BELL LABORATORIES RECORD

VERTICAL SOUND RECORDING
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MAINTENANCE TOOLS FOR COMMUTATORS
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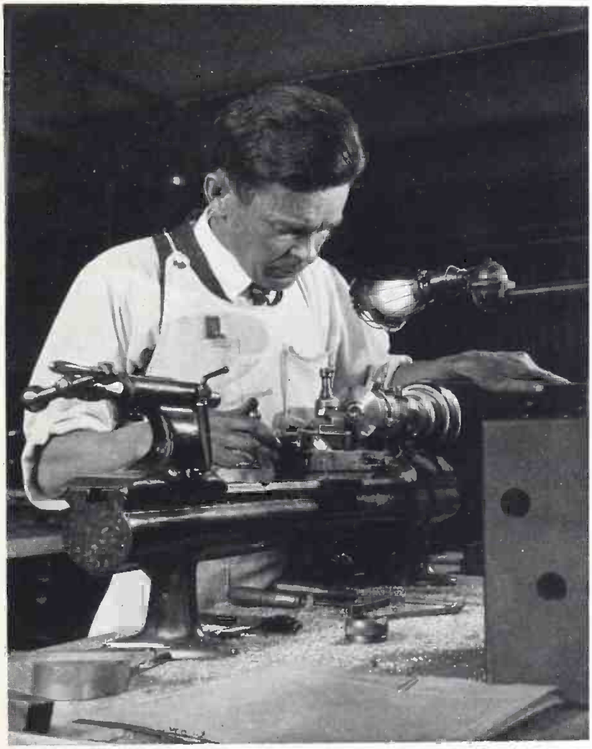
In this Issue

BELL LABORATORIES RECORD



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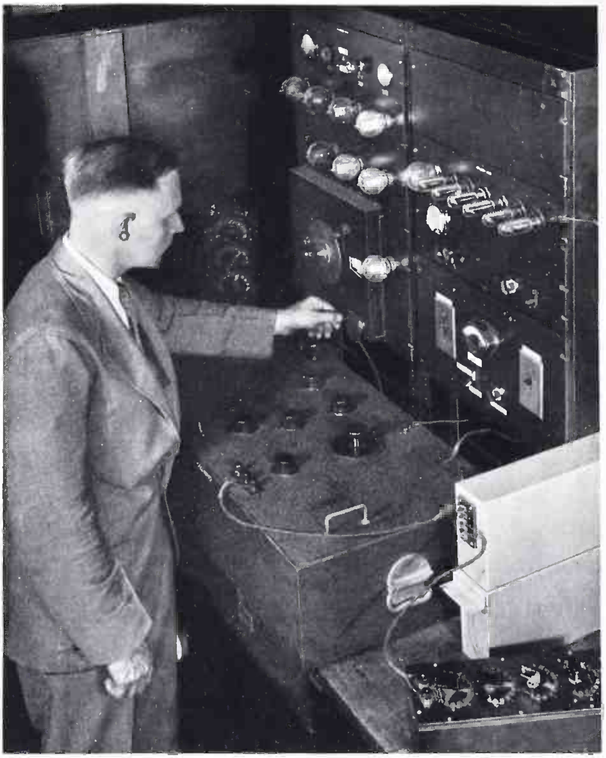


Electrical Reflections and Their Measurement

By W. G. LASKEY
Telephone Apparatus Development

According to Greek mythology, Narcissus was a handsome young man who saw his own reflection in a pool, became so enamored of it he unwisely rejected the love of the nymph Echo, drew upon himself the vengeance of the gods, and pined away and died at the water's edge. This early account of reflections exhibits them in the same role of trouble-makers that they play today in the telephone plant.

Energy in any form will be partly reflected when it suddenly encounters a change in the resistance to its passage. Whether this change is an increase or a decrease, some reflection will occur. Careful observation of a thick pane of glass will always disclose two partial reflections of the objects facing it: not only the one where the light leaves the air and enters the glass, but another where the light emerges again to meet the air.

In a similar way electrical reflections take place at discontinuities in the impedance of a line through which electrical energy is passing (Figure 1). A portion of the energy of an electrical impulse that reaches such a point in a line is thus returned to its source. It can be shown that the amount of energy reflected in this manner is proportional to the "reflection coefficient," defined as the ratio of the difference of the impedances to their sum. $r = (S-X)/(S-X)$.

The fact that reflections will take place at discontinuities of impedance can readily be made apparent. Figure 2 shows a uniform line, infinite in extent and with a characteristic impedance S. To examine its behavior at any point such as O, the line can be regarded as composed of two similar infinite lines: and the left-hand line, which propagates energy toward O, can be replaced by an impedance with the value S, with which an equivalent series electromotive force E is associated. The resulting current both sides of O is $i_1 = E/2S$.

To introduce a discontinuity of impedance at O, the right-hand line can be replaced by another with the different characteristic impedance X. In order to discover what changes in current and voltage occur in the first line as a result of this discontinuity, it can first be assumed that no changes at all take place. Under this assumption it is obvious that the current in the new second line will be changed to $i_2 = E/(S-X)$. But now to suppose that i_1 is the only current in the first line is impossible, for i_1 and i_2 have different values; and there cannot be a discontinuity of current at O, even though there is a discontinuity of impedance. Thus there must be a third current i_3 in the left-hand line, balancing i_1 and i_2 in such a way that $i_1 + i_3 = i_2$. Since i_1 is the only current which can be propagated toward O, i_3 must be a current propagated away from O, back toward the source of electromotive force.

This reflection of energy obviously diminishes the efficiency of the line. But, when the line is used for telephone purposes, far worse effects are possible. Reflection may introduce distortion by affecting certain frequencies more than others, cause disturbing echoes by returning the speech signal to its source after a noticeable time interval, limit the gains at which repeaters can be operated, or increase cross talk between circuits. If these effects of reflection become large enough to be important, their compensation can be accomplished only by expensive means, such as equalizers, echo suppressors, impedance-modifying transformers, and more frequent transpositions on open-wire lines, and in some cases only by reconstruction work to remove the irregularity.

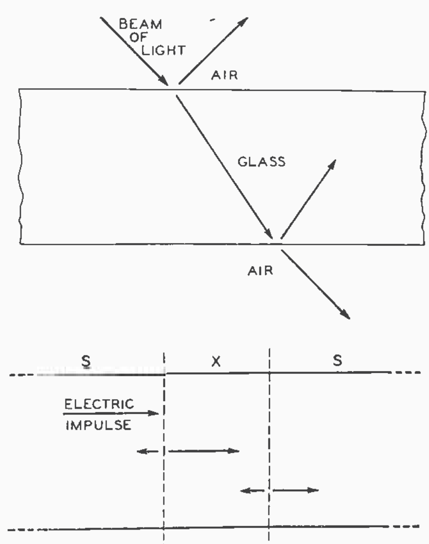


Fig. 1—Electrical reflection is somewhat analogous to optical reflection

Every effort is made, therefore, to eliminate reflections by matching the impedances of all telephone apparatus. The reflection coefficient is taken as the measure of the reflection which a particular piece of apparatus will introduce into a given circuit. To minimize reflections in the telephone system as a whole, limiting

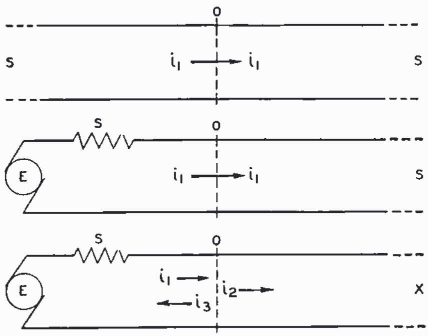


Fig. 2—A current, i_3, will be reflected from O back toward E if the impedance X differs from S

requirements are placed upon the reflection coefficients of all pieces of apparatus, such as filters, that might be responsible for this phenomenon in telephone circuits.

The fulfilment of these requirements can be verified only by testing the apparatus. Impedance bridges could be used for this purpose, but their use would be uneconomical because in many cases the apparatus impedance changes rapidly with small changes of frequency, making it necessary to measure the impedance at closely spaced intervals over a frequency range. From these measurements the reflection coefficients would then have to be calculated. To draw a curve of reflection coefficient versus frequency would require a large number of such measurements within the band of frequencies desired, especially if the coefficient fluctuated rapidly with frequency. A special circuit was therefore developed for measuring the reflection coefficients directly, which materially reduces the time required for such measurements.

