BELL LABORATORIES RECORD

BROAD-BAND CARRIER SYSTEMS
H. A. AFFEL

MEASUREMENTS AT HIGH FREQUENCIES
F. R. DENNIS—C. H. YOUNG

MESSAGE REGISTER CAMERA
W. HERRIOTT

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In this Issue

Broad-Band Carrier Systems 242
H. A. Affel

Measurement of Attenuation at High Frequencies 247
F. R. Dennis

A New Noise Meter 252
J. M. Barstow

A New Message Register Camera 257
W. Herriott

A 5-Megacycle Impedance Bridge 261
C. H. Young

Applying Solderless Cord Tips in the Field 266
L. N. Hampton

A New Ring for Distributing Frames 269
O. C. Eliason

Volume 15—*Number* 8—*April*, 1937

BELL LABORATORIES RECORD

Calibrating gauges to be used for testing cables by gas pressure

APRIL, 1937

VOLUME FIFTEEN—NUMBER EIGHT

Broad-Band Carrier Systems

By H. A. AFFEL
Toll Transmission Development

IN carrier transmission a number of telephone circuits are obtained on a single pair of conductors by using frequencies above the voice range. The greater the frequency range the more telephone channels can be operated on the same conductors. Carrier transmission is therefore attractive, but there are, of course, serious technical barriers, due to the tendency, in general, for the circuit losses and interference effects to increase as the frequency is raised, and to problems incident to the stepping up and down, and to separating the high frequencies. By 1918, these problems had been solved to a degree sufficient to enable the first multi-channel carrier-telephone system to be designed and put into commercial service. A later standardized system—the Type-C—which by using frequencies up to 30,000 cycles, provides three telephone circuits in addition to the regular voice circuit on a single pair of open wires, has been extensively applied all over the country.

In the meantime, development engineers have been working to widen the frequency range to obtain more circuits on a single pair of conductors, and to extend the usefulness of the method by applying it to the fine-wire pairs in cables as well as to open-wire lines. They have also been developing a new type of transmitting structure, especially suitable for transmitting very high frequencies, this being known as the coaxial circuit.*

From this work three new carrier systems are resulting. Because of the wide band of frequencies they transmit, these are all classed as broad-band systems. One system, for cables, whose development is fairly well completed, will give 12 telephone channels on each pair, using frequencies up to 60,000 cycles. Another, the coaxial system, in its experimental form, could be used to give 240 circuits, using a frequency range up to one million cycles. The third system under development is for open-wire lines, and will provide 12 telephone circuits in addition to the three circuits of the existing Type-C system and the voice circuit, 16 circuits in all on a single pair of conductors. The top frequency is 140,000 cycles.

Various features of these systems will be described from time to time in the pages of the RECORD so that with the details of construction we are not here concerned, but the wide difference in the frequency bands transmitted on the three types of conductors naturally raises questions as to the determining factors. A few points may be of interest.

On the open-wire lines the large gauge and wide spacing of the conductors are favorable to high-frequency transmission, but this exposed type of structure is difficult to keep free from unwanted currents induced by other nearby telephone circuits, by power lines, lightning, or other outside disturbances. The limiting factor in using higher frequencies on open-wire

*RECORD, *July*, 1935, *p.* 322.

lines has generally been induction or crosstalk between nearby circuits.

Until recently 30,000 cycles, the top frequency of the Type-C system, represented about the upper limit of transmission from the standpoint of keeping similar systems on different pairs from crosstalking unduly one into another. Crosstalk on open-wire lines is reduced by applying transposition systems; that is, the wires of a pair are crossed over at predetermined intervals so that the inducing potentials and currents tend to balance out. For high frequencies these transpositions have to be made very frequently and precisely. There have been certain important developments in the art of transposition designing during the last few years; also the spacing between the two wires of a pair is being reduced from 12 inches down to 6 or 8 inches so that there is a greater distance between the pairs and less direct pickup by each pair. These improvements will make it possible to raise the frequency to about 140 kilocycles, thus paving the way for the 12-channel carrier systems which are being designed.

The fine-gauge paper-insulated pairs in existing cables do not inherently make good high-frequency conductors; the attenuation is too great. This is offset to some extent by the shielding effect of the lead sheath, which largely excludes external disturbances, and thus permits greater amplification at repeater points than can be used with open-wire circuits. Even so, repeaters will be required at much more frequent intervals than for the open-wire line for a corresponding frequency of transmission. Here again, crosstalk between the pairs, which in cables are packed close together, is

New York terminal of the experimental coaxial system the practical limiting factor in determining the upper frequency and the number of channels which can be applied. Since the pairs in a cable are twisted, or in a sense transposed with respect to each other, in such a way that they can not be changed after having once been installed, there is no way of improving the crosstalk situation comparable to changing the transposition system as with open-wire lines.

It has been discovered recently, however, that it is possible to balance out, to a large extent, the crosstalk between the different pairs on which carrier systems are to be applied, by using small adjustable inductances or condensers. These balancing units will be connected at intervals between all the pairs involved. A separate balancing unit is required between a given pair and each of the other pairs involved. In this way the practical frequency range of operation on the cable pairs is being extended from a few thousand cycles to about 60,000 cycles.

In the coaxial conductor, the engineers set out to design a new structure which would combine the favorable low attenuation characteristic of the open-wire lines with the interference-free characteristic of shielded cable circuits. With such a structure a large number of circuits can be obtained on but one set of conductors, using a frequency range up to a million cycles or more if necessary.

In a coaxial unit, the outside tube is a good metallic shield at the high frequencies. If currents are induced from external fields, such as power circuits, static, or lightning, they tend, because of skin effect, to confine themselves to the outside surface of the tube, while the useful currents for the same reason are on the inside of the tube. The space between the inside conductor and the outside tube is largely air, which is a good dielectric having no losses. The spacing insulators of hard rubber fill up only a relatively small proportion of the space, and they are of low-loss material. Also, the tube conductor is particularly well proportioned to offset skin effect and thus reduce the series losses. It should be noted, however, that a very satisfactory high-frequency conductor can be made of a pair of wires separated by spacers within a metallic shield. Such balanced pair structures may also play a part in future high frequency transmission systems.

While these various broad-band systems have different frequency ranges, they have many common fundamental problems. Probably the most important is that of the repeater or amplifier. In all cases the repeaters are spaced much more frequently than is necessary for lower frequencies. The approximate intervals are: for the cable system, 16 miles; for the million-cycle coaxial system, 10 miles; for the open-wire system, 50 to 100 miles. This means using many amplifiers in tandem, which in turn means that each amplifier must be quite perfect. Elaborate regulating means must also be provided to make the amplifiers compensate for the varying attenuation of the line circuits with temperature or weather changes. The regenerative or negative-feedback type of amplifier, which has already been described in these pages,* is employed in the different broad-band systems. It has a tremendous advantage over older types from the standpoint of stability, freedom from battery variations, and in linearity or perfection of amplification. The improvement over other amplifiers in these respects is a hun-

*Record, *June*, 1934, *p.* 290.

dredfold or more, and thus puts the feedback amplifier in a class by itself for purposes of this kind.

Amplifiers require power, and the power plant designers have been busy producing new types of battery reserve plants for the auxiliary repeater stations which will be added between existing stations. For the coaxial system, means have been provided for transmitting the power for the repeaters over the structure itself.

The highest repeater amplifications, some 60 or 70 db, will be employed with the well-shielded conductors, that is, the cable pairs and coaxial systems. This is about 20 db, or about a hundredfold power ratio greater than amplifiers employed in the telephone plant in the past. It is interesting to note that here, for the first time, repeaters will be employed in which the degree of amplification is set, not by external interference, but by interference which arises within the conductors themselves — the so-called thermal noise or resistance noise*. The motion of the free electrons within the conductors sets up tiny electromotive forces which have a spread-out frequency distribution covering the entire frequency spectrum. This in effect is Nature's own limitation to the amount of amplification which can be employed in any system.

It should not be judged, however, that other interference problems are absent in the case of the sheathed conductors. For example, in the case of the cable-carrier system, there has been a particularly severe problem in reducing the man-made interference, which arises within telephone offices when battery circuits are broken by the operations of switches and relays. Each current break creates a tiny high-frequency oscillation, the effects of which are readily picked up by induction in the various cable pairs as they pass through the building. In applying the cable-carrier system, it is necessary, therefore, not only to shield the carrier pairs and apparatus in such offices but to keep this artificially created interfering current from traveling out along the other wires in the cable and crosstalking into the pairs used for carrier systems. High frequency filtering circuits will therefore be applied to all the non-carrier pairs where a cable leaves such an office.

A common part of all of the broadband systems is a group of modulating and filtering equipment that provides twelve voice channels over the frequency range from 60 to 108 kilocycles. In the system for cable circuits one of these groups is transmitted over a single pair of wires, but by a second step of modulation it is placed in the frequency band from 12 to 60 kilocycles. A similar group of channels on another cable pair is used for the return transmission.

The open-wire systems will use two of the 12-channel groups on each pair, one for each direction of transmission, the first placed by a step of modulation above 30 kilocycles, which is the upper limit of the present three-channel system, and the second, for return transmission, above it, with a top frequency of about 140 kilocycles.

The coaxial system, as at present being used experimentally, can transmit 20 groups in the frequency range from 60 to 1020 kilocycles, employing a second modulation for 19 of the groups. This, as noted, gives 240 channels. A similar coaxial provides the 240 opposite directional channels. Ultimately such systems will probably be arranged to transmit a considerably greater number of channels.

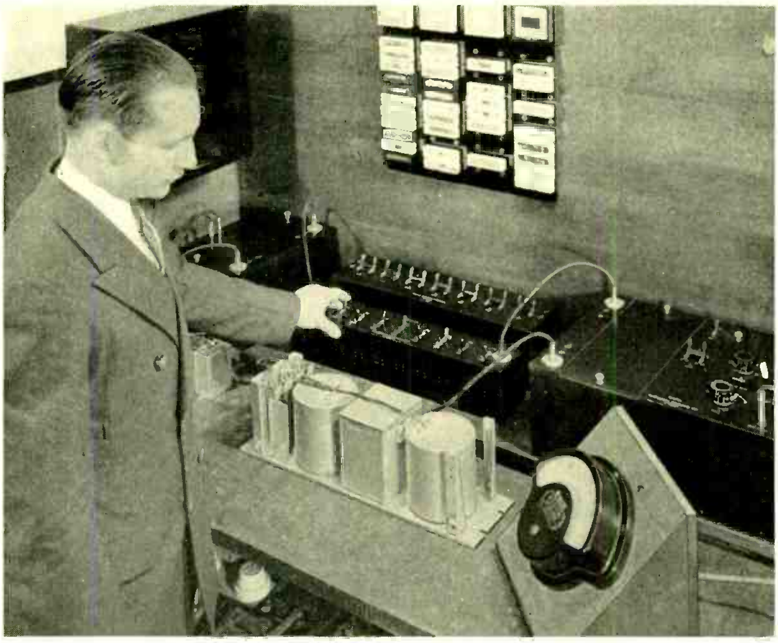
It is interesting to note that with

*Record, *February*, 1937, *p.* 185.

the coaxial and cable-carrier system it is found better to use different metallic circuits for opposite directional transmission than to use different frequencies on the same pair as has been a common practice on open-wire lines. One reason is that in these systems, repeaters will be needed so often, that the directional filters which would be necessary at each repeater point to separate the opposite directions of transmission would unduly increase the costs. In the open-wire systems, the attenuation is lower, as noted previously, repeaters will be 50 to 100 miles apart; and it is feasible to use directional filters. Furthermore, on open-wire lines there are no possibilities of getting the necessary high degree of opposite directional crosstalk separation except by using different frequencies. Separate pole lines are obviously impractical.

