmission line and an antenna coupling unit. The control unit, coded the 20A, also may be installed in any convenient place. It permits the operator to apply carrier to the antenna system, to adjust the speech level for proper modulation, and to monitor the modulated carrier. The announcements may be made either from the control unit or from some remote point over special telephone conductors.

A quartz crystal oscillator is employed to supply the carrier. The crystals are so cut that their temperature coefficient is practically zero, and as a result no temperature control is required. A slight adjustment is provided, however, to allow the oscillator to be set to the assigned frequency. Following the oscillator are two intermediate radio frequency amplifiers and a balanced output amplifier in which modulation is effected by the grid-bias method. Two stages of audio-frequency amplification are provided, together with rectifiers for both plate and grid-bias voltages with their associated filters and all necessary control and protective circuits. The number of meters and controls, as may be seen from Figure 2, have been reduced to a minimum, thus simplifying the operation of the set.

The grids of the final push-pull amplifier are biased to considerably beyond cut-off, and the radio-frequency voltage is applied to them out of phase. The audio-frequency voltage, on the other hand, is applied to both grids in phase and effectively in series with the fixed grid-bias voltage. In this way the grid-bias voltage is varied in accordance with the audio-frequency modulating voltage. By changing the bias in

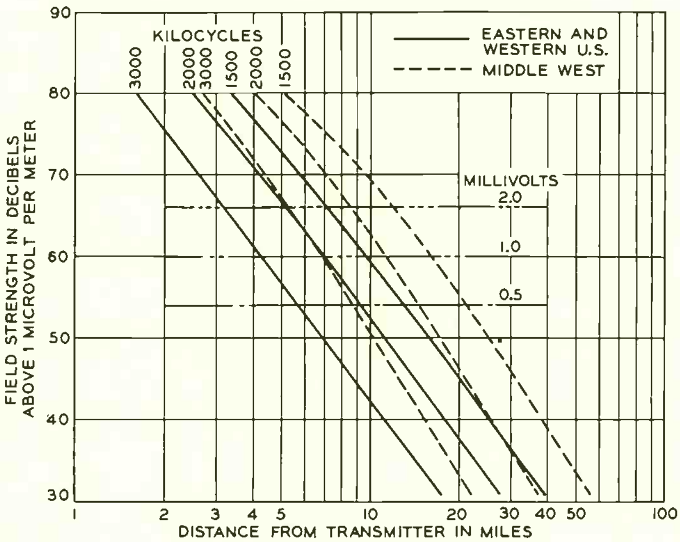


Fig. 1—Relationship between strength of signal and distance for 100-watt transmitters at various carrier frequencies

this manner, the radio-frequency output voltage is varied between zero and twice normal value, which constitutes complete modulation. The output impedance of the amplifier is such that the relationship between input and output voltages is essentially linear.

The audio-frequency amplifier has sufficient gain so that with the speech level obtained from the ordinary desk telephone set, the carrier will be completely modulated. The overall audio-frequency response of the transmitting equipment is practically flat over a wide range of voice frequencies. Monitoring is accomplished by means of a resistance connected in the high-voltage return lead of the final amplifier stage. The audio-frequency component of the rectified carrier appears in this circuit, and by listening with a headset, a true indication of the quality of the transmitted message is observed.

The primary purpose of the control unit is to permit the operator in charge of the transmitting in small communities to perform other duties besides dispatching calls. This unit includes a transfer key, a volume control, a modulation meter, a tone key, and jacks for the microphone and monitoring headset. The transfer key permits the dispatcher to select either the local microphone, plugged to the control unit, or a remote microphone reached by special telephone conductors. With this key in either position, high voltage is applied to the transmitter. The modulation meter, of the rectifier type, is calibrated in per cent modulation, and is in the circuit for either the local or remote positions of the transfer switch. Its indication guides the adjustment of the volume control.

Preceding the dispatching of a message, it is customary to send out an "attention" tone, which is the purpose of the tone key. A small audio-frequency oscillator in the control unit supplies the tone. Operation of the key disconnects the microphone from the speech input equipment and connects the oscillator to it. This tone is also employed at regular intervals for sending out time signals.

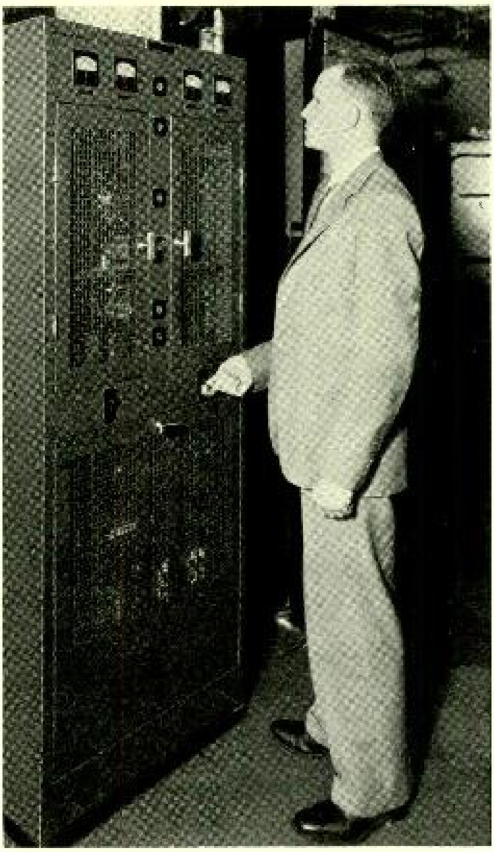


Fig. 2—The new 100-watt transmitter, known as the 15A, makes small demands on space and is simple to operate