Shown in the headpiece the measuring apparatus consists of a special bridge, a detector, and an oscillator whose frequency can be varied by turning a dial. Two arms of the bridge (Figure 3) are formed of two equivalent impedances R. The third arm is formed of the circuit X to be tested; and the fourth, of a circuit S having the impedance which is supposed to be matched by the impedance of the circuit X. It can be shown that the ratio of the voltage across terminals 1 and 2 to that across terminals 3 and 4 is proportional to the reflection coefficient that X would have when connected to S. If the voltage across terminals 3 and 4 is kept constant by the oscillator, the voltage across terminals 1 and 2 is proportional to the reflection coefficient. Under this condition, by suitably calibrating the voltmeter, its scale can be made to read directly in reflection coefficients.

To measure the reflection coefficient of a piece of apparatus at a particular frequency, the oscillator is set at this frequency, the switch is thrown to connect the detector across terminals 1 and 2, and the meter of the detector is read. The switch is then operated to connect the detector to the potentiometer across terminals 3 and 4 and the dial controlling the potentiometer is turned until the reading of the detector's meter agrees with the previous reading. The switch is finally thrown back and forth and the dial adjusted until the reading of the meter remains the same regardless of the position of the switch. The reading of the potentiometer dial now gives the reflection coefficient at the frequency of measurement.

Since the requirements placed upon apparatus apply not to a particular frequency but to a large range of frequencies, within which the reflection coefficient should nowhere exceed a specified value, many measurements of the sort just described would ordinarily have to be made. Of especial practical value, therefore, is the possibility of rapidly determining with this apparatus whether any particular value of the coefficient is exceeded within a specified frequency range. For this purpose the oscillator is first set at some frequency near the middle of the range in question, the potentiometer dial is set at the value of the reflection coefficient which is not to be exceeded, and the reading of the detector when connected to the potentiometer is recorded for reference. The detector is then connected across terminals 1 and 2, and the frequency of the oscillator is continuously varied through the range of interest. If the detector's meter at no point of this range indicates a voltage exceeding that previously recorded, the apparatus meets the requirements.

Because of the great rapidity with which an entire range of frequencies may be scanned by it, this latter method is of great value for shop tests on filters. By constituting a means for checking rapidly the performance of apparatus within such a frequency range, this method has made it practicable to specify reflection-coefficient limits applying at all frequencies within the range. Thus the cost of filters meeting given reflection limits can be materially reduced.

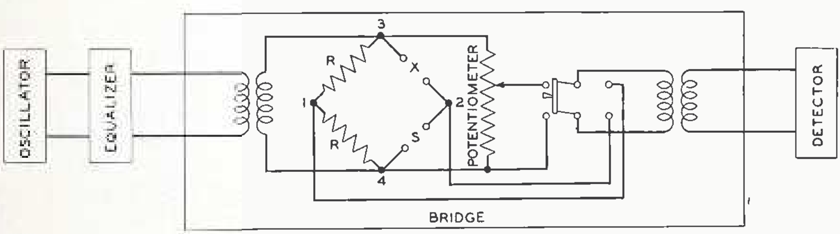


Fig. 3—The ratio of the voltage across terminals 1 *and* 2 *to that across terminals* 3 *and* 4 *is proportional to the reflection coefficient X would have when connected to S*

A Low-Frequency Oscillator

By J. M. HUDACK
Transmission Apparatus

A SOURCE of extremely low frequencies is often required for certain of the research and development work carried on by the Laboratories. Frequencies as low as 35 cycles are used for measuring the transmission loss, phase angle, and impedance of apparatus for picture and program transmission; and in connection with telegraph circuits, frequencies of the order of ten cycles are in common use. In developing apparatus for these services experimental data are often needed at even lower values. Frequencies as low as four cycles per second have been employed for determining the adaptability of certain choke coils to telegraph circuits.

Until recently it has been necessary to build special oscillators whenever frequencies below 20 cycles were needed. This situation has now been changed with the development of a new low-frequency oscillator, known as the D-91894. Good sine waves are obtainable from it over the range from three to several thousand cycles. The oscillator in itself is designed for frequencies from 10 to 800 cycles, but only the plugging in of external coils is required to extend its range in either direction.

The complete oscillator includes an oscillator stage, consisting of two tubes connected in push-pull, and an amplifier stage—also of two tubes and in similar arrangement. Frequency adjustment is obtained by operating a key to select one or the other of two oscillator coils, and by adjusting the four dials of a decade condenser in accordance with a calibration which is supplied. Three other keys are provided for extending the range of the decade condenser for very low frequencies. The appearance of the front of the oscillator can be seen in the photograph at the head of this

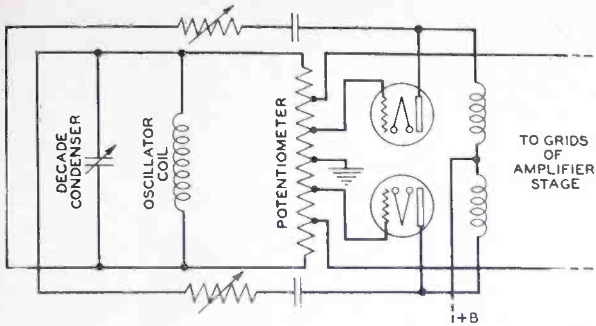


Fig. 1—A simplified schematic of the oscillator stage omitting keys and accessory equipment

article. The two tubes at the left are for the oscillator stage and those at the right, for the amplifier. The two middle bulbs are ballast lamps used for controlling the filament current.

Because of the very low frequencies generated, several unusual circuit arrangements are incorporated in the new oscillator. One is a potentiometer device which serves both as the step-down from the plate to the grid circuits of the oscillator stage, and as a means of obtaining a portion of the oscillating voltage for the grids of the amplifier stage. The arrangement is shown in Figure 1. It avoids the necessity of using either a regular two-winding or auto-transformer type of oscillating coil for the plate-to-grid step-down of the oscillator stage, and also provides a convenient method of taking part of the oscillator voltage for amplification and delivery to the load.

Another feature different from the usual oscillator design is the output-control potentiometer. The ordinary location for such a device is either between the oscillator and the amplifier, or between successive amplifier stages. With the unusual arrangement of the new oscillator, however, these locations did not prove practicable, and as a result the potentiometer was placed after the amplifier stage. Since the terminating impedances of the attenuator in this location are the output impedance of the amplifier, and the load, which may vary between wide limits, the attenuator has been designed so that it depends only on the internal impedance of the oscillator, which varies only between narrow limits.

The arrangement of the output control is shown in Figure 2. It consists of a ten db dial attenuator with steps of one db, and two fixed attenuator networks by which the attenuation may be extended to approximately thirty db. A key is employed to select one or the other of these networks, or to cut them both out of the circuit.

The new oscillator delivers a maximum output current of 23 milliamperes into a 600 ohm load at fre-

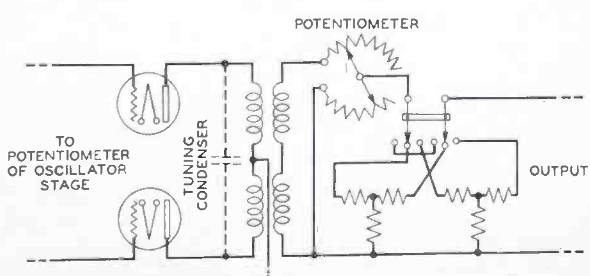


Fig. 2—Beyond the output transformer is the potentiometer by which the output current may be changed in one db steps regardless of the load impedance

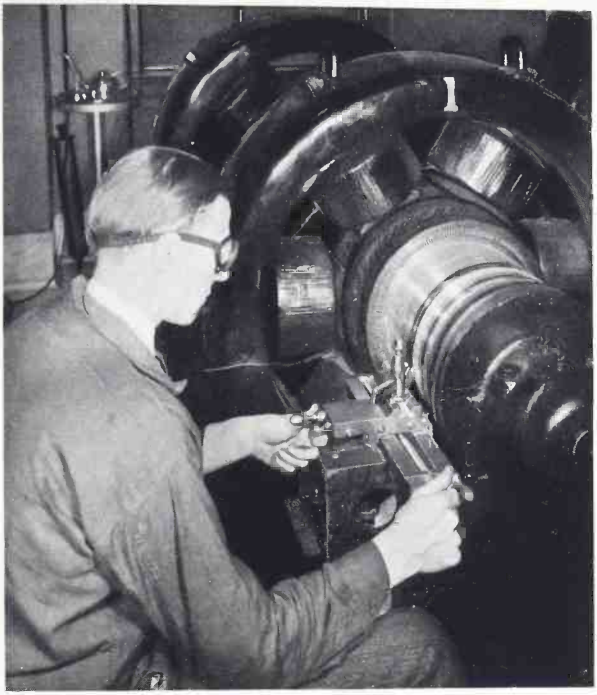
quencies between 10 and 800 cycles. Its harmonic content at all points is less than 3% of the fundamental. As already mentioned this frequency range may be extended both up and down by inserting plugs connected to external coils, into a jack provided on the front panel. For frequencies below ten cycles it is necessary, in addition, to tune the output transformer by using the condenser shown in dotted lines in Figure 2. The output below ten cycles is somewhat less than that at the higher frequencies.