To summarize—broad-band systems will use much greater frequency ranges than has been practicable in the past. For the most part these broad-frequency ranges will be chopped up into narrow bands for telephone or telegraph purposes. Bands of several million cycles in coaxial conductors can if needed also be made available for television purposes. Each of the new systems will fill a useful place in the Bell System plant—the cable and open-wire systems, particularly where these lines already exist—the coaxial system where new structures are needed, and, in particular, on the heavy traffic routes. Of course, considerable complicated equipment is required and for the immediate future these various systems will probably be found economical chiefly for transmission over the longer distances.

One not obvious but important advantage deserves mention in closing. Broad-band systems are all being applied on non-loaded conductors. This means that they are high-speed systems whose wave velocity approaches that of light. As a matter of contrast, the older type, long-haul, four-wire loaded cable circuits have a velocity of only 20,000 miles per second as compared with 100,000 miles and upwards for the broad-band systems. On 20,000-mile-per-second circuits, problems of echoes are exaggerated and even two-way talking may be awkward on circuits several thousand miles long, because of the time taken for a talker at one end of a circuit to be heard at the other end, and to receive a reply. Broad-band high-speed circuits will practically relieve us of concern about matters of this kind.



Measurement of Attenuation at High Frequencies

By F. R. DENNIS
Apparatus Development

APPARATUS for measuring attenuation loss at high frequencies has received considerable attention by the Laboratories during the past few years. This has been found necessary because of new requirements imposed by broad-band carrier telephone systems. These systems include a large number of filters and equalizers, the design and production of which depend in part on having available accurate means of measuring their loss-frequency characteristics. The measurements are made by applying an electromotive force of known frequency to the equipment under test and to a standard attenuator and adjusting the attenuator until the loss is the same in both circuits. The attenuation of the equipment under test can then be read directly on the standard attenuator.

A fundamental circuit of the type used is shown in Figure 1. The output of an oscillator, which can be varied continuously in frequency from 50 to 5000 kc, is applied simultaneously to the input of the apparatus under test and the standard attenuator through terminating resistances. The apparatus and attenuator terminate at the other ends in resistances which are equal to the characteristic impedances of the apparatus and attenuator respectively. The detector is a superheterodyne and a microammeter indicates the point of balance because the ear cannot detect small enough differences in sound level to make head phones satisfactory for precision work.

The errors due to the inherent inductance and capacitance of the circuit increase with frequency. If the circuit impedance is made high, the error due to the shunt capacitance becomes predominant, and conversely if low the error due to the series inductance predominates. For the frequency range of this circuit, an impedance of 100 ohms was chosen as the best compromise. These limitations also prohibit the use of decade resistances for terminations and small plug-in resistors were, therefore, developed for the purpose. These resistors have a smaller phase angle than the decade type and allow the set to be kept more compact.

Losses of at least 80 db have to be measured to determine the attenuation peaks of filters. In making balanced-to-ground measurements of losses of this magnitude, longitudinal currents, which flow down both sides of the circuit and return through ground or by some other path, are the principal cause of error. Since these currents are not in general the same in either phase or magnitude in the two branches of the circuit, they result in a false balance if they flow into the detector. To reduce this error, the circuit is isolated at input and output with carefully shielded and balanced repeating coils. A grounded center tap on the measuring set side of the output coil gives a low impedance path to ground for the longitudinal currents. In addition to this it was found necessary to use wire having a very tightly woven copper-braid shield for all leads between the component parts of the set-up and to make sure that these wire shields are continuous with the external shields of the apparatus. This was done in the latest set constructed by using recently developed coaxial plugs and jacks for making all connections between the necessary leads and the apparatus.

In attempting to make high loss unbalanced measurements it was found necessary to construct the input and output sections of the measuring set in separate shielded compartments which were insulated from each other. This was required to eliminate multiple ground paths.

The absolute accuracy of the measurements made with a circuit of this kind is dependent upon the accuracy

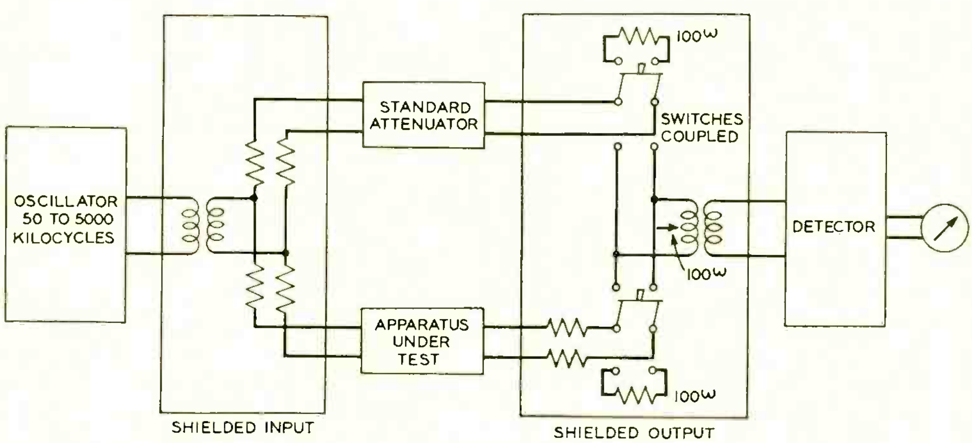


Fig. 1—Attenuation at radio frequencies is measured by comparing the loss in the apparatus under test with that of a standard attenuator

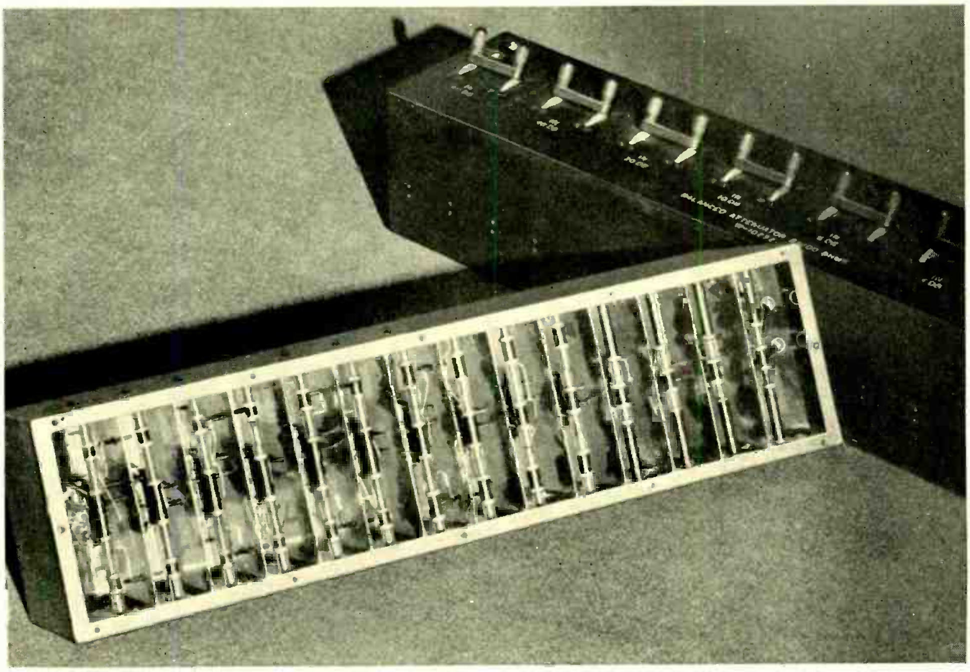


Fig. 2—Standard attenuator constructed with parallel-opposed resistance units wound on small glass tubes

of the attenuator used as a standard. It has, therefore, been necessary to develop attenuators having negligible frequency errors along with suitable measuring circuits. These attenuators are made of constant-impedance resistance networks provided with suitable means for switching. Any reactance in these resistances or in the associated switches and wiring results in increasing departure from the theoretical value of the attenuator as the frequency is increased. This undesirable effect has been reduced by taking advantage of recent improvements in winding low-phase-angle resistances. Two types are being used at present; one with a parallel-opposed winding on a small glass tube and the other, which may be wound to higher resistance values, of the woven wire type. In both forms the phase angle is negligible except for very low or very high resistance values.

Two types of both balanced and unbalanced attenuators which use these resistors have been developed. In one type, shown in Figures 2 and 3, the networks are cut in or out by means of double-pole double-throw keys. These are relatively inexpensive but have the disadvantage that the reactance of the keys and wiring of the networks not in use is still in the circuit. Rotary switches are used in the other type which represents a distinct improvement over previous switching methods.

An unbalanced attenuator of this type is shown in Figure 4. As may be seen the networks are connected directly between the switch contacts; this allows the wiring to be kept at a minimum. The construction of the switch is such that the spurious capacitances are extremely small; otherwise they would be very troublesome at the higher frequencies. The switch which has 10 db steps is double decked

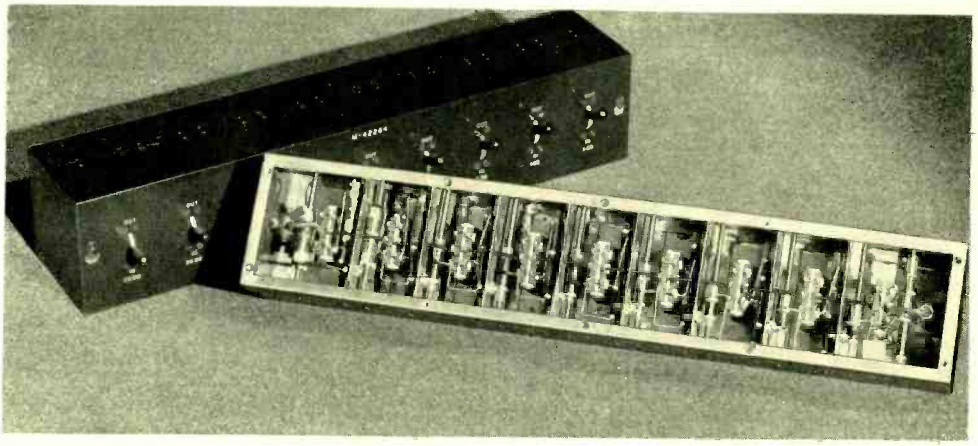


Fig. 3—The resistances of this standard attenuator are mounted in two rows with keys between to cut the units in and out

with a network in each deck for losses above 30 db. Splitting the higher losses into two networks in this manner keeps the series resistances from becoming unduly high and also helps to decrease the direct capacitance between input and output. A shield plate is inserted between the two decks and the complete switch is enclosed in a shielding box.

To reduce still further the direct capacitance between input and output of the switch it was necessary to include additional brushes to ground the adjacent network on either side of the one in use. Much thought and experimentation was required to work out the proper method of making the various ground connections on this attenuator, since the ground impedance must be properly placed in the circuit if accuracy is to be obtained at the higher loss settings. With attenuators of this type it is now possible to measure losses of 90 db at 5000 kc with an accuracy of 1 db. This is a considerable improvement over equipment previously available.