The power-control and protection circuits guide the sequence of application of power to the various circuits of the transmitter, and protect the equipment from possible damage in case of failure of any of the apparatus. All power but the high-voltage plate potential is turned on by one of the switches on the front of the cabinet. The high voltage is applied either by a second switch on the front of the cabinet, or by the transfer switch of the control unit. This provides almost instantaneous application of the carrier, thereby minimizing delay.

Installations of the new 309A Radio Transmitting Equipment, as the combination of transmitter and control unit is called, have already been made at Tampa, Florida, and in Kenosha, Wisconsin. They are proving highly satisfactory, and should find many more applications in the near future.

Remarks of President Walter S. Gifford

of the American Telephone and Telegraph Company during the broadcast celebration of its fiftieth anniversary

"The American Telephone and Telegraph Company is fifty years old. It has become a great American institution. It is owned by you and your neighbors in every state in the Union. It belongs to 'Main Street.' More than half of its nearly seven hundred thousand stockholders are women.

"Its nation-wide organization, existing in substantially the same form for half a century, makes possible telephone service as we know it today. A telephone call is so easy to make that the person making the call has no idea of the complicated physical equipment and the vast organization of workers behind it. Now, it obviously does not just happen that practically anyone, anywhere, any time of the day or night can talk promptly with anyone else, anywhere in this country—or for that matter almost anywhere in the world. Nor does it just happen that the number of telephones per hundred of population in the United States is more than sixteen times the average of that for the rest of the world and is nearly 50 per cent higher than in any country in Europe. It is the result of the free play of individual initiative and ability fostered and given free rein during all these years in an institution which recognizes the American ideal of equal opportunity for each individual to develop to the fullest his talents and personality.

"I want to express my admiration of the great army of telephone workers, over a quarter of a million in number, in all ranks of responsibility, who are engaged in operation, research, manufacturing and the many other activities necessary for furnishing telephone service to the 125,000,000 people of our country. These men and women are not only courageous and resourceful in emergencies, they are skilful and thoughtfully courteous in their day-to-day activities. They are determined to 'get the message through.'

"In the Telephone Company, our policy and our method of operating are based on the long pull. We are celebrating one fifty years and looking into the next. Practically everyone uses the telephone; most of the money in the business is the life savings of people and most of the work in it is done by people who devote their lives to it.

"We shall continue our efforts to further improve telephone service and make it more economical for the user. We shall continue to try to keep the Bell System an attractive institution for people to work in and safe for investors. Above all, we shall continue to strive to merit the good-will and the esteem of our fellow citizens and to keep the American Telephone and Telegraph Company an institution that the American people can be proud of."

A Bridge for Measuring Small Phase Angle

By C. H. YOUNG
Transmission Apparatus Development

An electrical impedance is a complex quantity and thus requires two parameters for its full description: either its absolute value and an angle, called its phase angle, or its two right-angled components, resistance and reactance. In calculations involving impedance, one or the other of these pairs of parameters is employed—which is chosen depending on the type of problem. In many problems in electrical communications an expression of impedance in terms of its absolute value and phase angle simplifies the calculations, and so is generally employed. In measuring an impedance, on the other hand, it is usually more convenient to measure its resistance and reactance components. Because of the use to which the data from such a measurement will be put, however, the measurement is usually spoken of as one of phase angle.

An ideal resistor would be an impedance with zero phase angle, but this ideal can seldom be attained without the sacrifice of other characteristics even more important in precise work. Many of the resistors employed in communication apparatus and in laboratory measuring equipment, however, are required to have either negligible or known reactance components, so that apparatus must be provided for determining the two necessary parameters. To simplify the technique and increase the precision of such measurements a special type of impedance bridge has been designed and constructed in these laboratories. It will measure the reactance component of small phase angle resistors that may have any value between 0.01 ohm and 10 megohms at any frequency from 1 kilocycle to 100 kilocycles.

The bridge is of the unity-ratio comparison type employing resistance ratio arms. For measuring reactive components of resistors of small value, an inductance standard is provided by means of which a known inductance may be inserted in series with either the resistance standard or the apparatus under test. For resistors of larger value a capacitance standard is provided which may be placed across any one of the four arms. The complete bridge, which is slightly over two feet square, is shown in use in the illustration at the head of this article.