Summer Ailments and Their Treatment

By LEVERETT D. BRISTOL, M. D., Dr. P. H.

Health Director, American Telephone and Telegraph Company

Summer Plagues	Cause	Prevention	Emergency First-Aid
Sunburn.	Over-exposure of skin to sunlight.	Avoid exposure for long intervals, acquire tan gradually.	Soothing applications Carbolated petrolatum, plain vaseline, 3 parts olive oil, 1 part lime water.
Heat Exhaustion (associated with symptoms of shock and circulatory failure).	Excessive heat and humidity.	Avoid direct sunlight and over-exertion during period of excessive temperature and humidity.	Send for doctor at once. Remove to cool, well-ventilated place. Keep body warm and give stimulants and hot applications. Keep head low.
Sunstroke (associated with pain in head and unconsciousness).	Excessive heat and humidity.	Avoid direct sunlight and over-exertion during period of excessive temperature and humidity.	Send for doctor at once. Remove to cool place, remove clothing and give cold applications or cold bath. Avoid stimulants.
Blisters.	Pinching, chafing or irritation of skin.	Avoid over-irritation of skin as in tennis, rowing (hands), and walking or climbing (heels).	Apply small amount of iodine over blister and puncture carefully with sterilized needle. Apply vaseline and dressing.
Ivy Poisoning.	Irritation of skin by a resinous substance in the sap of poison ivy.	Become acquainted with the three-leafed poison ivy plant and learn to avoid it. Free use of alkaline soap and water. Washing must be prompt and thorough without harsh scrubbing. Alcohol or gasoline may be used, but avoid danger of fire and use of lead gasoline.	Free use of alkaline soap and water (strong laundry soap is best) made into thick paste and applied over rash. Weak (5%) solution of permanganate of potash may be applied. Consult your doctor.
Insect Bites and Stings.	Various insects.	Avoid and eliminate insects through cleanliness, sanitary measures and screening.	Application of a paste made of baking soda or a compress moistened in ammonia water. Beware of infected bites.



Portable Maintenance Tools for Commutators of Generators

By C. M. GULDNER
Equipment Development

IT is important that the commutators of generators used for charging storage batteries in central offices be kept in good condition at all times. With long use they may become eccentric, due to uneven wear, or grooved along the track of the brush. Variable contact resistance and sparking at the brushes are likely to result, which in addition to accelerating wear may introduce noise into the talking circuits. If the brushes to be used are of the metal gauze type such as are provided with M-type generators, for many years standard in the Bell System, the mica sheets between the commutator segments are made flush with the surface. These brushes wear the mica down as fast as the copper segments so that the mica remains even with the segments throughout the life of the commutator. With less abrasive brushes, however, such as the grades of carbon brushes used with the present standard commercial generators*, the mica,

*Bell Laboratories Record, *December*, 1927, *p.* 113.

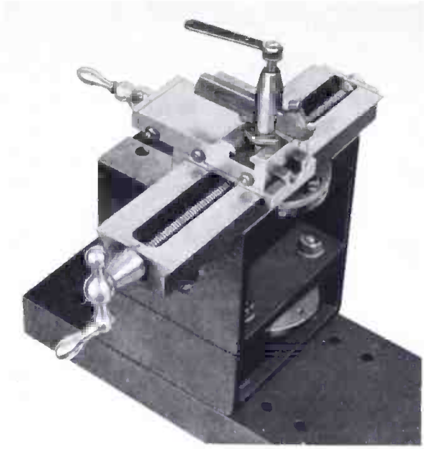


Fig. 1—By using a combination of supports, the slide rest may be brought to the proper height for any machine

if left flush, would not wear so rapidly as the copper and in time would form a series of ridges crossing the commutator—a condition known as "high mica." It is customary, therefore, to undercut the commutators of such machines. The mica is removed for perhaps a thirty-secondth of an inch below the surface.

Commutator maintenance thus consists principally in two operations. One a truing of the surface, done by sanding, grinding, or turning; and the other—on certain types of machines only—an undercutting of the mica. To standardize and simplify the equipment used for the purpose, the Laboratories have recently designed a portable outfit, fitting into two cases, which may be readily carried about from office to office as desired. The apparatus is easily and quickly assembled on any of the standard machines having the open pedestal type of bearings. Some of the smaller sizes of generators are equipped with the end shield type of bearings and this construction does not provide enough space to set up a satisfactory turning tool. The armatures of these machines, however, are comparatively light in weight so that they may be readily removed and the necessary work done in a lathe.

In a preliminary investigation it was found that neither sanding nor grinding was very satisfactory. Both processes are slow and produce a large amount of dust which it is difficult to keep out of the machines where copper particles might form undesirable conducting paths. The most satisfactory method of truing a commutator is by "turning" with a regular lathe cutting tool, but most of the available apparatus was found not sufficiently rigid

Fig. 2—A small driving motor is provided mounted on a wooden base which is braced against the frame of the main machine while in operation

to do a first class job. The New York Telephone Company, however, was using a mounting which was satisfactory in this respect and the Laboratories used it as a basis for their development. It was necessary, however, to make certain modifications to adapt it interchangeably to all sizes and types of machines, and to develop an undercutting tool as well. The actual turning of a commutator with the new equipment is shown in the photograph at the head of this article.

Different methods are employed for supporting the cutting tool, depending on the size and type of the generator. One of those most commonly used employs an eight-inch channel iron as a base, which is cut long enough to span the baseplate of the machine. Longitudinal slots are cut in the middle of the web of the channel near one end through which a bolt is passed and screwed into a hole drilled and tapped into one side of the base of the generator. The other end of the web is drilled with a series of holes along each side. These are used for securing the channel to the other side of the generator base and for attaching the support for the turning tool to the channel. Enough holes are drilled to allow the support to be located in the best position for the size of cummutator being turned.

A set of supports is provided to accommodate the various sizes of machines. The top of each is machined and drilled for mounting the compound slide rest used for turning. The latter is provided with a circular base pivoted about a central stud so that it may be lined up with the commutator before being fastened down. The arrangement is shown in Figure 1 where two supports, one on top of the other, are employed. By this provision of multiple supports it is possible to accommodate all sizes of machines with a small number of parts.

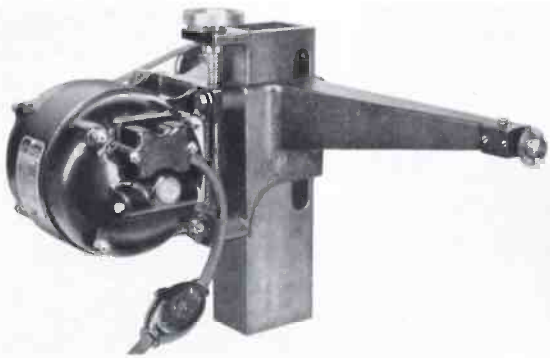


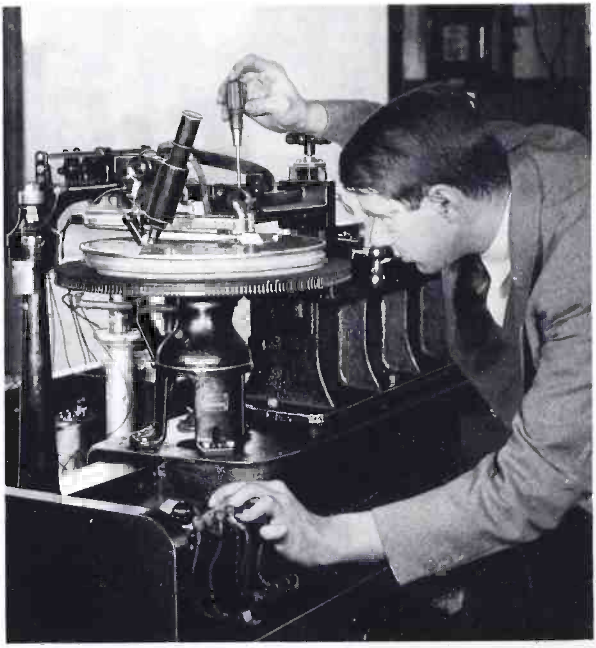
Fig. 3—Two bolts in the lower end of the vertical post secure the slotting attachment to the slide rest

The rest has the usual double slide construction giving two directions of motion of the tool at right angles to each other. The lower slide is long enough for the widest commutator and the upper or cross slide, in conjunction with the selective mounting holes in the base, gives sufficient motion perpendicular to the commutator for the work required.