The oscillator must be extremely well shielded and must have high stability in amplitude and frequency if precision measurements are to be obtained. The detector must likewise be well shielded and must have high sensitivity and also stability. A tuned

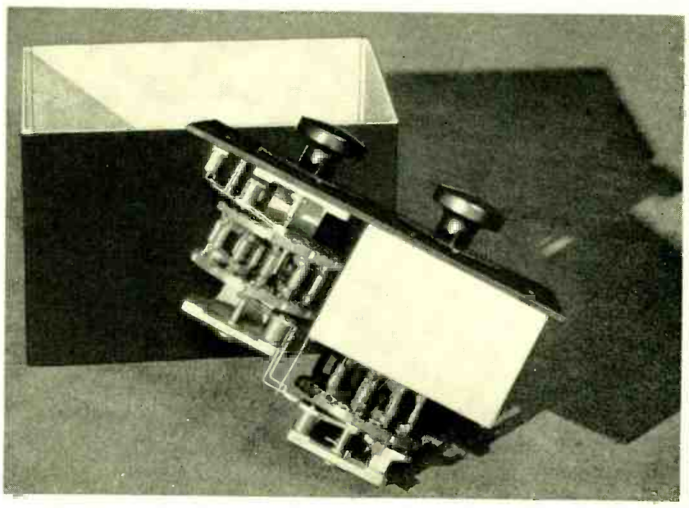


Fig. 4—Standard attenuator of the unbalanced type with rotary switches and woven wire resistance units

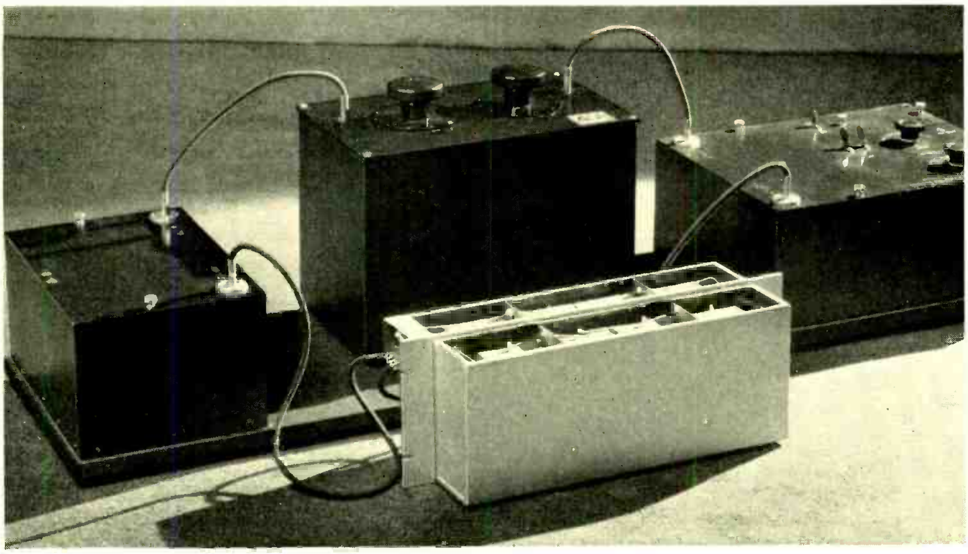


Fig. 5—The input and output sections of the measuring set are in separate shielded compartments with space for the apparatus under test and the standard attenuator

detector is necessary to prevent errors due to oscillator harmonics for measurements in the attenuating range of networks. A superheterodyne type of detector seems to meet all of the requirements in the simplest manner. The intermediate frequency is modulated by a built-in oscillator so that a frequency of approximately 1000 cycles is obtained in the output. In the latest form the indicator consists of a diode-triode rectifier tube with a microammeter connected in the plate circuit of the triode section. By proper choice of circuit constants a 3 db linear scale can be obtained on this meter which makes it possible to read a balance with a precision of 0.05 db. This meter can be calibrated at 1000 cycles and then serves as a check on the accuracy of the attenuator in the high-frequency circuit for small increases in attenuation. The use of a calibrated meter makes steps smaller than one or two db unnecessary on the attenuator and thus saves the expense of several additional keys or one decade. A further advantage is that the tube cuts off on overload so that it is impossible to damage the meter.

An attenuation measuring set embodying the latest developments is shown in Figure 5. The repeating coils are provided with plugs and are inserted in different jacks for balanced and unbalanced measurements. Two sets of coils are provided, one covering a nominal frequency range of 50 to 1500 kc and the other from 1500 to 10,000 kc. By the lower key the output coil is switched from the attenuator to the apparatus under test; the upper key gives a 180-degree phase shift in the input to the detector and thus serves as a check on the presence of longitudinal currents when measuring balanced apparatus. The equipment to be measured is connected between the jacks in the lower corners and those above either to a balanced attenuator or an unbalanced one.

The increased accuracy attainable with the new equipment will make it useful in development work where precise measurements of insertion loss at high frequencies are required.

A New Noise Meter

By J. M. BARSTOW
Transmission Development

SINCE the very early days of the telephone, efforts toward maintaining and improving the service have required some method of measuring noise on telephone circuits. At first a simple form of listening test was used, and the amount of noise tolerated depended largely on the judgment of those operating the telephone plant. This led to different standards in different localities, which naturally was not a satisfactory arrangement, and as a result the method was supplanted by the use of the 1A noise measuring set. This set incorporates a buzzer to produce a noise, and a potentiometer with which the noise volume may be varied over a wide range. By listening alternately to the noise on the circuit and to the output of the measuring set as the latter is reduced in volume by the potentiometer, it is possible to find the point at which the two may be judged to produce the same interfering effect, and the reading of the potentiometer at this position is a quantitative measure of the circuit noise.

Although the 1A noise measuring set was a great improvement over previously existing devices, the results obtained with it did not attain the degree of objectivity desirable, since they rested in the ultimate analysis on a personal subjective judgment. This judgment required the balancing of an adjustable amount of standard buzzer noise against the unknown amount of circuit noise, not on the basis of equal loudness but on the basis of the interfering effect of the noises on the interpretation of speech. If the buzzer and circuit noises differed greatly in quality the balance was difficult. Unless care and good judgment were exercised, two noises that were judged to be equivalent by use of the 1A set might be found to have different interfering effects on a transmitted conversation.

The defects of the 1A set were largely remedied in the 1A Noise Amplifier, brought out in 1929 for measuring noise in toll offices. This amplifier employed frequency weighting based on the then available data on the relative interfering effects of single-frequency tones, and used the 6A Transmission Measuring Set as an indicating device. By eliminating the ear as the basis for deter-

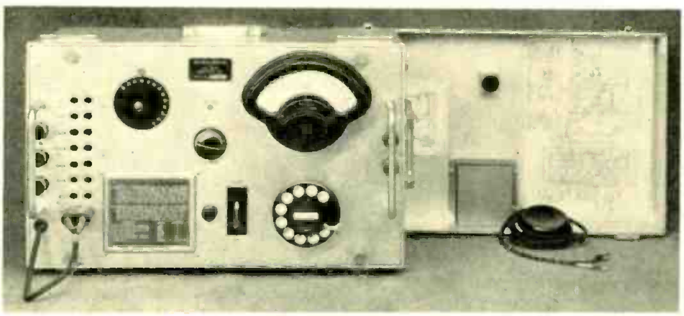


Fig. 1—The 2A noise measuring set, with cover removed, showing arrangement of apparatus on the front panel

mining the noise magnitude, a distinct gain in objectivity of measurement was made, but the set fell short of the ideal in other ways, such as portability, dynamic characteristics of the indicating instruments, and additional frequency weightings.

Recently a new noise measuring set has been brought out that goes much farther toward realizing the primary objectives of noise measurements. This set, shown in Figure 1, is known as the 2A noise measuring set, and incorporates the results of many years' research on the problem of noise measurement. It carries its own power supply in the form of dry cells, and is designed to be used as a portable instrument although brackets may be obtained for mounting it on central office frames when desired.

The interfering effect of noise depends, in general, on its frequency composition, on the relative magnitude and spacing of the various frequencies, on the duration of the noise, on the type of circuit on which it occurs, and on the person who is listening to it. This large number and variety of factors very greatly complicates the design of a satisfactory noise measuring set. The subjective element of noise is largely eliminated by employing a meter to give the indication of noise; but before such a method can be satisfactorily used, much research must be done to determine the interfering effects of different noises on speech as heard by the ear, and then circuits must be incorporated in the set between the noise input and the meter to simulate the action of the ear.

Since the effect of noise depends to a very large extent on its component frequencies, a weighting network is incorporated in the set to attenuate the noise frequencies in inverse ratio to their interfering effect. The importance of various frequencies depends, however, on the type of circuit and on the position in the circuit where the noise is being measured. On an ordinary telephone circuit, for example, which does not efficiently transmit frequencies above about 3000 cycles, a noise frequency of 5000 cycles would

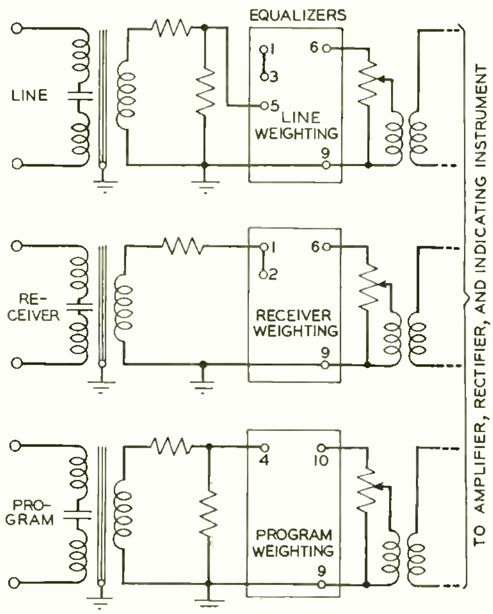


Fig. 2—Circuit arrangement of noise set when connected through "line" jacks, "receiver" jacks, and "program" jacks

have little effect, while on a program circuit a noise of this frequency might be very objectionable. Similarly the subscriber's telephone set, including an induction coil and a condenser, affects the frequencies transmitted—chiefly in attenuating low-frequency voltages. The weighting which should be used in the measuring set would be different, therefore, depending on whether the set was to be used at a subscriber's receiver or at a toll office.

If the noise were of a single frequency, these networks would insure that its measured effect would be that determined by the average ear for representative amplitudes of both speech and noise; but when, as is usually the case, the noise comprises many frequencies, the action of the ear in combining different frequencies must also be considered. The measuring set includes a rectifier for converting the alternating noise current to a direct current for actuating the meter, and this rectifier is designed to combine the weighted noise currents in such a way that the sum is approximately equal to the square root of the sum of the squares of the weighted components. Tests have been made which show that this rule of combination is similar to that in the ear for a number of common noises.

After all these adjustments of the noise have been made, the period of duration of the noise must still be considered. As a result of considerable research, it has been found that for the usual noises found on telephone circuits a time of about 0.2 second is required for the noise to be fully appreciated by the ear. To incorporate this factor into the measuring set, the indicating meter has been given such dynamic characteristics that a noise enduring for 0.2 second will produce the same deflection that a continuous noise would, while noises of shorter duration produce proportionally smaller deflections. For intermittent noise, such as static, this dynamic characteristic makes the meter somewhat more difficult to read, but by establishing rules for reading the meter on intermittent noises, approximately equal meter readings can be obtained for both steady and intermittent noises having equal interfering effects.