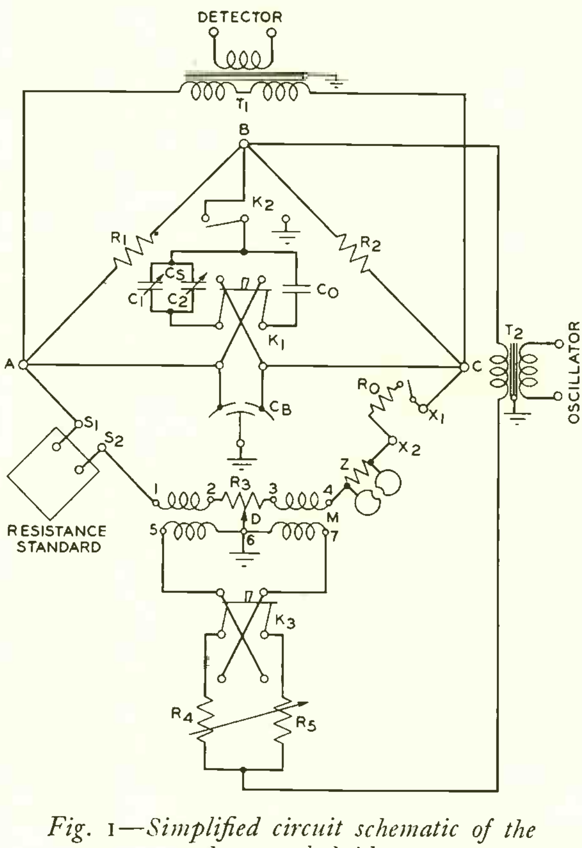


Fig. 1—Simplified circuit schematic of the phase-angle bridge

A schematic circuit diagram, with shielding omitted, is shown in Figure 1. The inductance standard, shown in the

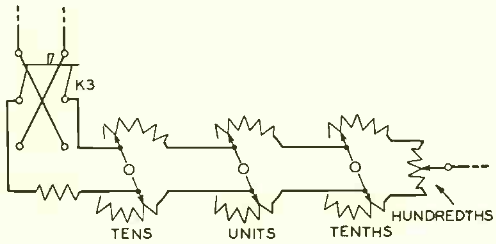


Fig. 2—Three double decades, a single decade, and a fixed resistance permit the total control resistance to be kept at 200 ohms, while the division between the two sides may be varied in steps of .01 ohm

diagram at M, is one of the unusual features of the bridge. It consists of a system of balanced windings on a common toroidal core of non-magnetic material, the coupling between the windings being fixed. The total mutual inductance between windings 1-2, 3-4, and 5-6-7 is 10 microhenrys. The currents through the two sections of winding 5-6-7 are controlled by the adjustable resistors R_4 and R_5. The arrangement of these resistors is such that their sum is constant at 200 ohms. With the control dials set at their zero positions, the balance condition obtains with 100 ohms in each branch. With the dials in their extreme positions there is no resistance in one branch and 200 ohms in the other. These resistors consist of a fixed 100-ohm unit, three double decades, and one single decade arranged as shown in Figure 2. The double decades are each operated by a single dial, while the single

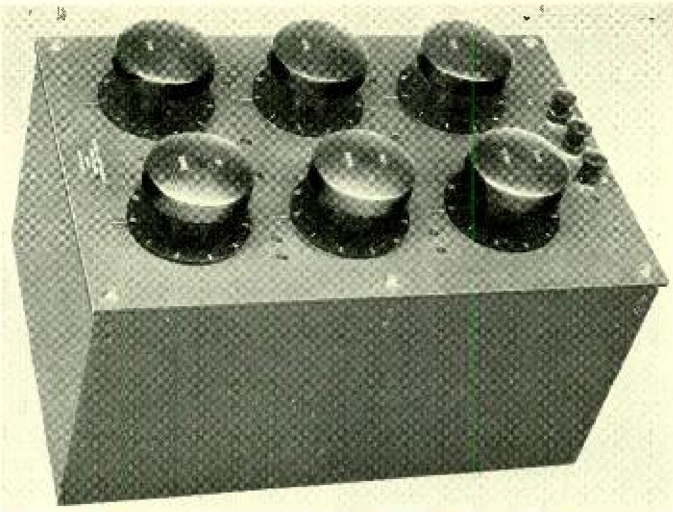
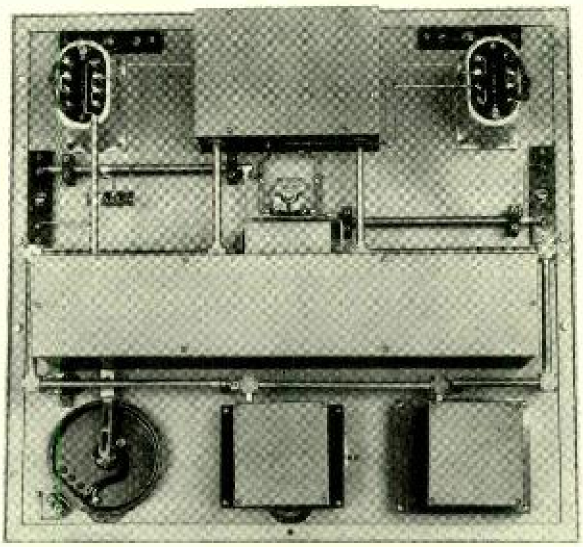


Fig. 3—Resistance standard used with the phase-angle bridge

decade serves as the feed point for the two branches of the inductometer.