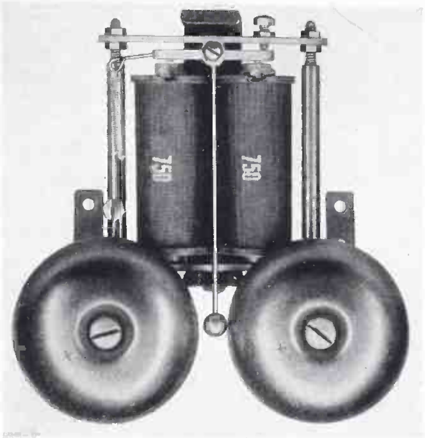
The driving motors for the generators ordinarily run at too high a speed to be used for the turning operation. A separate motor is provided for this purpose, which is shown in Figure 2. A reduction-gear unit is fastened to one end of the motor and drives a two-step pulley mounted on the same base as the motor. A belt slipped over the generator coupling serves as the driving link. The wooden sub-base of the motor rests on the floor at one side of the generator and a wooden arm bolted to it and braced against the generator base holds the driving motor at the proper distance from the generator and maintains tension on the driving belt.

For slotting the commutators, a motor driven attachment—shown in Figure 3—has been designed which mounts on the slide rest in place of the tool post. A small motor, belted to a shaft carrying the cutter, furnishes the power for slotting. The motor, cutter shaft, and supporting frame slide on a vertical post, and their motion is controlled by a handwheel at the top graduated in thousandths of an inch. This permits an accurate adjustment of the tool to make the proper depth of cut. The two motions of the slide rest give the additional control needed for the operation of the cutter.

This assembly provides in a compact arrangement all the equipment needed for maintaining the commutators of the larger standard sizes of charging generators. Two carrying cases have been provided into which the equipment comfortably fits and divide the weight into easily portable amounts. One outfit thus serves for an entire area since it may readily be carried from one office to another as occasion demands.



Regulating the depth of an unmodulated groove in a phonograph record



The Station Ringer

By W. M. STUART, JR.
Local Systems Development

ONE of the secondary problems that confronted Bell after his first successful demonstration of the telephone was the provision of some means of attracting the attention of the person at the other end of the line. In his experimental work with Watson, Bell had shouted "Hello," or more commonly, the nautical "Ahoy" into the transmitter. In the first telephone installed for commercial service the calling signal was given by tapping on the diaphragm of the transmitter, first with a lead pencil, and then, when it was found that the former method was injurious to the diaphragm, with a device called a "thumper." Next came a vibrating reed device invented by Watson which sent a buzzing sound into the telephone of the called party.

None of these devices was entirely successful and consequently Watson undertook the construction of a bell signal. After starting work in the electrical shop of Charles Williams, Jr., in Boston, Watson had read a book called Davis' Manual of Magnetism. There he encountered a description of a "magneto shocking machine," which developed current by electro-magnetic induction. An adaptation of this machine gave a suitable generator for sending alternating current over a line, and Watson devised a polarized ringer to be operated by this current. Such a polarized ringer, of a design employed in the Bell System for many years, is shown in skeleton form in Figure 1. Two soft iron cores, fastened together with an iron yoke, called a heel iron, at one end, are each supplied with a winding. These windings are connected in series in such a way that current passing through them tends to make the free pole of one core north and of the other, south. Facing these two free ends of the cores is an armature mounted on a central pivot left pole is a definite amount less than that at the right. As a result there is an increased magnetic pull from the left-hand electro-magnet and a decreased, from the right-hand, which compensates for the pull of the biasing spring.

Other improvements made from time to time, in the method of winding and insulating the wire and in the materials of both the core and the permanent magnet, have enabled the ringer to meet successfully all of the demands which present-day telephone service imposes upon it. The recent change* to the arrangement shown in the photograph at the head of this article and in Figure 2, has resulted in a considerable saving in space by mounting the gongs of the subscriber set parallel to the base instead of at right angles to it as previously. The operation of the ringer, however, is the same. It is a tribute to Watson's inventive genius that despite the many changes and innovations that have resulted from the development of the telephone system, the polarized ringer still remains as the standard subscriber's signal, with its fundamental principles of operation unchanged from the time it left his hands.

*Record, *October*, 1931, *p.* 43.

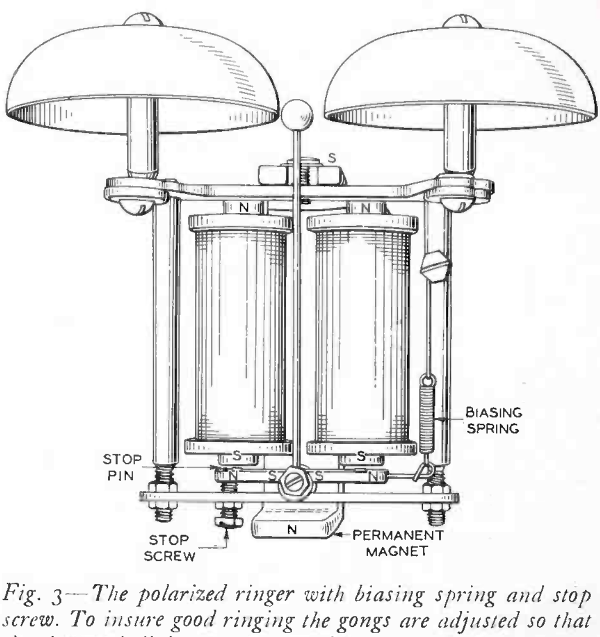


Fig. 3—The polarized ringer with biasing spring and stop screw. To insure good ringing the gongs are adjusted so that the clapper ball does not rest on either gong when stationary, but under ringing conditions, the flexibility of the rod is sufficient to permit the ball to strike the gong

A New System of Sound Recording

By H. C. HARRISON
Transmission Instruments Engineering

WHEN the scientists of Bell Laboratories first became interested in the recording of sound, shortly after the war, they brought into the art an electrical technique based on long experience with telephone systems. Instead of cutting the record with only the very small energy of the sound waves, they were prepared to convert the sound to corresponding electrical waves of much greater energy content, and to employ electromagnetic forces for the actual cutting. The lateral cut system, most commonly used at the time, was the type of recording chosen because an analysis of fundamentals showed that with the types of structures then available, the inherent advantages of the vertical type would be more than offset by difficulties in making the needle follow the groove contour at all frequencies. As a result of the contributions of the Laboratories, the orthophonic phonograph was brought out, and later, the sound picture.

Although the recording and reproduction in both of these systems was far better than anything that had been attained before, the Laboratories' engineers realized that much improvement was still possible. During the last few years, therefore, the complete subject of sound recording and reproducing has been reinvestigated. Methods have been developed by which it is possible to reproduce with markedly improved quality. This has required both that a wider band of frequencies be recorded, and that more of the extraneous frequencies, either in the form of surface noise or of distortion, be excluded. Such a twofold gain was made possible only by a coordinated development along three lines: the design of apparatus that would record and reproduce a wider band of frequencies, the production of a record with considerably less surface noise, and the securing of decreased distortion arising from improper tracking of the reproducing needle. These improvements were obtained by an improved design of recorder and reproducer, by a new method of processing the records, and by a different manner of cutting the groove.

In the studies of sound recording and reproducing that followed the orthophonic phonograph and the sound-picture, careful measurements soon showed that a certain amount of distortion introduced in the reproduction was to a large extent inherent in the method of cutting then employed. With that method, known as lateral cut, the depth of the cut remains constant. The cutting stylus is moved radially in correspondence with the actuating sound to chisel a wavy groove on the rotating disk, as shown in Figure 1. This groove is of the same width along the radius of the disk at all points. Since it is a wavy one, however, winding toward and away from the center of the record with the variations of sound pressure, the distance across the groove—perpendicular to its sides—is not constant. It is widest at top and bottom of the waves and narrowest on the slopes as shown in Figure 2. The reproducing needle, on the other hand, is round, and its diameter cannot be greater than the distance across the groove at its point of greatest steepness. Along these sloping sections of the groove the needle is guided by both sides and follows the actual form of the groove with fair precision. Along the tops and bottoms of the sweeps of the groove, however, it is in contact with only one side of the groove at a time, and may skid from side to side, thus introducing distorting frequencies.

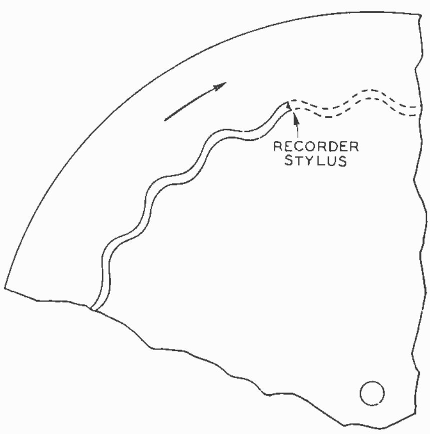


Fig. 1—In the lateral system of recording the cutting stylus is moved radially in response to the sound to cut a wavy groove on the disk

Another method of recording on wax is known as vertical cutting. With this method the stylus is moved up and down and thus leaves a groove of which the depth varies according to the sound. It gives a series of hills and valleys along the groove, and the method, for this reason, is often referred to as "hill and dale." It is illustrated in Figure 3. In reproducing from this type of record the needle is held to the bottom of the groove by an unbalanced portion of the weight of the reproducer head. Although the actual pressure on the disk is small, it is sufficient—in conjunction with a light spring by which the needle is fastened to the reproducing head—to force the light stylus to follow the exact undulations at all times. There is no skipping, so the distorting frequencies that sometimes occur with side-cut records are absent with the vertical.