Besides these elements already discussed, the noise set must also include a coupling or connecting circuit so as to present a suitable impedance to the circuit to which it is to be connected. The complete measuring set thus includes an input circuit, a weighting network, an attenuator, an amplifier, a rectifier, and an indicating meter. The last four elements will remain the same regardless of the type of circuit or the point of measurement, but provision must be made for suiting the weighting and input networks to the particular measurement being made. This is accomplished by incorporating in the set the various networks required, and by providing on the front of the instrument, evident at the left of Figure 1, a number of pairs of jacks—each connected to the amplifier-rectifier circuit through input and weighting networks suitable for the various types of measurement. Connection from the line under test is usually made to a pair of binding posts, and a plug—connected to these binding posts inside the set—is

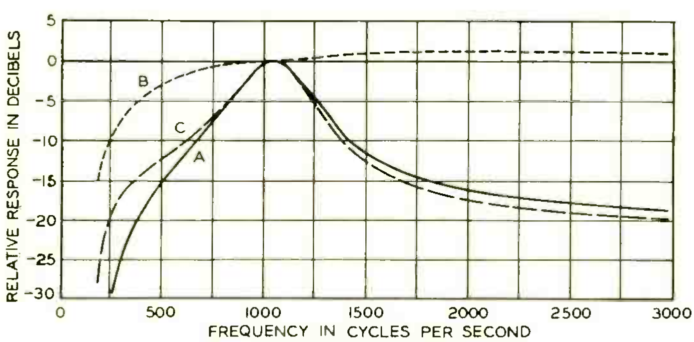


Fig. 3—Characteristics for frequency-weighting networks used with 2A noise measuring set: Curve A shows that for the "line" position and curve C that for the "receiver" position. Curve B represents the frequency characteristic of voltage transmission between the line and the receiver, which is the difference between curves A and C

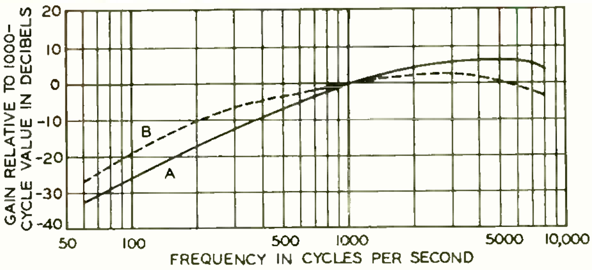


Fig. 4—Weighting curve for program circuits, curve A, and for sound and volume measurements, curve B

employed to make connection to the proper input circuit.

The bottom pair of jacks is marked "line," and is used for measuring noise on a telephone circuit at some other place than the subscriber's receiver—for example, at the toll office. Its input circuit presents an impedance of 600 ohms so as to match the line impedance. The circuit arrangement is shown at the top of Figure 2. The weighting network used for this connection has the characteristics shown by curve A of Figure 3. This curve represents the sum of two weightings, viz., a frequency weighting for the relative interfering effects of single frequency voltages in the telephone receiver (curve C) and the frequency characteristic of the circuit between the line and receiver (curve B).

When measurement is to be made at the subscriber receiver, the set is connected across the receiver and has a high input impedance. The circuit employed, shown in the center of Figure 2, has an impedance of about 2000 ohms. A different weighting network is required for measurements at the subscriber's receiver because of the frequency characteristic of the attenuation between the line and receiver terminals of the telephone set, which is indicated by curve B of Figure 3. The weighting characteristic provided is therefore that shown by curve C which differs from curve A by the attenuation characteristic of the telephone set being measured.

For measurements on program circuits, the arrangement is somewhat similar to that for the "line" connections, as shown in the lower part of Figure 2, but a different weighting characteristic is required because of the wider transmitted band of frequencies. The characteristic employed is shown as curve A on Figure 4.

While these three types of measurements are those that will be most commonly employed, the usefulness of

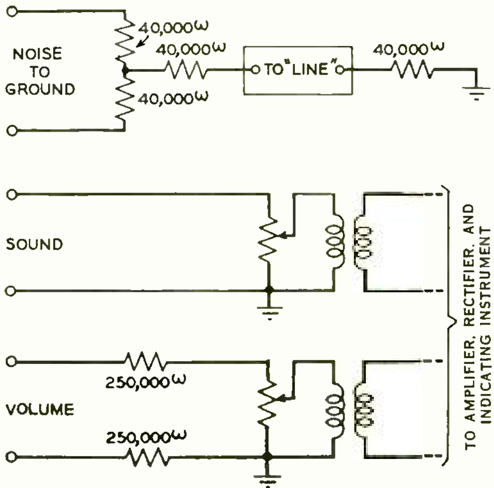


Fig. 5—Circuit arrangements for measurements of noise to ground, above; of sound, in center; and of volume, below

the set has been widened by providing jacks for four other types that prove advantageous under various conditions. It is sometimes desirable, for example, to measure noise on a telephone circuit without breaking the circuit. To make this possible a "bridging" input circuit is provided, which presents an impedance of about

6000 ohms. The output of this circuit is connected to the input of the "line" circuit, and it thus uses the same weighting network.

In making any of these measurements the potentiometer is turned until the meter pointer is on the scale, and the noise magnitude is then the sum of the readings of the potentiometer and the meter—the potentiometer having a range of 60 db, and the meter, of 18 db. Reference noise in all cases is the meter reading that would be obtained with 10^{-12} watts of 1000-cycle power dissipated at the point of measurement.

Another input circuit, shown at the top of Figure 5, makes it possible to measure noise voltage to ground. This measurement is often desirable when it is expected that large longitudinal voltages are operating through circuit unbalances to cause metallic-circuit noise. This circuit consists of a 100,000-ohm input circuit and the "line" input circuit in series. Reference noise to ground is that which will cause a zero reading on the meter when arranged for noise-to-ground measurement.

A "sound" input circuit, shown schematically in the middle of Figure 5, permits the set to be used, with the aid of a microphone and matching transformer, for measuring sound levels. Minimum measurable level depends on the sensitivity of the microphone and the efficiency of the transformer, but with the 630A microphone and the 115A repeating coil, sound levels as low as about 55 db above reference sound level can be measured. The weighting employed is that shown by curve B of Figure 4. Reference sound level corresponds to 10^{-16} watts per square centimeter at 1000 cycles in a free progressive sound wave in the open air.

By use of the "volume" input, shown schematically in the lower part of Figure 5, volume measurements may be made on message circuits, but not on program circuits, because the response of the volume circuit is not flat, the weighting being the same as for the "sound" circuit. The relatively low response in the volume circuit at low frequencies is not of great importance in measuring message circuit volumes, but causes serious errors in measuring volumes on program circuits.

The upper pair of jacks and the telephone set dial are used for calibrating the set. Operation of the dial sets up a train of waves which impress a predetermined input across the set. The gain of the amplifier is then adjusted until the peak swings of the meter pointer (ignoring the first deflection) are on a red line marked on the scale. This method gives a calibration for all circuits by a single operation.

Although the 2A Noise Measuring Set is not a perfect instrument for all conditions, the results of a wide range of tests indicate that it agrees better with tests of the effects of noise than does any other apparatus available. Its applicability to a wide variety of conditions should make it very useful in maintaining satisfactory noise conditions in the telephone plant.

TELEPHONE
TRANSMITTER
LABORATORY

I

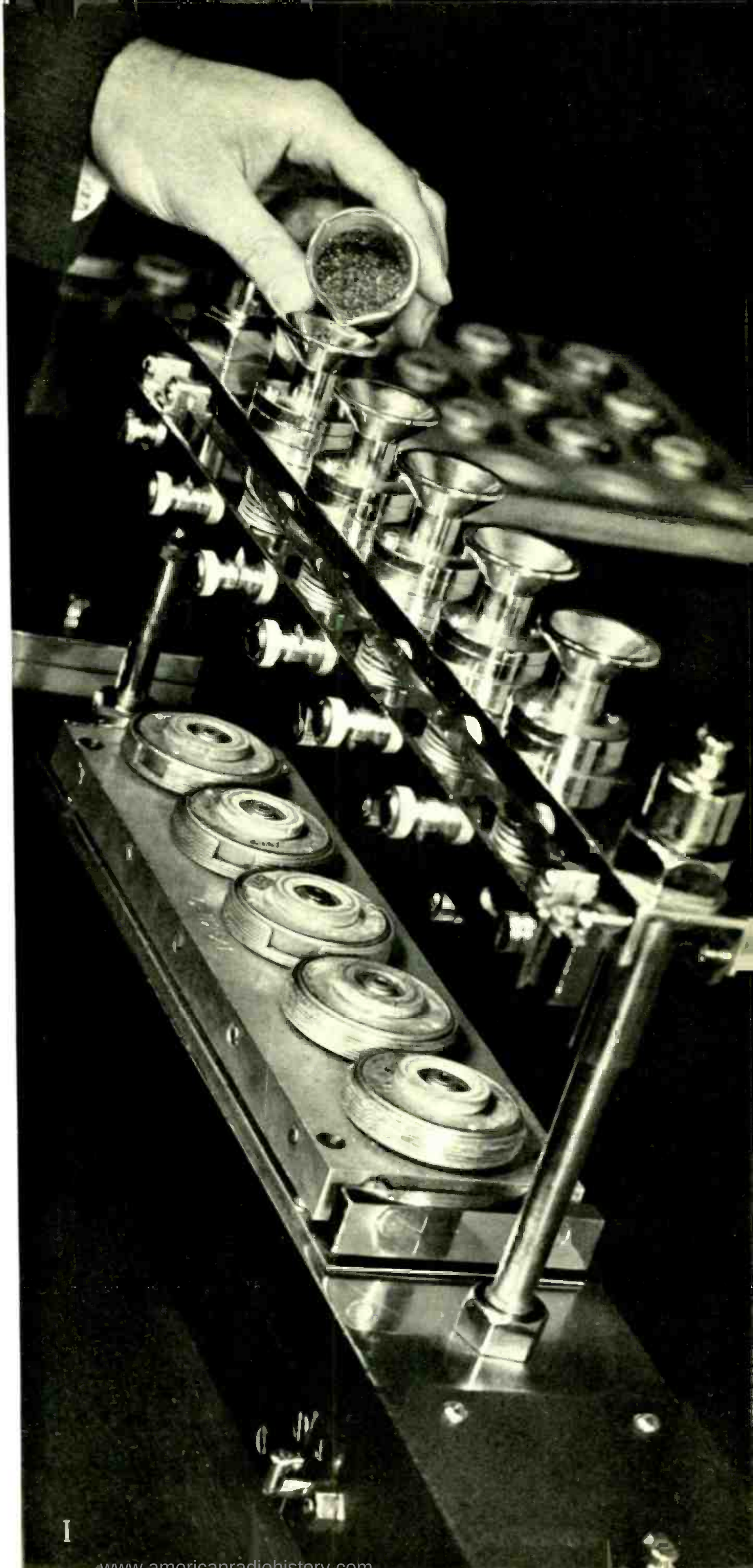
Uniform fullness of transmitters is secured by controlled agitation of this filling machine