When the dials are at their zero positions the current before entering the bridge divides equally between the two branches consisting of the resistors R_4 and R_5 and the balanced windings 5-6-7 of the coil. These currents induce equal quadrature electromotive forces in the windings 1-2 and 3-4 in the standard and unknown arms of the bridge respectively, and the system balances. If the dials are set at some other value, however, the currents no longer divide equally, and unequal electromotive forces are induced in the bridge arms, the effect being similar to adding self-inductance to one of the bridge arms. The decade arrangement thus makes it possible to add the total inductance of 10 microhenrys in steps of 0.001 microhenry, which corresponds roughly to the inductance of 1 millimeter length of large wire. The key K_3, which interchanges the connections between the decade resistors and the coil, permits the inductance to be added in either the standard or unknown arms as may be desired.

The inductance standard is generally adequate for measuring the phase angles of resistances up to 300 ohms. For resistances from 300 to 1000 ohms, the capacitance standard marked C_s on the diagram is employed. This consists of two air condensers, one having a range of 100 micro-microfarads in steps of 10 micro-microfarads, and the other being continuously variable over a range of 12 micro-microfarads. Two keys, K_1 and K_2, permit this capacitance to be placed across any one of the four arms. A compensating condenser,



Beneath-the-panel view of phase-angle bridge with shields in place.

C_n, having a capacitance equal to the residual value of C_s, is arranged in the circuit so that it is thrown across the arm conjugate to that across which C_s is placed. The capacitance C_s is ordinarily placed across the standard or unknown arms, but when the capacitance required exceeds that of C_s, an extension of the range of the capacitance standard is provided by placing it across one or the other of the ratio arms.

The resistance standard employed, shown in Figure 3, consists of six ten-step decades with a range from 0 to 11,111.10 ohms in steps of 0.01 ohm. As described in a previous article*, these decades have their units mounted in a rotor so that only one unit is in the circuit at a time. This arrangement materially reduces the distributed capacitances, and thus simplifies the phase angle calibration. For the smaller units, 0.01, 0.1 and 1.0 ohm decades, where inductance is more important, all units of the decade, including the short circuiting unit, are designed to have the same inductance. Used in conjunction with the resistance standard is a slide wire, marked R_3 in the diagram, employed for precise adjustment.

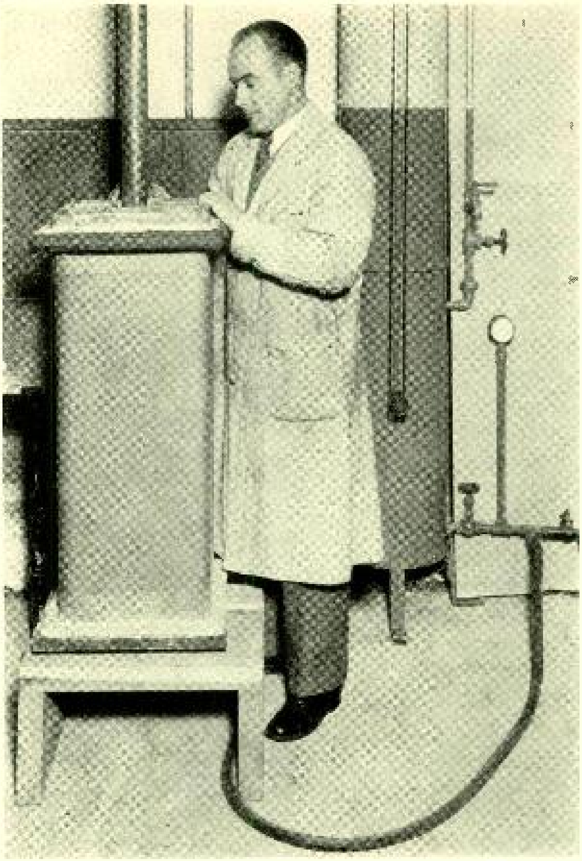
Besides these standard capacitance and resistance units, there is the variable air condenser C_B which is adjusted to balance internal capacitances of the bridge in the open circuit condition and the small impedance unit Z, which compensates for the residual impedance of the standard. The resistances of the ratio arms are of the woven-wire type described in the article already referred to. When the resistance to be measured exceeds 10,000 ohms, a fixed resistance of 10,000 ohms, R_0 in the diagram, is connected across the unknown.

This bridge provides a rapid and efficient means for determining small phase angles of resistance elements and networks. In addition, it is employed to calibrate the reactance components of adjustable resistance standards used in impedance measuring equipment in the Laboratories.