Although vertical recording has been employed by others before, the greater part of the development of the past has been in connection with side-cut records. Because of the inherent reduction in distortion that analysis and preliminary studies indicated could be obtained with vertically cut records, however, vertical cutting was taken by the Laboratories as the basis of the new method. It has another advantage over the side-cut record in making possible a longer playing time. With side-cut records the radial distance between adjacent grooves must be great enough to allow the maximum displacement of both grooves from mean position—corresponding to the greatest volume of sound—without danger of cutting through from groove to groove. The actual annular space allowed for a groove must be the width of the cutting stylus, plus twice the maximum displacement of the groove, plus a small remainder to insure that adjacent grooves remain separate. With vertically cut records, on the other hand, very little allowance need be made in the spacing of adjacent grooves for the displacement of the groove. Due to the tapered sides of the cutting stylus there is a widening of the groove as the depth increases, but it is of minor importance compared to the full displacement of the groove that must be allowed for with side-cut records. Because of this fact it is possible to cut vertical records with a pitch of from 150 to 200 grooves per inch—thus giving standard twelve-inch records that will play from 15 to 20 minutes on one side, or ten-inch records that will fit in the cover of a 1000-foot film can and play for from ten to twelve minutes. The difference between the two types of record is shown in Figure 4.

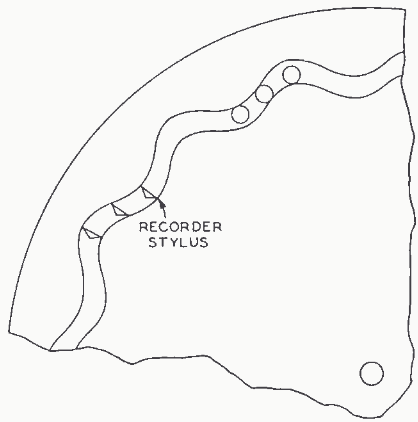


Fig. 2—The width of the groove measured radially is constant since it is equal to that of the cutting stylus. The width of the groove perpendicular to the sides, however, is not constant because of its undulating character

Although the adoption of the vertical method laid the foundation for better sound reproduction, the major development work was still to be done. Perfection in recording requires not only that distortion—in the form of false frequencies or sounds—be eliminated but that all the frequency components in the sound be present in their correct volume ratios. Although the ear recognizes as sound all periodic pressure variations in air occurring at frequencies from about 30 to some 16,000 cycles per second, all sections of this range are not equally important. Recent investigations have shown that the quality of orchestral music improves materially up to about 8000 cycles but that the reproduction of only a few pieces, such as the percussion instruments, is noticeably bettered by the inclusion of frequencies above 10,000 cycles. The ear also recognizes as sound, vibrations over a pressure range of about a million to one, or 120 db. The best phonograph and sound-picture practice included comparatively small amounts of frequencies above 5000 cycles for a range of loudness corresponding to a pressure range of but 50 db.

Vertical cutting makes it much easier to increase the loudness range because, as already pointed out, an increased depth of cut does not necessitate a corresponding increase in the spacing of the cutting groove as it does with the side-cut record. Moreover a small amount of overlapping of the grooves is of no great matter with the vertical system since the reproducing needle follows the bottom of the groove, and is not affected by the sides provided they are smooth. The adoption of vertical cutting thus made it possible not only to eliminate the distortion arising from improper tracking but to increase the loudness range as well. To include a wider band of frequencies, however, an improved recorder and reproducer were required.

This widening of both frequency band and loudness brought in still further difficulties. In the ordinary record there is a certain amount of surface noise, caused by lack of smoothness of the record, which is ordinarily made unobjectionable by recording at a displacement that is high compared to the irregularities in the surface. To record at a wider range of loudness while maintaining the same magnitude of surface irregularities and the same ratio between cutting displacement and surface irregularities, would require too deep a cut. If, on the other hand, this ratio were decreased without decreasing the surface irregularities, the result would be very noisy records, and the good effect of the inclusion of the higher frequencies would be largely lost because of masking by the surface noise. It seemed necessary, therefore, be-

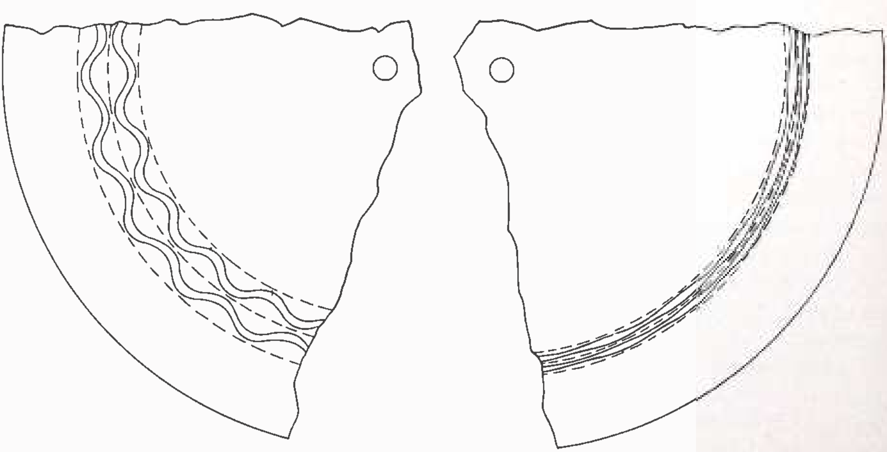


Fig. 3—The waves cut by the new method are in a vertical rather than a horizontal plane

sides a new recorder and reproducer, to develop a smoother record surface.

Here, also, certain methods which had been tried and rejected by others in the past seemed to offer great possibilities if a technic of manufacture could be provided which would avoid the earlier causes of failure. A large amount of work has been required over a number of years. The several lines of development had to be coordinated and carried on simultaneously. The result, however, has been eminently successful. A method is now available which results in the ability to record and to reproduce frequencies up to 8,000 cycles per second—about 3000 cycles higher than has been commercial sound-picture practice. It results also in so improved a surface that the usually prevalent needle scratch in the best recordings is nearly inaudible: a necessary requirement if full advantage is to be taken of the presence of the higher frequencies. The overall result is a much greater naturalness: voices and instruments are more readily identified and the finer shades of tone are better brought out. The ultimate objective of reproduction—complete illusion of the actual presence of the orchestra or voice—is nearly attained.

Not the least of the advantages of the new system is that the method of processing the records is as simple and inexpensive as the present method. The various steps require neither highly skilled operators nor delicately controlled processes. The record is cut on a thin layer of wax flowed onto a metal disk, and after being cut is given a thin plating of gold by a method called sputtering. This surface is then heavily plated with copper to strengthen it, and records are made, by a hot pressing process, of a very smooth and practically unbreakable material. The reproducing stylus is not a replaceable steel needle but a permanent sapphire. Because of the light pressure of the reproducing stylus, records will last for several thousand playings with no noticeable deterioration.

Bell Laboratories, by its recent developments, has thus made available a greatly improved system of sound reproduction, which should have many commercial uses in the future. In addition to a variety of miscellaneous uses, there is, of course, the possibility of greatly improved sound pictures but the usefulness of the system is not limited to this field. A new form of phonograph employing the improved records and electrical reproduction seems an attractive possibility since 15- or 20-minute records of music almost indistinguishable from the original would be invaluable. One of the fields of immediate usefulness is that of the production of high-quality records for broadcasting purposes. The frequency range of these records is so much wider than the broadcast bands that the radio listener cannot distinguish between an electrical transcription made with this type of record and an original production. Whatever use is made of the new system, however, it is now possible because of this development to reproduce music and speech with such fidelity and so free from disturbing scratch that almost perfect naturalness is obtained.