II & III

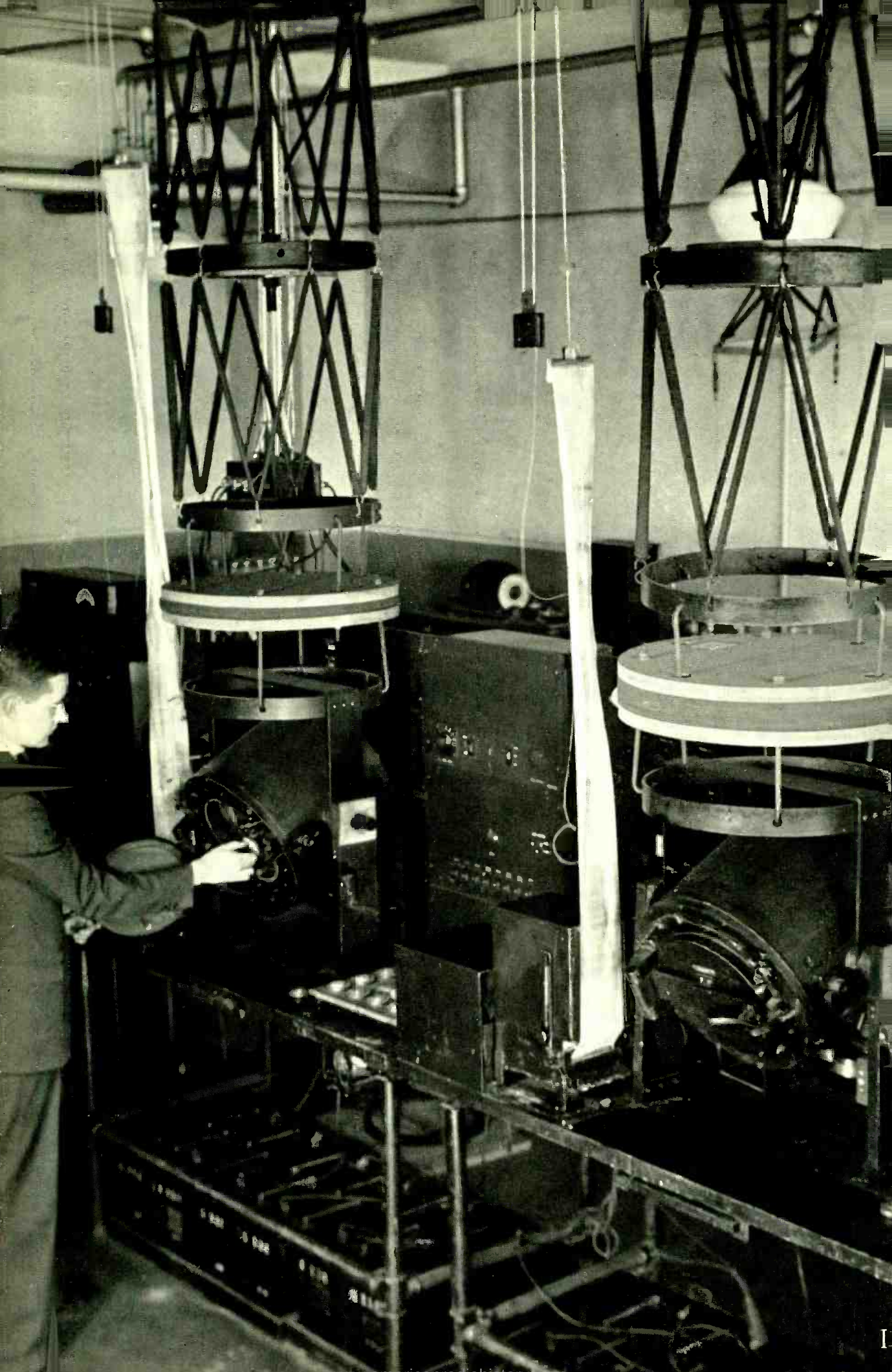
To measure internal noise, a transmitter is carefully shielded from vibration in this spring-suspended chamber

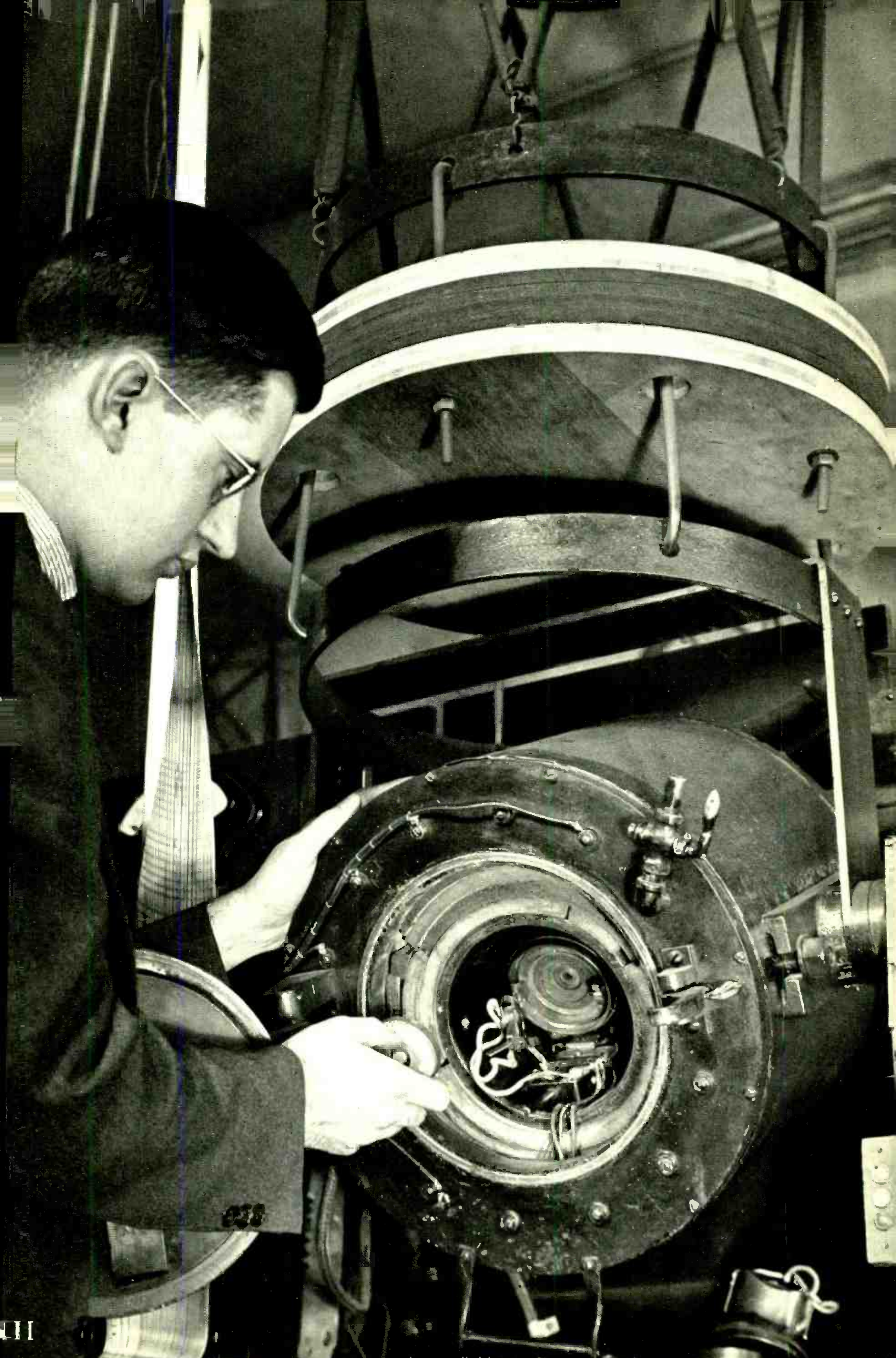
IV

Simulating service conditions, this test drops the handset into its cradle



I





A New Message Register Camera

By W. HERRIOTT
Telephone Apparatus—Electromechanical

MUCH of the local telephone usage in the larger cities is billed on a message basis. To record this usage as many as 10,000 individual message registers may be mounted on racks in each central office. The monthly job of recording the readings of these registers requires considerable time and effort. For many years it was accomplished universally by sight-reading routines which varied in details but usually involved sending teams of two girls each into the terminal rooms during the night hours.

In an effort to develop other and better means for doing the job, cameras of special design have been made to photograph the registers. The one now used in a few of the largest cities, Figure 1, is a manually operated camera which has a special hood in front to fit against the registers photographed. Inside of the hood are four 50 c.p. 24-volt lamps to provide illumination. The records are made on sensitized paper of high photographic speed and contrast which is wound on a wooden-cored spool with metal ends and protected by a heavy opaque leader and trailer. The spacing of the sensitized paper and setting of the shutter are done simultaneously by operating the winding handle and the exposure is made by pressing a finger release located at the side of the camera. Ten registers are recorded at a time and since each spool of sensitized paper takes 100 exposures, space for photographing 1000 registers per loading is available.

When the recordings are made the camera hood is adjusted against the upper left group of ten registers. After the first exposure, turning the hand crank resets the camera and then a record is made of the adjacent block of ten registers. This operation is repeated one hundred times after which the camera is unloaded and the spool sealed and sent to the laboratory for development. It is then ready for the Accounting Department. Figure 2 shows typical exposures made in the hand-operated ten-register camera.

It was found that this camera could be improved from the standpoint of ease of handling and speed of operation since much time is lost in the manual operation of hand cranking

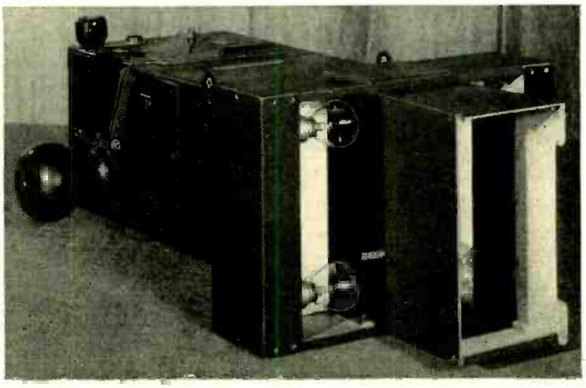


Fig. 1—Photographic records of message register readings are now made in some exchanges with a manually operated camera

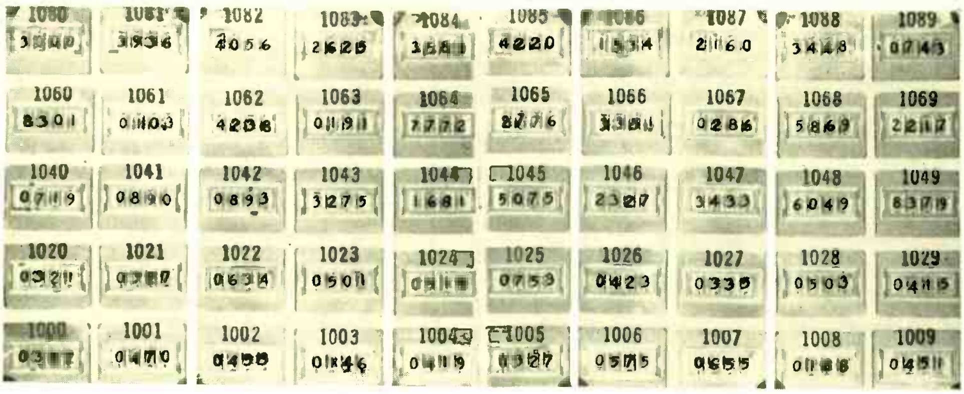


Fig. 2—The present message register camera photographs ten registers at a time

between each exposure. Accordingly, a new camera shown in Figure 3 has been developed in which a small universal motor is used instead of the hand to move the sensitized paper, control the illuminating lamps, and set the shutter. Twenty-five registers are photographed at a time, thus requiring only 40 exposures per 1000 registers. A single switch controls the entire action of the camera and it operates on either 110 volts ac or dc, which is supplied through a cord with terminal plug mounted flush in the side of the camera. The body of the camera is made of sheet duralumin and the exterior surfaces are lacquered black.

A projecting hood rests against the register cover as in the previous design. Illumination is provided by four 50-candlepower double-filament automobile lamps mounted two on each side of the camera under removable protecting covers. Condensing lenses are placed immediately in front of the lamps to increase the illumination at the plane of the register and a vignetting device serves to blend the illumination from the two sides of the camera over the central section of the area photographed. Four mirrors of chromium-plated metal line the interior of the projecting hood. These serve to build up illumination at the sides of the picture area and to insure proper lighting of numbers located near the edges of the picture. A mirror inclined at 45° near the lens deflects the light toward the base of the camera where the sensitized paper is located. A large section of the back cover extending from the loading chamber to the top of the camera is removable to give access to the lens, shutter and inclined mirror.