*Record, *Jan.*, 1935, *p.* 136.

The Edward Longstreth Medal

has been awarded by the Franklin Institute to Edmond Bruce "for his development of antennas for use in short wave radio communication, which has greatly improved trans-oceanic transmission and reception."



Conduit Plugs

By J. H. GRAY
Outside Plant Development

MANY thousands of underground ducts enter the basements of central offices of the Bell System to bring in the cables that link them to subscribers all over the country. Early in the development of telephone systems it was realized that these ducts might also serve as channels through which water and gases could enter, and thus be potential sources of flood and fire. High tides, heavy rains, or water from broken mains might easily gain access through these ducts to flood and damage the heating or power equipment; and gases, escaping from leaking mains or faulty sewers, could enter with equal ease if the ducts were not sealed at building entrances. In one instance an unusually high tide caused water to enter through inadequately sealed ducts in sufficient quantity to put out the fires under the boilers and to seriously threaten the power supply.

Similar conditions exist in the large office buildings, which may have one or several ducts entering their basements. In these buildings there may be several floors below the street level where valuable merchandise and equipment might be severely damaged by water if these ducts also were not adequately sealed. The sealing methods that have been employed are usually effective under normal conditions, but under severe conditions they may not always provide a positive closure.

The sealing of ducts naturally divides itself into two rather distinct problems. Many of the ducts entering a building are not yet occupied by cables, and under these conditions sealing is not so difficult. Plugs made of creosoted wood have frequently been used, or the openings have been plugged with ordinary oakum, and faced with cement mortar. Such plugs have generally proved satisfactory except when subjected to high water pressures. When the duct is occupied by a cable, however, the situation is somewhat more involved. It is generally necessary to resort to some caulking process, which is sometimes supplemented by a final application of a cementing compound. The difficulty of providing seals which would be adequate under all conditions, and of assured permanency, made it appear desirable to undertake a study of the subject with the objective of developing conduit plugs that would be effective, economical, and easily applied.

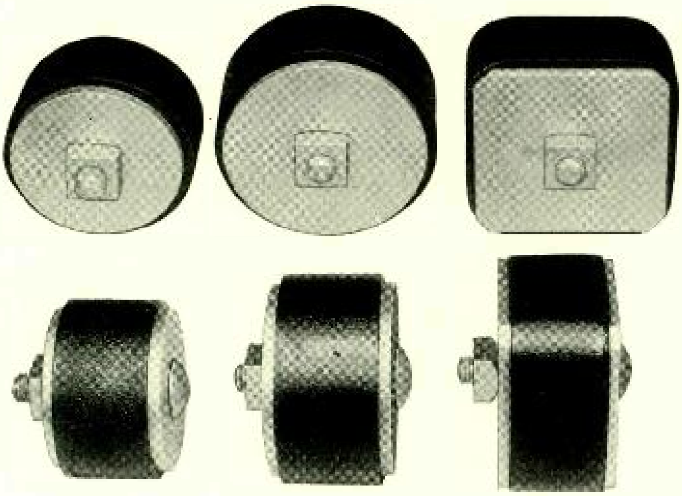


Fig. 1—Plugs for empty ducts are blocks of rubber compressed between steel end plates

As the result of this study, expansible rubber plugs have been developed and made generally available. Their operation depends on the simple principle that when a block of rubber is squeezed between two parallel plates, it will expand or bulge along the unconfined surfaces. The first application of this principle was to plugs for vacant ducts. The plugs designed are shown in Figure 1; those at the left being for round duct and that at the right for the standard square-bore clay conduit.

The plug for vacant ducts consists of a block of rubber compound, molded to conform to the shape of the duct and with a bolt-hole through the center; and two galvanized steel

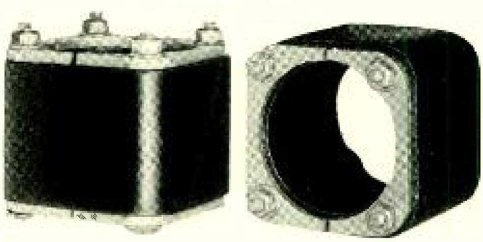


Fig. 2—For occupied ducts the end plates and plugs are split so they may be slipped over the cable