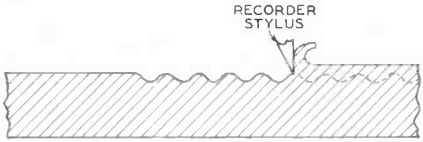


Fig. 4—A schematic indication, not to scale, of the difference between lateral and vertical records

A Measure of Physical Quality for Central Office Equipment

By R. B. Miller
Inspection Engineering

UPON completion of the assembly and adjustments of a new central office, certain checks must be applied to insure that the equipment will operate satisfactorily and with a reasonable degree of maintenance when placed in service. The final procedure to assure this involves a visual inspection as well as performance tests. This inspection is to determine that the requirements for apparatus adjustments and framework assembly have been met and that the wiring is in a satisfactory condition. Although inspection in some form has always been necessary in the final stage of preparing a central-office unit for service, requirements for such a procedure have only in recent years been standardized in the form of specifications. These specifications involve several features which are unique in this type of work. In general, they provide definite quality standards for physical condition of the equipment and indicate a detailed and systematic procedure which will insure that the parts of each central-office unit will be included in the inspection. This paper deals with the technical aspect, and not with the administration, of the inspection plan.

Because of the very large amount of equipment in a central office, its inspection is a task of considerable magnitude. In a standard 10,000-line office of the panel type there are, to mention only the more common types of apparatus, some 50,000 relays, over 25,000 multiple brushes, nearly 5000 each of commutators, clutches and sequence switches. On the average there are about fifteen requirements applying to each piece of apparatus so that there would be over eight million points of inspection if the apparatus were to be completely covered. Obviously such an inspection, because of the time, expense, and particularly the danger of changing adjustments by handling the equipment, is highly undesirable. A complete inspection in general has been made unnecessary by a procedure of sampling inspection described by the specifications referred to.

It is an accepted truth that in producing large numbers of any piece of apparatus, all pieces cannot be made identical. As a result, a certain variation may be included as a part of each requirement. In a large number of similar parts there will always be a certain number in which the requirements have been exceeded—a certain number of the finished parts, in other words, will be defective. To attempt to eliminate all these defective pieces before the equipment is put into service would result in an increase in manufacturing or inspection costs that would not be justified by the improvement in quality gained. It is more economical to allow a small proportion of defective pieces to exist and to have them discovered and remedied by the regular maintenance procedure, than to attempt to eliminate all of them before the equipment is turned over to the telephone company. Hence it is desirable to set another type of tolerance to govern the allowable proportion of defective parts. If, for example, the armature travel of a certain lot of relays were known to be within its manufacturing requirements in all but 2% of the relays, the lot would be considered

DEFECT TOLERANCE AND SAMPLING

REQUIREMENTS

STEP BY STEP - LOCAL MANUAL

CENTRAL OFFICE EQUIPMENT

E,F,H,R & T TYPE RELAYS
(FLAT TYPE RELAYS)

TABLE X-65562-08 Issue 2

Lot Range				A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Lot Size (Number of Flat Type Relays in Equipment Group)				1 160	161 300	301 450	451 700	701 1000	1001 1500	1501 2500	2501 4000	4001 7000	7001 10000	10001 15000	15001 20000	20001 30000	30001 50000	50001 70000
Sample Size (Relays)				All	160	170	185	210	240	310	390	550	770	1100	1500	2000	3000	4000
Inspection Item**		Allowable Per Cent Defective For Lot	Basis		Allowable Defect Numbers													
					AN	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN
1.Relay Mounting	*	3.0	Relay	-	2	2	3	3	4	5	7	11	17	26	36	50	77	106
2. Cover Spring Pressure and Guide Position	*	3.0	"	-	2	2	3	3	4	5	7	11	17	26	36	50	77	106
3.Tightness of Assembly	*	2.0	"	-	1	1	1	1	2	3	4	7	10	16	23	32	45	68
4. Contact and Spring Alignment		2.0	"	-	1	1	1	1	2	3	4	7	10	16	23	32	45	68
5.Armature Stud Clearance		2.0	"	-	1	1	1	1	2	3	4	7	10	16	23	32	45	68
6.Spring Tang Position		3.0	"	-	2	2	3	3	4	5	7	11	17	26	36	50	77	106
7.Adjusting Stud Clearance		2.0	"	-	1	1	1	1	2	3	4	7	10	16	23	32	45	68
8. Adjusting Nut Tightness (Including Adjustable Stop Pin Tightness on F Type)	*	3.0	"	-	2	2	3	3	4	5	7	11	17	26	36	50	77	106
9.Armature Travel	*	3.0	"	-	2	2	3	3	4	5	7	11	17	26	36	50	77	106
10.Straightness of Spring	*	2.0	"	-	1	1	1	1	2	3	4	7	10	16	23	32	45	68
11. Separation Between Springs		2.0	"	-	1	1	1	1	2	3	4	7	10	16	23	32	45	68
12.Contact Pressure		2.0	"	-	1	1	1	1	2	3	4	7	10	16	23	32	45	68
13.Stud Gap		2.0	"	-	1	1	1	1	2	3	4	7	10	16	23	32	45	68
14.Contact Separation		2.0	"	-	1	1	1	1	2	3	4	7	10	16	23	32	45	68
15.Contact Follow		2.0	"	-	1	1	1	1	2	3	4	7	10	16	23	32	45	68
16.Spring Sequence		2.0	"	-	1	1	1	1	2	3	4	7	10	16	23	32	45	68
17. Notes (Armature Spring Tension)		3.0	"	-	2	2	3	3	4	5	7	11	17	26	36	50	77	106
18. Electrical Requirements (Including Timing Requirements When Specified)	*	3.0	"	-	2	2	3	3	4	5	7	11	17	26	36	50	77	106
Sample Size					Inspect all Covers Removed for Relay Sample													
19. Can Covers (Common) Fit, Finish, Damage (w)	*	5.0	Cover	-	3% of Covers Inspected													

(w) Requirements for items marked with a "w" are based on accepted Standards of Workmanship. For requirements for the remaining items refer to Bell System Practices, Section A461.004, Issue 1-D.

** In the application of Spottiness Numbers, SN, indicated in the Table below, each requirement involved in inspection item 8 or 17 may be treated as a separate inspection item.

* The lot can be considered satisfactory for each item marked with a star if no defects are found with respect to that item in the inspection of the first 100 relays for specified sample size less than 400 relays and of the first 25% of the sample for specified sample sizes exceeding 400 relays.

AN = Allowable Number of defects in sample.

RELAYS: Spottiness

Spottiness Numbers

Size of Sub-Sample	SN
10 - 25	2
26 - 70	3
71 - 125	4
126 - 175	6
176 - 200	7
201 - 250	8

Size of Sub-Sample	SN
251 - 300	10
301 - 350	11
351 - 400	12
401 - 450	13
451 - 500	14
501 - 550	16

Size of Sub-Sample	SN
[illegible]	[illegible]
601 - 650	19
651 - 700	20
701 - 750	[illegible]
751 - [illegible]	[illegible]
801 - [illegible]	24

SN = Spottiness Number (applying to sub-samples).

For detailed explanation and use of Tables refer to X-65562-02 and X-65563-02 for Step by Step, and Local Manual Central Office Equipment respectively.

BELL TELEPHONE LABORATORIES, INC.

DEPT. 314-B

X-65562-08 Issue 2

Based on Bell System Practices, Section A461.004, Issue 1-D

Fig. 1—A typical sampling specification applying to flat type relays

satisfactory as a whole. The 2% would be the maximum allowable percentage of defects in the lot. One of the principal features of the inspection specifications, known as Defect Tolerance and Sampling Requirement Specifications, is a listing of these allowable percentages of defects for each inspection item.

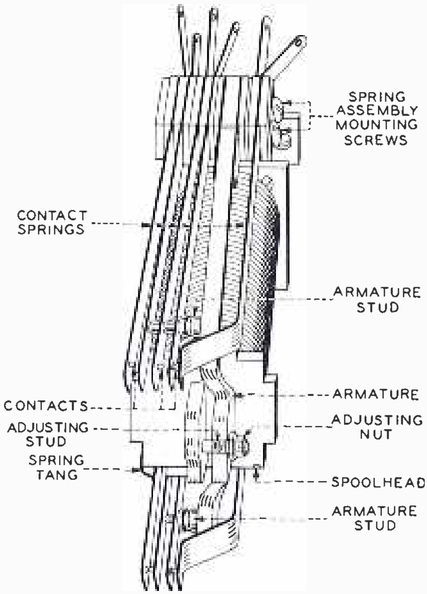


Fig. 2—A typical flat type relay showing points of application of some of the requirements

In general each type of apparatus will have such an allowance applying to each of its requirements, and none must be exceeded for any lot of apparatus to be passed. These percentages, of course, are limits, and on the average the various lots passed will be well below the limits applied to them. If complete inspection were always employed, these percentages would serve no useful purpose since obviously there would be no advantage in allowing defects to remain once their presence and location were definitely known. The establishment of such limits, however, makes it possible to use sampling inspection. Only a certain number of pieces out of each lot of apparatus is inspected, and if the number of defects in this sample is below a certain small number, calculated from the theory of probability, the entire lot is passed as satisfactory. This not only reduces the time and expense of inspection but has the more important advantage of reducing the deterioration which inevitably follows from the handling necessary to inspection.