The loading chamber, shown in

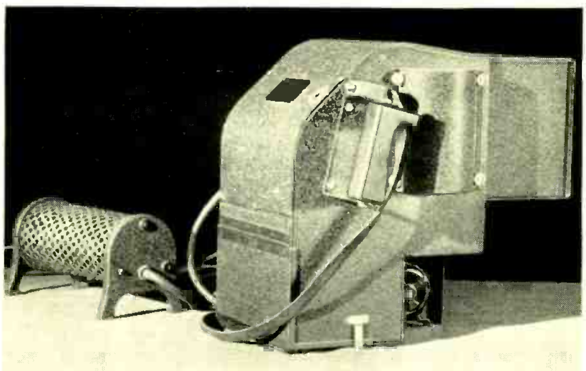


Fig. 3—In the new message register camera a motor moves the sensitized paper, controls the illuminating lamps and sets the shutter

Figure 5, is covered by a light-tight door for loading and unloading. The roll of unexposed sensitized paper is mounted at the left-hand side of the chamber. It passes under an idler roller and around the drum at the left in front. This drum has a toothed sprocket mounted immediately below the spool to measure the advance of the sensitized paper for each exposure. It is then drawn across the exposure aperture which is parallel to the base of the camera and wound onto the take-up roller shown in the right-hand section of the loading chamber. The operator knows when the sensitized paper is in position for the first exposure and again when the last frame is in place by the lighting of a miniature bulb behind a small red window in the camera. Cut-outs in the edge of the sensitized paper actuate the circuit which controls this lamp.

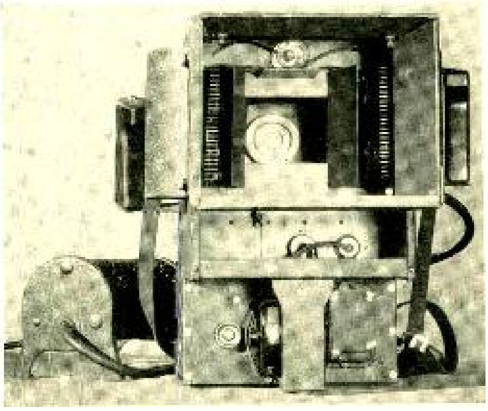


Fig. 4—Mirrors, condensing lenses and vignetting devices are used to blend the light from the lamps and direct it onto the registers photographed

The mechanism which transmits power to the sensitized paper spools and to the measuring roller also controls the current to the lamps used to illuminate the registers. These lamps are lighted a very short time before the actual exposure is made and turned off immediately afterward. This decreases the duration of exposure to approximately a third of the time required for the full cycle of camera operations and materially reduces the effect of heat from the lamps. The torque-voltage characteristics of the motor are such that any variation in line voltage automatically changes the exposure. If the line voltage is high, the lamps burn more brilliantly but the motor speed will then increase so that the lengths

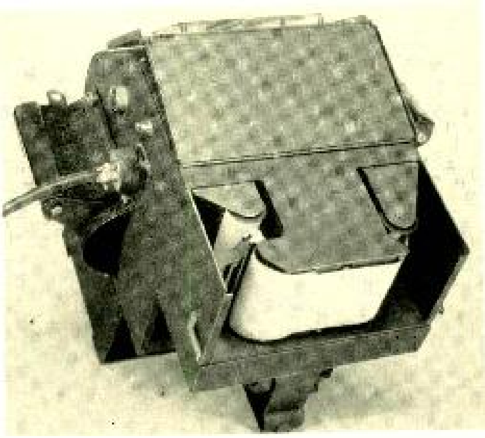


Fig. 5—The sensitized paper passes from the spool at the left around a toothed measuring sprocket and across the exposure area to the take-up spool

of the exposure portion of the cycle will be correspondingly shortened and over-exposure avoided. On the other hand, if the line voltage is low, the lessened intensity of illumination is compensated for by a lower motor speed which prolongs the exposure. Records made with the new camera are shown in Figure 6.

The operating mechanism is mounted as a removable self-contained unit located behind the plate to which the motor and gear box are attached. Power from the drive motor is transmitted through reduction gears to the pawl which controls the spacing roller, to the shutter, the toggle switches used to operate the lamps and motor, and to a precision clutch member which extends into the loading chamber to control the take-up spool. All four of the lamps in the camera are operated in series and a fixed resistance is added to reduce the line voltage to the 56 volts required by them.

This new camera is of relatively simple construction and is ruggedly built. Endurance tests, involving thousands of operations, have proven its ability to perform satisfactorily under practical conditions of use and with considerable saving in time over the previous design.

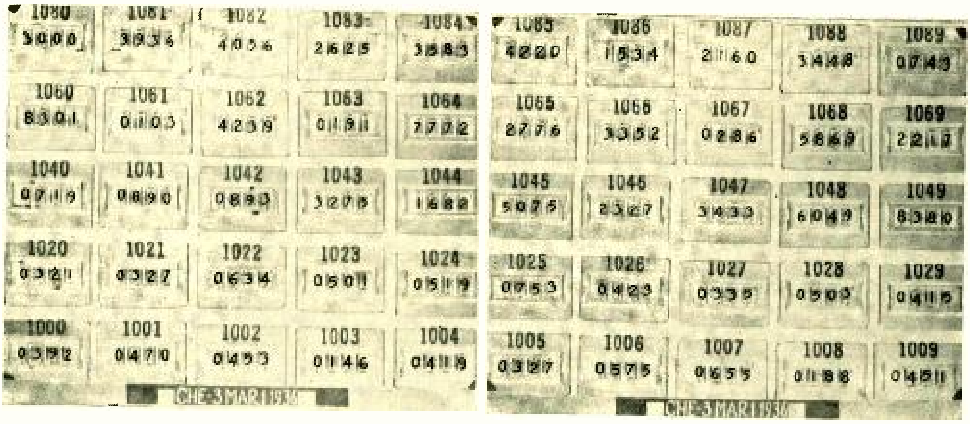
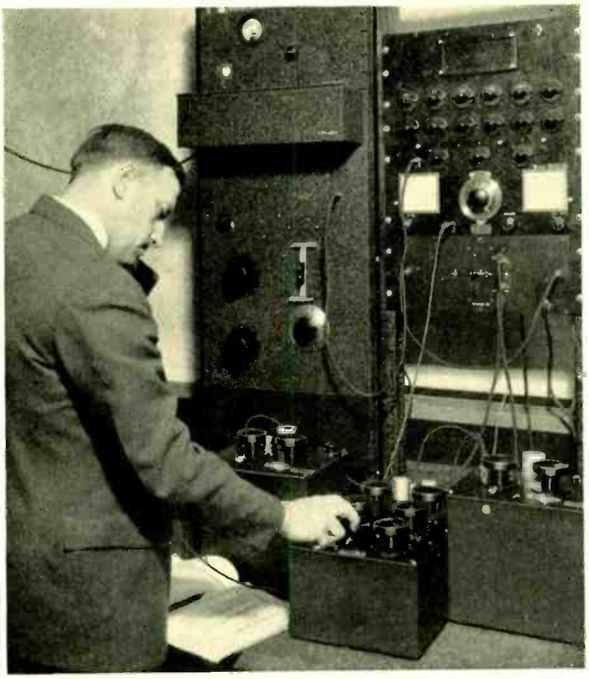


Fig. 6—The new message register camera photographs twenty-five registers at a time



A 5-Megacycle Impedance Bridge

By C. H. YOUNG
Telephone Apparatus Development

THE extension of wire communication systems to include higher and higher frequencies has made it necessary to design impedance-measuring equipment for a precision over this extended range, comparable to that obtainable in the audio and lower-carrier ranges. For this purpose, the familiar alternating-current Wheatstone bridge* was refined to meet the severe requirements imposed by the higher frequencies. While essentially the same as other a-c impedance bridges in circuit arrangement, it differs from them in the care taken to secure constancy of all residual impedances over a very wide frequency range, thorough shielding, and accurate circuit balances. An interesting innovation is the use of coaxial plugs and jacks for connecting to the standard impedances, to the unknown impedance and to the oscillator and detector.

The circuit for the new bridge is shown schematically in Figure 1. It consists primarily of a pair of double-shielded ratio arms, repeating coils for the oscillator and detector, and a set of six coaxial jacks by which the detector, oscillator, and the standard and test impedances are connected. These components are assembled on a seven by sixteen inch panel, and enclosed in an aluminum housing, which serves as a shield.

A photograph of this balance unit from the rear, with the covers removed from the double shielded ratio

*Record, *January*, 1932, *p.* 173.

arms, is shown in Figure 2. The ratio arms, each of 75 ohms, employ the woven-wire* resistor element, which is ideally suited for the purpose because of its very small distributed inductance and capacitance. They maintain their impedance balance or ratio to within one one-hundredth of one per cent for resistance and to a thousandth of a microhenry for inductance, over the entire frequency range from 10 to 5000 kilocycles.

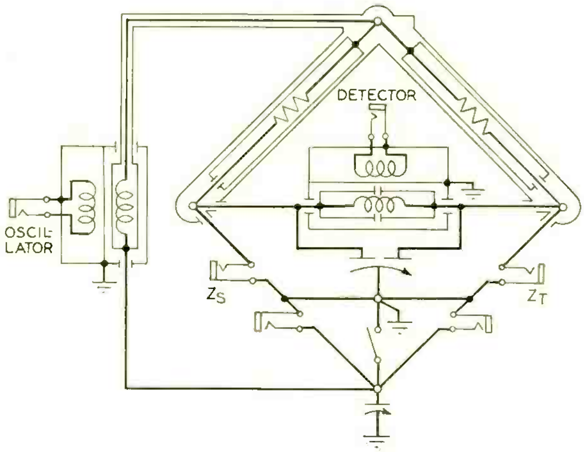


Fig. 1—Schematic diagram of the new high-frequency balance unit

The double-shielded repeating coils, which serve to isolate the bridge circuit electrostatically from the power source and the detector circuits, are scarcely less important than the ratio arms in their contribution to the satisfactory performance of the bridge. With an impedance ratio of one to one, they are designed and constructed with special care to insure a low value of intershield capacitance, and to minimize the capacitance between the elements separated by the ground shield.

As is partially evident in Figure 2, a very high degree of symmetry is maintained throughout the balance unit in mechanical layout, in wiring, and in the disposition of the ground admittance of the elements. The electrical symmetry obviates many of the errors that are peculiar to high-frequency measurements.

*Record, *January*, 1935, *p.* 136.

Two impedance standards have been designed for use with the new balance unit. One is a six-dial resistance standard and the other an adjustable capacitance standard. Both are equipped with coaxial jacks to permit them to be readily connected to the balance unit in a series arrangement or in a parallel arrangement.

The resistance standard, Figure 3, is similar to the six-dial rotor-decade already described in the Record.* The resistors are mounted in drums, which are rotated between fixed brushes so that only one resistor unit per decade is in the circuit at a time. The three larger decades employ resistors of the woven-wire type. In each of the three smaller decades, the resistor elements are made to have as nearly as possible identical inductance residuals, so that the total inductance of the bridge is maintained substantially constant for any setting.

The capacitance standard has a rotor-decade of mica condensers with step values of 1000 micro-microfarads and a special two-dial air condenser. One of the component air condensers has step values of 100 $\mu\mu$f and the other is continuously variable over a range of 110 $\mu\mu$f. The mica condenser is similar to the resistance decades in inserting only one unit in the circuit at a time. This arrangement not only minimizes stray internal capacitances, but keeps the series inductance of the

*Record, *January*, 1935, *p.* 136.