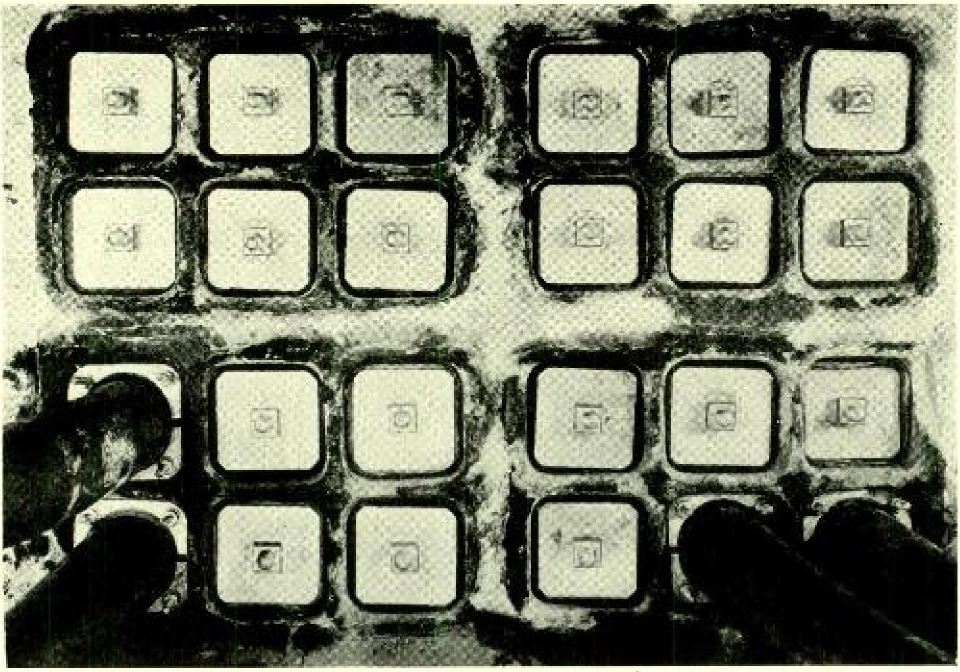


Fig. 3—A field installation of conduit plugs

plates, slightly smaller than the rubber part, with a galvanized carriage bolt passing through the center of the assembly. When the nut on the bolt is tightened, the plates are drawn together against the rubber, causing it to bulge out against the walls of the duct. The more the nut is tightened, the greater is the pressure of the rubber against the walls, and the more positive is the sealing effect. Care must be used not to overtighten the nuts, however, as pressures can be produced sufficient to rupture the conduit material.

The results obtained from laboratory tests and field trials of these plugs were so promising that work was undertaken to apply the same principle to seal ducts already occupied by cables. The problem was much more difficult, however. A full-sized cable, 2⅝ inches in diameter, leaves little space between itself and the walls of the duct in which to place a sealing device of any kind. Moreover the device had to be of a design that would permit its being placed over cables already installed and spliced.

With multiple clay conduit the ducts are from 3¼ to 3½ inches square, and since the cables are round, a little additional space is available at the corners. This space is sufficient to accommodate bolts of adequate strength, and consequently a molded rubber part was designed conforming to the shape of the duct on the outside and to the shape of the cable on the inside. The compressing plates were of the same shape but slightly smaller than the rubber plug. To permit the plug to be used on cables already installed, the rubber plugs were cut diagonally through one side, and the compression plates on each face were made in two parts. The arrangement is shown in Figure 2.

After the plugs had been designed and hand-made models obtained, it was necessary to find out what pressures of water and gas they would withstand. The first steps in this work were carried out in the laboratory, where conditions could be better controlled, and measurements more accurately made than in the field, while still maintaining a similarity to field conditions. For this purpose the set-up shown in the illustration at the head of this article was made.

A piece of standard nine-duct clay conduit was placed vertically on a low stand, and a reinforced cement collar was cast around each end to simulate the strengthening action of the walls of the building through which the duct passes. A short length of cable carrying one of the conduit plugs was then placed in the upper end of the middle duct. At the bottom end of the duct was placed one of the rubber plugs for vacant ducts, modified to allow a small pipe to be brought through it. This pipe was connected by a hose to a tank to which city water could be admitted. A pressure gauge is connected to read the pressure of the water in the duct, and any pressure up to full city water pressure may be obtained by allowing water to enter the tank and compress the air in the upper part of it.

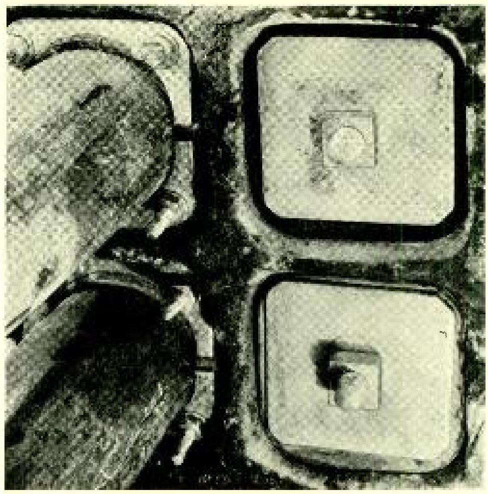


Fig. 4—A close-up of one corner of Figure 3 showing the bulging of the rubber when placed under pressure

To test the effectiveness of the plug to air pressures, water is admitted to the duct, and as it rises, the air above it is compressed. A small amount of water is poured over the upper surface of the plug, and any air leaking by it will cause bubbles and thus be detected. To test the plug with water, the air in the conduit is allowed to escape before the plug is tightened, so that the conduit will be full of water. The pressure of this water is then adjusted by changing the pressure in the supply tank as before. During these tests it was found that the plugs were actually tighter than the conduit itself; whatever minor leakage occurred under unusually high pressures resulted from the seepage of water and air through fine cracks and porous places in the conduit material and not around the plug.