For various types of central-office apparatus, sections of the Bell System Practices are available as has already been described in the Record*, and for each such type of apparatus, of which sufficient quantities are used in a single office to make sampling feasible, Defect Tolerance and Sampling Requirement Specifications are also provided. Illustrative is the sampling specification for flat type relays shown in Figure 1. The possible lot sizes of these relays that may be encountered in equipment groups are divided into ranges, and beneath each lot size is given the sample size that applies to it. Opposite each of the various inspection items are the number of defects that may be allowed in the sample. The probability basis for the selection of the allowable defect numbers has already been described in the Record†.

The entire sample is inspected for each of the items and if the number of defects found for any one item is greater than the allowable number, the entire lot is inspected for that par-

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*Nov. 1929, p. 123; at that time called Requirements and Adjusting Procedures.

†Bell Laboratories Record, Dec. 1929, p. 154.

ticular item. If on the other hand the number found is not greater than the allowable number, no effort is made to locate possible defects in the remainder of the lot. All defects found are, of course, corrected. Double sampling criteria are provided for certain items that are starred on the table of Figure 1, which may reduce the amount of inspection required. If, for example, no defects whatever are found in the first 100 relays inspected (or the first 25% if there are more than 400 in the lot) the lot is considered satisfactory.

Defect Tolerance and Sampling Requirement Specifications, similar to that described above, apply to all local telephone systems. For toll systems a higher degree of quality is required and investigations are under way to ascertain how assurance of this higher quality can most economically be obtained.

To insure that all parts of a central-office unit will be included, the planning and layout of the inspection is described in the Inspection Procedure Specification. All information is given here as to the proper time for inspection, the correction of defects, and other general features. Detailed information is furnished for dividing the office into natural equipment groups which will form convenient inspection units. Each group is divided into lots, each of which consists of a single type of apparatus. A typical plan of this type for a panel office is shown in Figure 3.

In choosing the sample, care must be taken to make sure that the quality of the sample will be representative of the quality of the lot. To accomplish this the samples are generally divided into sub-samples, for whose distribution, requirements are included in the specifications. The manner in which these sub-samples are distributed in a particular case is shown in Figure 4. In the specification the illustration is accompanied by detailed instructions.

In certain cases complete inspection will be required because of limited quantity, nature of the possible defects, or importance of the apparatus in operation. This may apply only to certain types of apparatus in a group, such as the interrupters on panel selector frames, or to an entire group, as for example, the power equipment. For each telephone system the types of apparatus requiring complete inspection are designated in Inspection Procedure Specifications.

This new type of specification thus

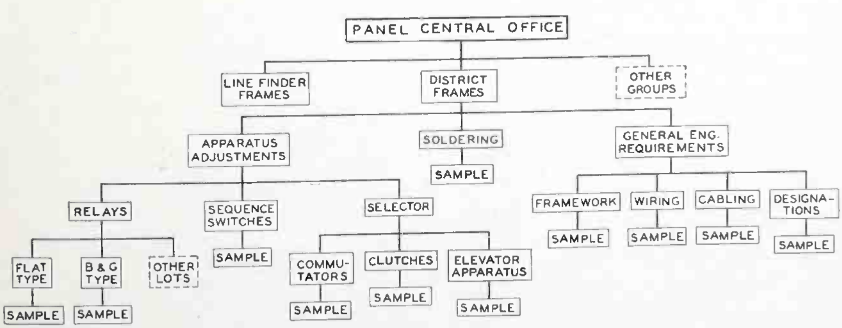

Fig. 3—Method of arranging apparatus in a panel office into groups and lots

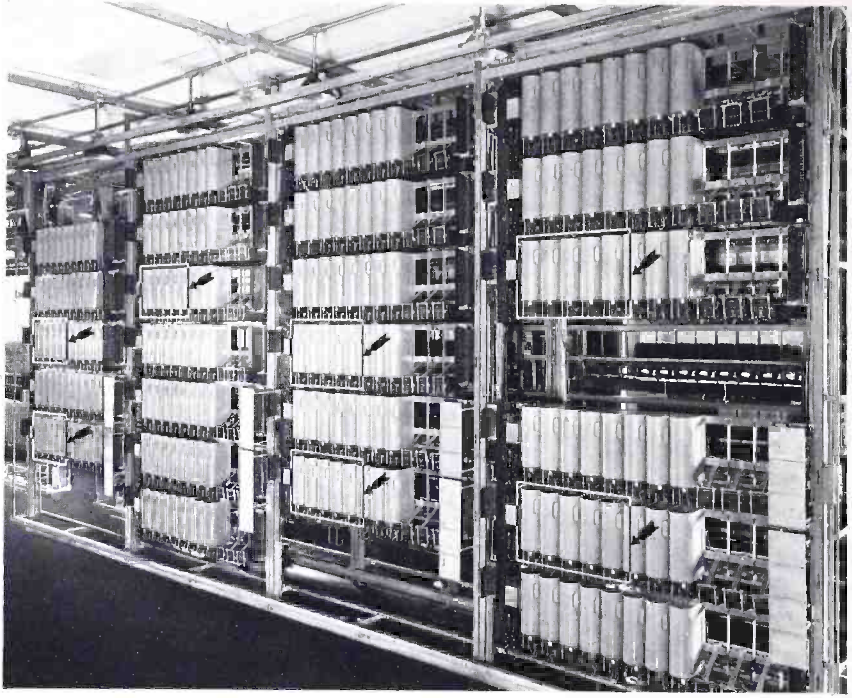

Fig. 4—Location of sub-samples in a lot of connectors

provides a measure by which more uniform physical quality can be assured for central office equipment. Records arising from the inspections may be used by the operating companies in place of inspections by their own people. The records also provide the Laboratories with important data for use in connection with the study of design improvements and for the revision of the quality standards of the inspection specifications themselves. The Laboratories has issued these specifications to fix standards of physical quality applying to central office equipment at the time it is turned over to the operating companies. Their operation is under continuous observation and study to make certain that they shall be most effective in ensuring that equipment entering the plant of the Bell System will give a maximum of utility for every dollar invested.

Western Electric Photomatic Equipment

By J. C. FIELD

Special Products Development

THE use of the photoelectric cell as a pick-up device for communication work is best known in picture transmission, television, and sound reproduction from film. Engineers of Bell Telephone Laboratories have had many years' experience in the development of photoelectric cells and the circuits for use with them. This technique has now been applied to the development of a photoelectric outfit for certain industrial use. In this outfit, a beam of light acts to control the current flowing in an electrical circuit, which in turn may cause any desired sequence of events to take place. Among applications to which this equipment is adapted are the counting of persons passing through a doorway; warning of the entrance of intruders into a room; holding elevator doors open as long as anyone is standing in their path; and in electrical measurements where the beam of light from a mirror galvanometer may control various operations.

The new device will be known as the Western Electric 1-A Photomatic Equipment. It consists of a light unit and a light-relay unit. Both are designed to operate from commercial 50-60 cycle, 115 volt alternating current mains. The connection of the AC supply and of the circuit to be controlled comprise the only electrical connections required.

Inside the light unit is an automobile headlight bulb fed by a suitable transformer, a condensing lens to produce an essentially parallel beam of light, and a filter to render the beam invisible if desired. That part of the light unit containing the lamp and lens, shown in Figures 1 and 2, may be pivoted through a wide angle around the base. It may also be tilted 10° from its normally vertical position, thereby permitting the direction of the light beam, which is normally parallel to the base of the light unit, to be raised or lowered.

Fig. 1—Light unit of Photomatic equipment

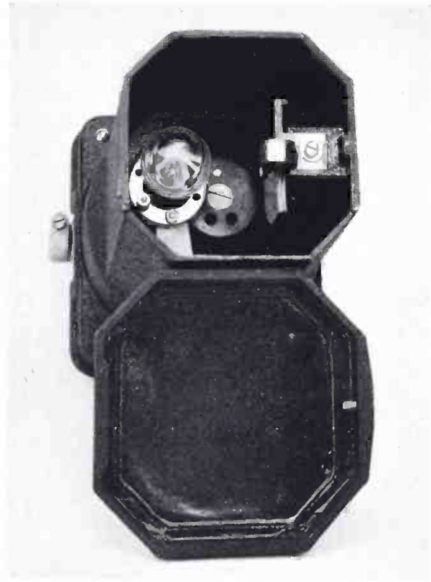

Fig. 2—Light unit with cover removed showing lamp and filter

The light-relay unit, Figure 3, consists of a cast aluminum housing with a circular window $1\frac{1}{16}''$ in diameter to admit light to the cell, and contains a photoelectric cell, an amplifying vacuum tube, a relay, and associated apparatus. Additional aperture-plates are provided, with circular openings of $\frac{3}{4}$, $\frac{3}{8}$, and $\frac{3}{16}$ inches, for use if desired. The circuit can be arranged for "forward" operation in which, as long as the cell is illuminated, the relay is energized, or for "reverse" operation, in which the relay is not energized when the cell is illuminated. In burglar-alarm work, for example, it might be desirable to give an alarm if an intruder intercepted the light-beam, and also if the power failed; here the "forward" connection should be used. To give an alarm if the lights in a room were turned on, the "reverse" connection is applicable. An alarm for power failure is also provided on this connection, since failure of power would release the normally operated relay.