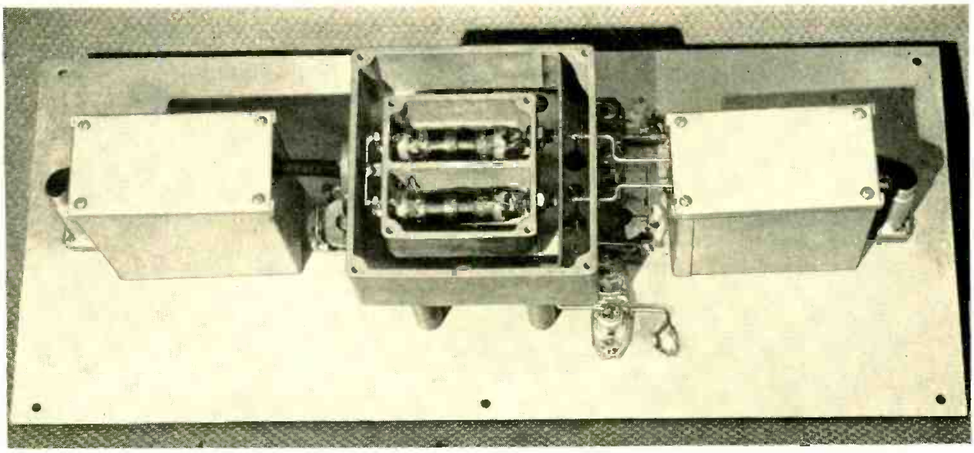


Fig. 2—Thorough double-shielding and symmetrical arrangement are featured in the balance unit of the five-megacycle impedance bridge

leads and wiring to a small constant value which may be compensated by adding an equal inductance in the opposite arm of the bridge. The complete capacitance standard removed from its case is shown in Figure 4, where the mica decade is at the left.

The air condenser unit, which is of exceptionally rugged design, has a single stator that is common to two rotors. Self-adjusting bearings are used on the rotors to compensate for wear and also to assure a low electrical contact resistance in the connections to the rotors. The stator is supported on three ceramic spheres, which minimize leakage by providing what are essentially point contacts with the frame, and which permit the stator plates of the condenser unit to be accurately aligned with those of the rotor.

The larger dial has a click detent mechanism arranged to stop the rotor at 100 $\mu\mu$f intervals as the dial is turned. The detents are individually adjustable so that the resulting steps may be made to agree with the nominal value to within ± 0.1 $\mu\mu$f. Settings are reproducible to within $\pm .03$ $\mu\mu$f. The continuously variable dial, at the right of Figure 4, carries an engine-engraved scale with a vernier that allows direct reading to within 0.1 $\mu\mu$f.

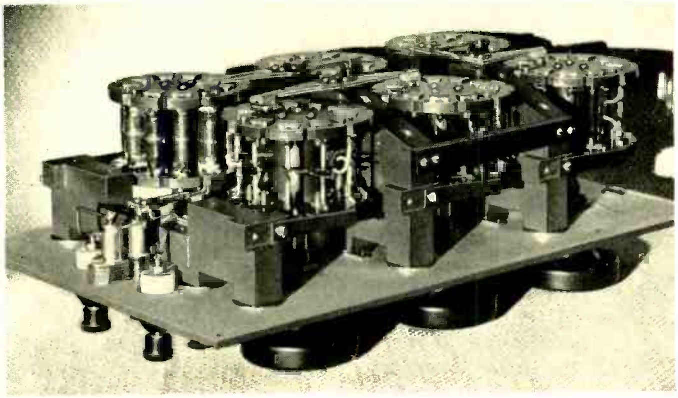


Fig. 3—The resistance standard differs from others of the same type chiefly in the provision of coaxial jacks and in the care taken to reduce and equalize the inductance and capacitance of the individual units

Although there is no need for observations of the condenser to better than .1 $\mu\mu$f, it is essential when measuring high impedances having a large ratio of reactance to resistance to be able to adjust the condenser with much greater precision. For this purpose a

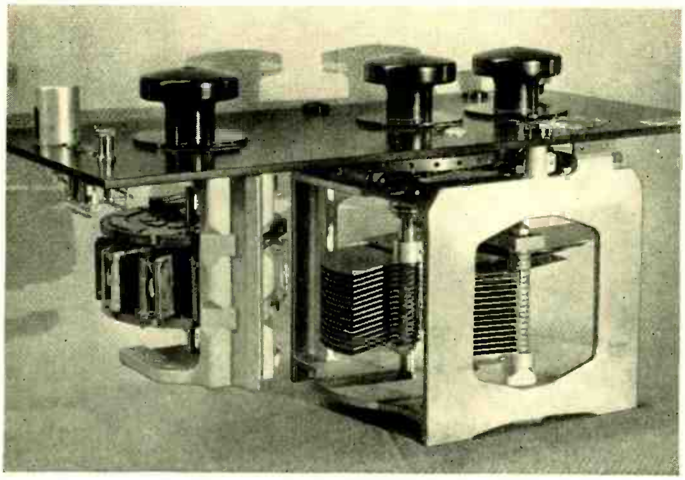


Fig. 4—The capacitance standard is ruggedly constructed to insure precise setting

slow motion device operating on the main dial of the condenser has been provided which permits easy adjustment to within .002 $\mu\mu$f. Rapid preliminary adjustment to within 1 $\mu\mu$f may be made by means of the large knob on the condenser shaft in the usual manner, and as smoothly as though the slow motion device were absent.

A novel feature of the bridge is the use of equal-length coaxial cords for connecting the standard and unknown impedances to the balance unit. In addition a small terminal unit, fitted with coaxial jacks, is plugged to the extremity of the leads for the test impedance to balance the residual impedances of the standards. In this way the symmetry of the bridge network is extended to the unknown impedance, and the uncertainty and the inconvenience of corrections due to the use of random leads are avoided. Moreover, since the potential drop in the sheath conductor of the coaxial leads is practically nil, the shields of the standards and the unknown impedance are brought to the same potential as that of the bridge ground.

The balance unit is arranged for both grounded and balanced-to-ground measurements; the switch just above the bottom corner of the bridge in Figure 1 is closed for grounded measurements and left open for balanced-to-ground measurements. For grounded measurements only the upper of the two jacks on each side and a single cord are used to connect the bridge to the standards and to the unknown. Such an arrangement is shown schematically in Figure 5. A

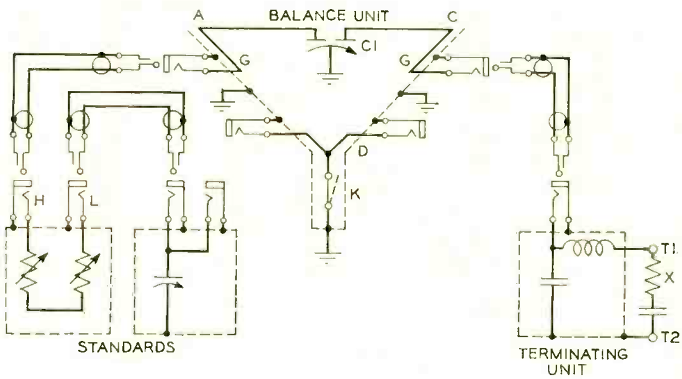


Fig. 5—Schematic for a grounded measurement

photograph of such a set-up is given in Figure 6. For balanced-to-ground measurements two cords are used from each side of the balance unit, and the standards used, although similar to those used for grounded measurements, have elements that are symmetrical with respect to ground.

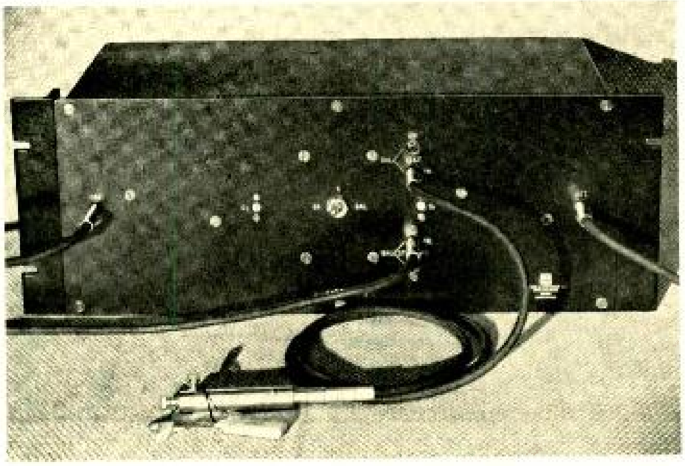
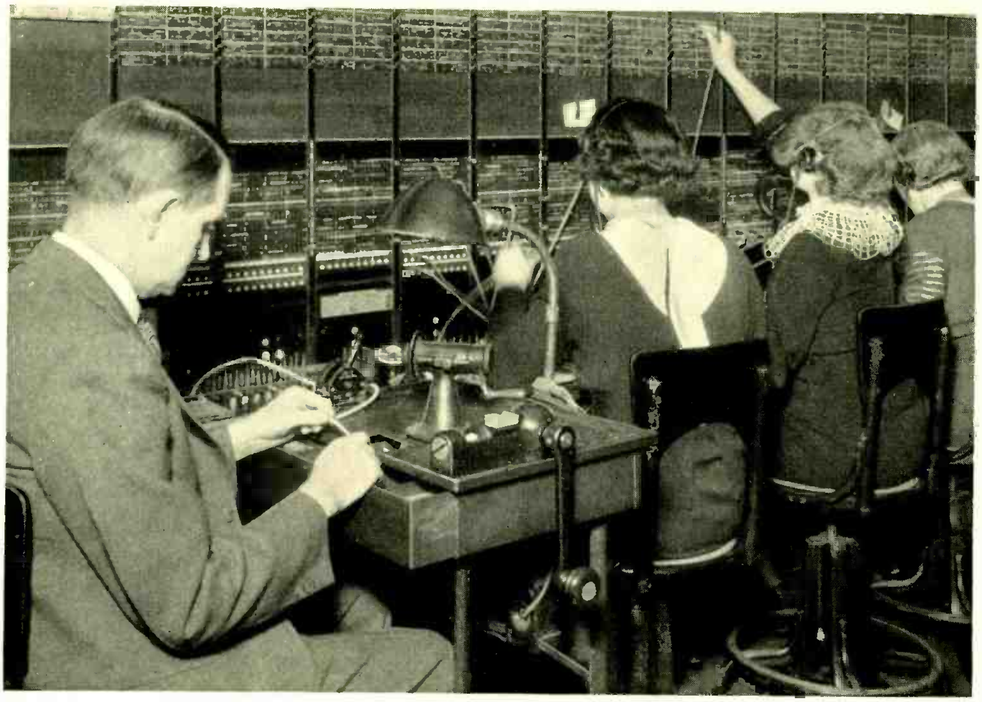


Fig. 6—The terminating unit is in the form of a small cylinder with binding posts to which the unknown is attached

A complete set-up for a high-frequency measurement is shown in the photograph at the head of this article. In the bay at the left is a precision type oscillator already described in the Record*. The balance unit is the lower panel of the right hand bay and above it is the detector. The capacitance and resistance standards are in the right foreground. A second capacitance standard is shown being calibrated.

The impedance range of this equipment is limited, of course, by the standards rather than by the balance unit. With the standards described above, the widest range is obtained with the parallel connection, where capacitances from practically zero up to .01 microfarad, with a wide range of power factor, may be measured. Inductances that can be resonated within this capacitance range may be measured also, provided the detector has adequate discrimination against harmonics originating in the power source. An inductive standard of suitable range may be substituted for the capacitance where it is undesirable to employ resonance methods.