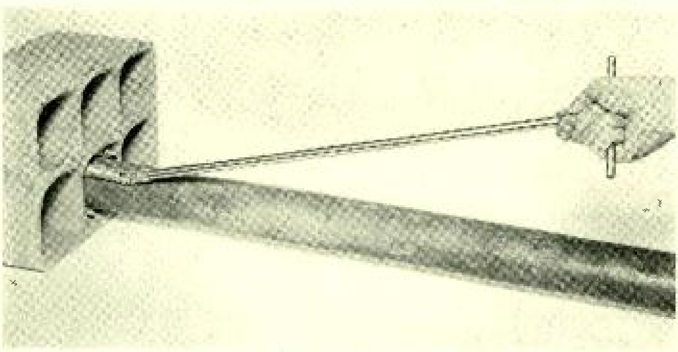


Fig. 5—A socket wrench with universal joint was developed to permit the bolts to be tightened when there are many cables crowded together

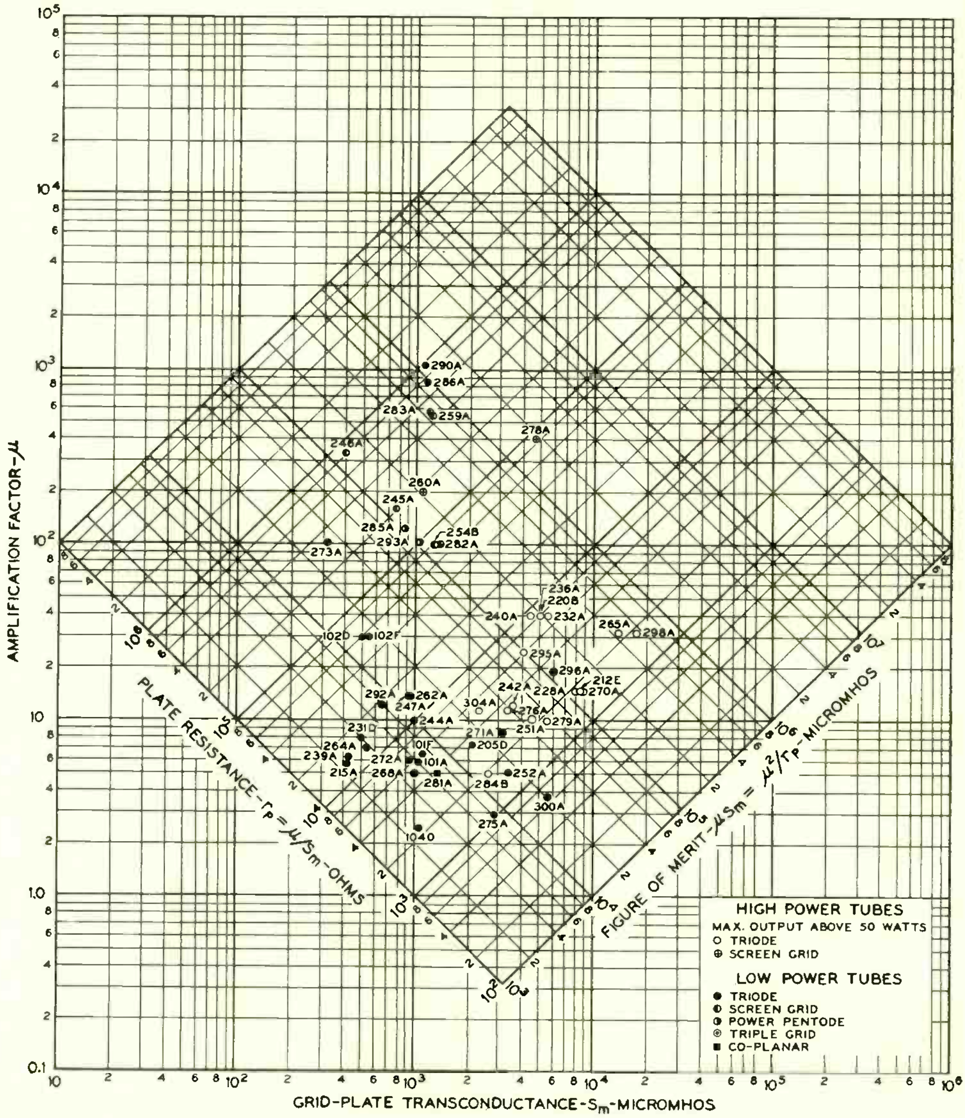
Following the success of the laboratory tests, preliminary installations were made in the field under actual service conditions. The most severe pressure conditions that could be found were selected, although the main objective was to observe how readily the plugs could be installed on cables that were badly out of shape at the duct entrance. Where the cables were badly bent at the ducts, considerable difficulty was experienced at first in sliding the plug along the cable into its place in the duct, because of friction of the rubber on the lead sheath and conduit walls. It was found, however, that by using soap and water as a lubricant this difficulty could be overcome. After certain minor changes had been made as a result of these preliminary tests and trials, the plugs were recommended to the operating companies on a broad trial basis. A typical field installation is shown in Figure 3. A close-up of one corner of this installation is shown in Figure 4.