In Figure 4 is shown a schematic circuit of the 240-A Light Relay connected for "forward" operation. The manner of operation under these conditions is as follows: When the Photoelectric Cell is not illuminated, its resistance is practically infinite, and the grid potential of the vacuum tube, as determined by the charge on the condenser C1, assumes a value which prevents the flow of plate current in this tube. When the photoelectric cell is illuminated, however, it provides a high resistance path whereby the charge on the condenser C1 and hence the grid potential is lowered, thereby permitting plate current to flow in the vacuum tube, and operate the relay S1.

The vacuum tube, of the 256-A type, is a special 3-element tube containing gas at a low pressure, in which the flow of a relatively large current in the plate circuit may be controlled

Fig. 3—The aluminum housing for the light-relay unit contains a hole for admission of the beam of light and a screw which may be removed for the only adjustment required

by a small amount of energy in the grid circuit. The photoelectric cell employed is of the caesium type widely used in sound picture reproducers, but is of the vacuum rather than the gas-filled type. A vacuum cell is used because of its stability, and its freedom from the possibility of injury by any illumination which can be given it by the light unit.

Connections for "reverse" operation are shown in Figure 5. Here a high resistance R_1 connects the grid to its cathode, so that when the photoelectric cell is dark, and so practically open-circuited, the tube acts as a rectifier, and provides pulsating direct current to operate the relay. When the photoelectric cell is illuminated, current will flow through it to the grid during half the cycle and so increase the grid potential enough to block the tube. During the other half-cycle the plate will be negative. Thus no current will flow during either half cycle, and the relay will not be operated.

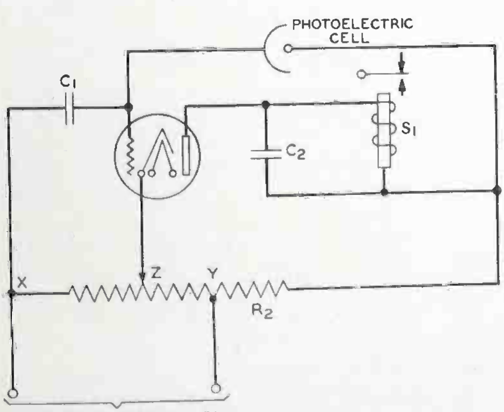

Fig. 4—Simplified schematic of light-relay circuit for "forward" connection

To obtain the optimum operating condition, the movable contact Z on the potentiometer is adjusted by a screw-driver, inserted through a hole, shown capped by a screw, in Figure 3. This adjustment is made after the

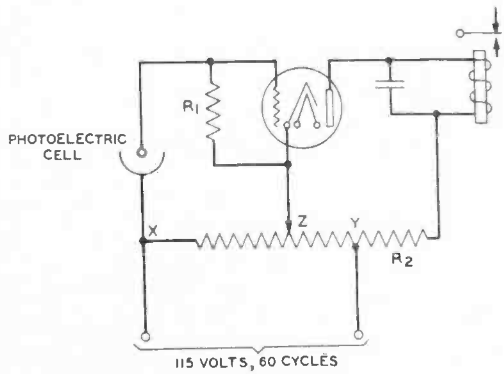

Fig. 5—Simplified schematic for the "reverse" connection

light-beam has been focussed on the aperture in the light-relay case. For the "forward" connection, the contact Z is adjusted so that the relay will release when the light-beam is interrupted. For the "reverse" connection, the adjustment is made so that the relay will operate when the light-beam is cut off and vice-versa.

The light-relay unit with cover removed is shown in Figure 6. The relay has one "make" and one "break" contact, capable of carrying ¼ ampere and of breaking 127 volts AC or DC. For greater current and voltage, an auxiliary relay is used. With a 15 c.p. lamp in the light unit and no light filter the light-relay will operate over a distance of 25 feet, while with a 50 c.p. lamp the distance is increased to 35 feet. For the reverse connection only, the resistance R_2 may be short-circuited and the distances above increased to 40 and 55 feet respectively.

Provision has been made for connecting an external milliammeter in the plate circuit where, in the "forward" connection, the current flowing is a measure of the illumination on the photoelectric cell. This arrangement is useful where quantitative indications are desired, as for example in the measurement of chimney smoke, and in optical pyrometry.

Fig. 6—Light-relay unit with cover removed

Contributors to this Issue

W. G. LASKEY's studies of electrical engineering at Massachusetts Institute of Technology were interrupted by the war. During the war period he supervised the installation of radio-telephone equipment in naval aircraft, and at its conclusion joined these Laboratories. From 1919 to 1925 he was concerned with the development of tungsten-filament lamps for switchboards. He has since been occupied with the development of filters and special circuits, and is now engaged in the application of quartz crystals to telephone uses.

J. M. HUDACK joined the Laboratories in 1916 as a member of the Transmission Research Department. Beginning at an early date he assisted in development work on testing apparatus. From 1924, when he received a B.S. degree at Cooper Union, until 1928 he was with the Special Products Division of the Apparatus Development Department where he was engaged in work on power line carrier telephone, public address, and loud speaker equipment. Since 1928 he has been engaged in the development of vacuum tube apparatus for use in connection with telephone transmission measurements.

C. M. GULDNER was graduated from Cornell University in 1926 with the degree of E.E. The following three years he spent with the Electric Division of the New York Central Railroad engaged in work on electric locomotives and cars. In the spring of 1929 he joined the technical staff of the Laboratories where he has been occupied with the development of power apparatus.

W. G. Laskey

J. M. Hudack

C. M. Guldner

W. M. Stuart, Jr. joined the Bell Telephone Company of Pennsylvania in 1906, and served, first as a subscriber's-station installer, and later as an inspector of this work. He was subsequently transferred to inspection work on PBX installations, and before joining the Western Electric Company, in 1915, was special inspector for the entire city of Philadelphia. He came to West Street as a member of the old circuit laboratory where he followed work on subscriber's station circuits, for which his earlier experience had admirably fitted him. At the present time he is a member of the Analysis and Testing groups.

R. B. Miller received his B.S. Degree from Dennison University in 1914. Shortly after graduation he entered the field of secondary education as an instructor in physics and chemistry. During the war he served over seas as a Master Signal Electrician with the Signal Corps. In 1920 he joined the Engineering Department of the Western Electric Company, now incorporated as the Bell Telephone Laboratories.

As a member of the Systems Development Department he was engaged in the analysis and testing of the first full-automatic testing circuits for panel type equipment. From 1921 to 1923 he was the Laboratories' representative at Kansas City, Missouri, during the installation of one of the first full mechanical panel type central offices.

Shortly after his return to New York he transferred to the Inspection Engineering Department where he has since been concerned with the practical application of statistical methods to central office inspection procedure.

After receiving his A.B. degree from Colorado College in 1910, H. C. Harrison came east and received an S.B. from the Massachusetts Institute of Technology in 1913. He remained at the Institute for a year as instructor and then joined the Engineering Department of the Western Electric Company, now incorporated as Bell Telephone Laboratories. Here he first engaged in fundamental studies of receivers and carbon-button microphones. Since then he has worked on receivers and horns for public address, sound recording and reproducing leading to the orthophonic and disk-type sound-picture systems. He has been instrumental in applying the principles of electric transmission theory to sound recording and reproducing equipment, and the development of the rubber line recorder and our use of the exponential horn both resulted from his studies. The new and improved system of sound recording and reproducing described in this issue of the Record was carried on under his supervision.

W. M. Stuart, Jr.

R. B. Miller

H. C. Harrison

J. C. Field

After receiving a C.E. degree at Princeton in 1903 and the degree of S.B. from M. I. T. in 1905, J. C. FIELD joined the Western Electric Company. Following a student course, he worked in the shop on switchboard assembly and testing, and in equipment engineering on preparation of specifications for switchboards and associated equipment. Transferring to the laboratory, he engaged in general circuit work and in the development of semi-automatic switching of the panel type. In the old "physical laboratory" he worked on the development of equipment for train dispatching with which he has been associated most of the time since. During the war period, Mr. Field was employed on deep-sea submarine detection work both in New York and at the naval laboratory at Nahant, Massachusetts. He also worked on methods of selective control of mine systems for the Coast Artillery. At the present time he is in charge of the group which is concerned with the development of train-dispatching apparatus.

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