*Record, *December*, 1936, *p.* 121.



Applying Solderless Cord Tips in the Field

By L. N. HAMPTON
Telephone Apparatus Development

SWITCHBOARD plugs, employed by the millions in the Bell System, are attached to cords having usually three conductors, as shown in the accompanying photograph. One conductor runs to the tip of the plug, another to the sleeve or main body of the plug, and the third to the ring—a small metallic band separated from the dead collar and sleeve by narrow segments of insulation. In assembling these cords and plugs in the Western Electric Shops, small metal cord tips are crimped onto the tip and ring conductors as already described in the RECORD.* The sleeve conductor is turned back over the main body of the cord which is threaded into the cord end of the plug thus making contact with the metallic body of the plug. Small screws fasten the cord tips to the terminals in the plug, and the outer shell is slipped over the assembled plug and fastened in place.

In service, wear on cords first becomes noticeable on the braid just back of the plug, where the greatest and most frequent bending occurs. Continued use of the cord would result ultimately in serious damage to the insulation and possibly breakage of the conductors, but the warning

*RECORD, *July*, 1926, *p.* 196.

given by the fraying of the outer braiding permits repair long before actual failure. Such frayed cords are repaired by cutting the cord a short distance back of the plug, beyond the place where the braiding is damaged, and reconnecting it to the plug. These repairs are often made in the central office where conditions do not warrant the use of the heavy crimping machine used for applying the solderless cord tips at the manufacturing plant. Until recently it was the practice to pierce the insulation with a special hand tool like a pair of pliers, and push the terminal screw through the hole. This method had several shortcomings and investigations were started to provide economical ways and means of placing solderless cord tips on repaired cords as a maintenance operation by the plant forces. The outcome of this investigation was the development of the No. 444-A tool which is mounted on the cord repair table, as shown in the photograph at the top of the opposite page.

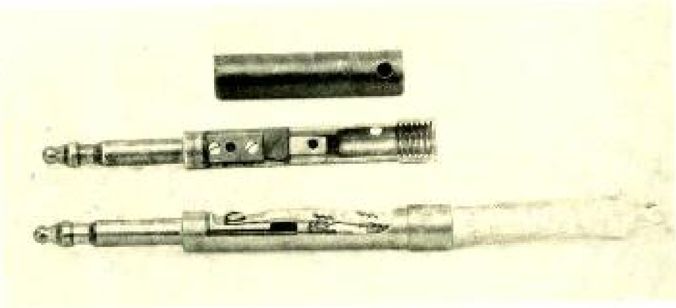


Fig. 1—Bottom: an assembled cord and plug with insulating sleeve or shell removed to show method of fastening conductors; top and center: plug without cord and with cord end cut in half to show threading

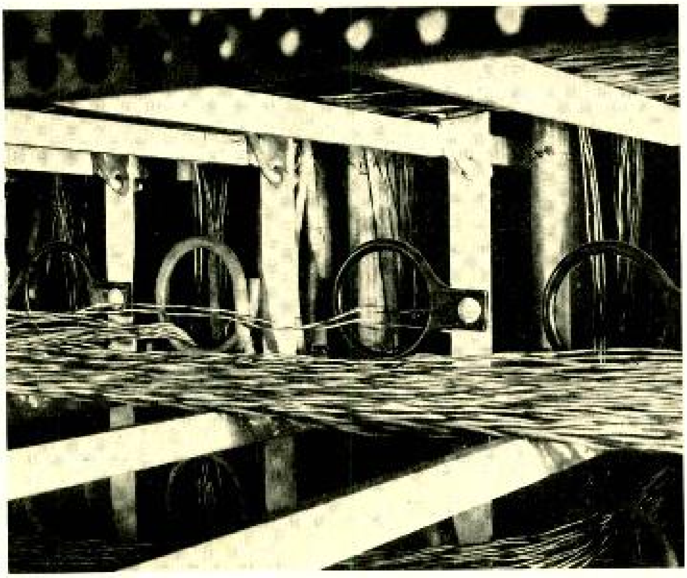
To provide the high pressure required to crimp the cord tip, the 444-A tool employs a lever operated cam. This moves the dies rapidly at the beginning of the operation, when little pressure is required, and more slowly as the pressure builds up. The lever is fairly long and massive with a heavy handle, which gives it a flywheel action as it is swung rapidly through one complete revolution. Pressures estimated to be in the neighborhood of 1000 pounds are required to apply a solderless cord tip satisfactorily, and this portable tool so balances opposing forces that only small unbalanced components react on the light portable table itself.

In operation the outer braid and tinsel conductor are cut back and the tip and ring conductors are placed in the gauge block on top of the machine. With cutting pliers each is then cut to its proper length. A tip is placed in one of the cavities of the die and a cord conductor is placed in it. The handle, which has been hanging vertically downward, is then brought up with an accelerated motion and turned rapidly through one complete revolution. During the downward part of the stroke, par-

Fig. 2—No. 444-A Tool for applying solderless cord tips to switchboard cords

ticularly during the last quarter when the greatest pressure is applied, the flywheel action of the handle adds a very appreciable amount to the actual force applied by hand. At the bottom of the stroke the cam is cut back to release the die, which is pushed back into its normal open position by a spring. The details of the die and gauge block are shown in Figure 2. With this new apparatus solderless cord tips may be rapidly applied without removing the cord from the switchboard. The repaired cord will be essentially the same in its terminal connections as a new one. The cords are long enough to allow several repairs to be made before being discarded.

Assembling the elements of an experimental vacuum tube in the Tube Development Laboratory



A New Ring for Distributing Frames

By O. C. ELIASON
Apparatus Development

THE distributing frame has been, in one form or another, a part of the telephone system since the early days. It carries terminals for the incoming lines on one side and terminals connecting to the central office apparatus on the other side. Cross-connecting wires between terminals on the two sides of the frame allow flexibility in associating cable pairs with the office apparatus so that, for example, a subscriber may move within the office area without having his number changed. Where the wires change direction, their side pull is carried by insulated rings.

The old No. 1 and No. 2 rings, which differ from each other only in the size of the rings, consist of an iron rod three-eighths inch in diameter, threaded on one end and bent to form an open circular ring. The threaded portion is used to mount the ring on the frame, while the ring portion with which the cross-connection wire comes in contact is insulated by a hard rubber covering. Rings of this type have been in use for forty years. Old and new rings, mounted side by side in a central office during the field trial, are shown above.

The new 9A ring, which was developed to replace both the No. 1 and No. 2 rings in new equipment, consists of a closed cast iron ring intermediate in size between the No. 1 and No. 2 rings. The whole ring is insulated with a coating of vitreous enamel. A shoulder engages the frame so that the ring is held in exact position by a single bolt.

The 9A ring offers the advantages of greater strength and rigidity than the old ring, fixed alignment in the frame and a hard, smooth insulating finish which will be practically impervious to wear and will not abrade the cross-connection wire.

Contributors to this Issue

F. R. Dennis received the B.S. degree in Electrical Engineering from the State College of Washington in 1929 and joined the Apparatus Development Department of the Laboratories in September of that year. A considerable part of his time for the first two years was spent making impedance and attenuation measurements on cables for carrier telephony. It became evident that the attenuation measuring sets then available were inadequate at the higher frequencies where measurements were beginning to be required. He therefore undertook the development of attenuators and attenuation measuring circuits which would maintain high accuracy over the radio frequency range. For the past year and a half the group with which he is connected has been charged with the development of oscillators, detectors and other vacuum tube apparatus. His present work is partly of this nature and partly continuation of work on attenuation measuring circuits and attenuation standards suitable for checking the accuracy of shop sets which operate in the radio frequency range.

F. R. Dennis

L. N. Hampton graduated from the Cooper Institute of Technology in 1916 and joined the Engineering Department of the Western Electric Company in 1917. During the next year he was in the drafting group working on various devices for detecting airplanes and submarines. He then transferred to the Apparatus Development Department, where, in addition to developing apparatus for the above uses, he designed radio apparatus for the Signal Corps. Since then he has remained with the same group and has been in charge of the development of a wide variety of apparatus for use in the telephone plant.

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.

J. M. Barstow was graduated from Washburn College in 1923 with the B.S. degree. He then took up graduate work at the University of Kansas and received his M.S. degree the following year. Following

L. N. Hampton

C. H. Young

this he was employed for three years as an instructor in Physics at the Kansas State Agricultural College. In June, 1927, he became a member of the Department of Development and Research of the American Telephone and Telegraph Company, his major work being on noise problems. As a member of Project Committee 1B of the Joint Subcommittee on Development and Research, Edison Electric Institute and Bell System he has conducted judgment and articulation tests on the interfering effects of various sorts of noise and has been instrumental in devising noise measuring devices. As secretary of the Technical Committee on Sound Levels and Sound Level Meters, he took part in setting up the American Tentative Standards for Sound Level Meters approved by the American Standards Association in February, 1936.

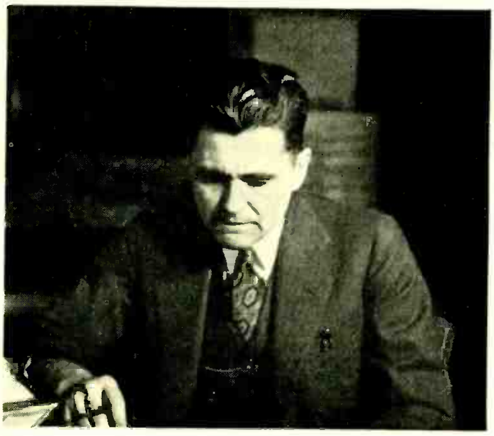
J. M. Barstow

After graduation by Massachusetts Institute of Technology in 1914, H. A. Affel returned for two years as a research assistant in electrical engineering. In 1916 he joined the engineering staff of the American Telephone and Telegraph Company, and with the organization of the Department of Development and Research in 1919 became associated with its Transmission Development group, where he engaged in studies of carrier and radio transmission. In 1929 he transferred to the Toll Transmission group where his work included among other things the design of repeaters, program circuits, and carrier systems. With the transfer of the Development and Research Department to the Laboratories in 1934, Mr. Affel remained with the same group. Now as Toll Transmission Development Director, he has been placed in charge of the entire department.

On graduation by Iowa State College in 1921, O. C. Eliason entered the Western Electric Engineering Department where he worked on electrolytic condensers and later on household appliances and farm equipment, at that time a merchandise activity of Western Electric. Then transferring to the Telephone Ap-

H. A. Affel

paratus Development Department he became a member of the group responsible for inside wires and switchboard cables. Here he has been concerned with a number of related problems such as the design of apparatus for humidity studies and for investigation of central office ventilation. On account of its close association with distributing frame wire, the 9A ring,



O. C. Eliason

which he describes in this issue, was one of his minor activities.

While an undergraduate at the University of Pittsburgh from 1914 to 1917, W. Herriott engaged in astronomical research at the Allegheny Observatory. This was followed from 1917 until 1920 by research in astronomical and aerial photography at the Eastman Kodak Company.

W. Herriott

Between 1920 and 1925 he was engaged in the development of optical apparatus for microscopy, photography and motion pictures with the Bausch and Lomb Optical Company. During the following three years he was in charge of the Scientific Department of the Fairchild Aerial Camera Corporation. In 1928 he joined the Engineering Department of the Electrical Research Products, Inc., to work on optical and photographic problems associated with sound pictures. Mr. Herriott came to the Laboratories in 1929 and continued work in sound pictures until October, 1936. Then he transferred to the Materials Group of the Electromechanical Division of the Telephone Apparatus Development Department.