In many places where the plugs must be installed, there is a maze of cables coming from a large bank of ducts. Under these conditions it is difficult to reach the nuts with any ordinary form of wrench. To meet these conditions a special socket wrench was developed with a long handle connected to it through a universal joint, as shown in Figure 5, permitting nuts to be tightened with the handle at a considerable angle with the bolt.

It frequently happens that plugs must be removed from the ducts after they have been in place for some time. Removing plugs from vacant ducts is comparatively easy with the tools available, but to remove plugs from occupied ducts, where there is the additional friction of the plug on the cable, is more difficult. The practice being followed to meet this difficulty temporarily is to loosen the four nuts and apply a pull to two diagonally opposite bolts with steel rods that have been drilled and tapped at the ends so that they can be screwed on to the ends of the bolts. This matter is being studied further, however, with a view to providing a more satisfactory method.

It was found that because of the compressibility of the rubber, a plug will seal around a cable which is considerably smaller than the size of the hole and consequently each plug can be used with several sizes of cables. Only a few additional sizes of plugs are required, therefore, to take care of all of the sizes of standard cables that usually range in diameters from 2⅝ to ½ inch.

Except for the problem of sealing around full size cables in round ducts, where the very limited space available for bolts has precluded the application of this design, these developments make available effective means of plugging both occupied and unoccupied ducts even against considerable hydrostatic pressure, thus disposing of a troublesome plant problem encountered often in the field.



This nomogram, prepared by G. L. Pearson, is analogous to one for circuit problems involving frequency, reactance, capacity and inductance, described by T. Slonczewski in the Record *for November,* 1931. *Having plotted the amplification factor* μ *as ordinate and the grid-plate transconductance (mutual conductance)* S_m *as abscissa, there is a point on this chart for every vacuum tube. Since plate resistance* r_p *is the ratio of these two quantities, one of a family of diagonal lines will indicate the value of* r_p *for any tube.*

Contributors to This Issue

F. E. NIMMCKE received the E.E. degree from the Polytechnic Institute of Brooklyn in 1923. After a year in the Westinghouse Graduate Student Course at East Pittsburgh, Pa., he spent two years as an instructor in the Educational Bureau of the Brooklyn Edison Company, New York City. In 1926 he joined the Radio Development Department of these Laboratories and since then has been occupied in the design and development of radio transmitters for broadcasting and police services.

J. H. GRAY graduated from Cornell University in 1917 with a C.E. degree. During the period of the war he served both in the French Army and in the United States Navy, and remained in France after the armistice to install American paper-mill machinery. In 1921 he joined the Department of Development and Research of the American Telephone and Telegraph Company, where he engaged in the development of outside plant materials and also of methods and structures for overseas radio telephone. At the present time he is engaged in the development of underground conduit systems with the Outside Plant Department of the Laboratories.

C. H. YOUNG received the degree of B.S. in Electrical Engineering from the University of Michigan in 1927. He at once joined the Technical Staff of the Laboratories, where with the electrical measurements group, of the Apparatus Development Department, he has engaged in the development of precise impedance measuring equipment and resistance standards with low time constants.

WALTER KOENIG, JR., received the A.B. degree from Harvard in 1923, remained for a year as instructor and research assistant. In 1924 he joined the Department of Development and Research, where he was associated with the group that, after consolidation with the Laboratories, became the Transmission Development Department. Mr. Koenig has been concerned chiefly with studies relating to transmission quality, which included analyses of the physical characteristics of speech and the structure of telephone conversation.

F. E. Nimmcke

J. H. Gray

C. H. Young

W. Koenig, Jr.

W. J. Thayer

T. G. Castner

Before joining Bell Telephone Laboratories in 1920, W. J. Thayer had been engaged for several years in railway signal engineering work. After becoming a member of the Technical Staff of the Laboratories, he spent about a year with the specification group, and then joined the Apparatus Development Department. Here he engaged for a short time in the development of substation apparatus, and was then assigned to the group developing audiometers, audiphones, and laboratory and testing apparatus. With this group he took part in the original development of both the buzzer and phonograph types of audiometers and the pocket and purse type audiphones. About six years ago he returned to the group with which he was earlier associated, and is now engaged in the development of station apparatus.

T. G. Castner graduated from Drexel Institute in 1925 with the degree of B.S. in Electrical Engineering, and spent the following year in graduate work in physics at Columbia University. In 1926 he joined the Technical Staff of the Laboratories where he engaged in general transmission and noise studies with the Research Department. At the present time he is in charge of transmission-quality testing and of the development of quality testing apparatus and methods.