BELL LABORATORIES RECORD

TALKING BATTERY
R. P. MARTIN, JR.

HOW PITCH CHANGES WITH LOUDNESS
A. R. SOFFEL

NEW AUDIOMETER
R. NORDENSWAN

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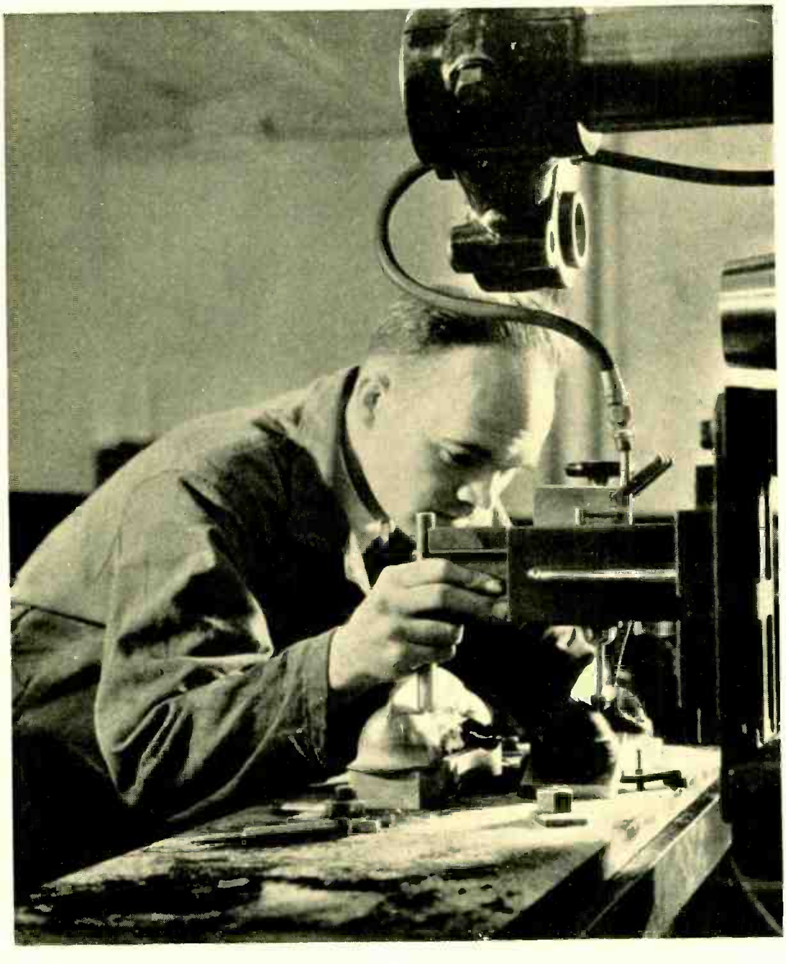

"Copying" the form of an experimental handset from designer's model

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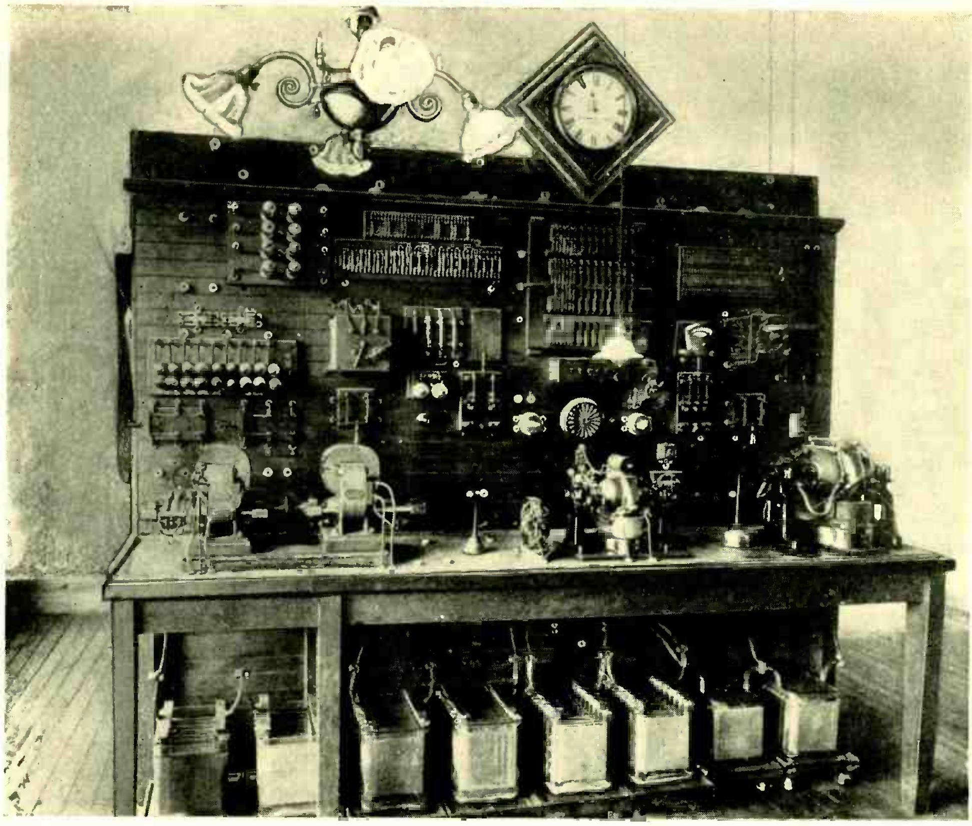


Talking Battery

By R. P. MARTIN, JR.
Power Development

TO those intimately concerned with the telephone plant, the terms "talking battery" and "twenty-four volts" are irrevocably linked through long association. Either term immediately calls the other to mind and yet many would probably be at a loss to know just how the association began. As with many an established practice, its origin is hazy in the historical mist. As a matter of fact, talking battery was used at the very beginning of the telephone. On that afternoon of June 2, 1875, when Watson—the first telephone maintenance man—was adjusting the reed of an experimental harmonic telegraph transmitter, and Bell heard the twang in another room, a battery was connected in the circuit between the transmitter and receiver.

The next night, June 3, Bell's first telephone instrument, having been hurriedly constructed by Watson, was tested with a battery in the circuit; and Bell's voice was faintly heard. There is no record of the type or number of cells used but it is more than likely that they were of the Grenet chromic-acid type — carbon and zinc electrodes in a solution of sulphuric acid, with potassium bichromate serving as the depolarizer. This cell has a potential of approximately 2 volts; and the number of cells used was varied according to the needs and availability. The sketches in the fundamental patent indicate either two or four cells, and the circuit that was used is shown by the second sketch in Figure 2.

Early in 1876 a radically different design of instrument was produced. Attached to its diaphragm was a wire whose depth of immersion in a weak solution of sulphuric acid contained in a metal cup was varied by the voice-generated movement of the diaphragm. Sulphuric acid — so familiar to us today as the electrolyte in the telephone talking battery —may be said to have been used to christen the telephone, for when some sulphuric acid from a spare cell was accidentally spilled on his clothing, the young inventor unintentionally gave to the new transmitter its first intelligible sentence on March 10, 1876.

Although the use of talking battery gave some improvement in operation, there was a strong desire to improve the apparatus so that no battery would be necessary. Thus Bell, writing in July, 1876, says:—"In order to attempt the transmission of speech to Philadelphia, it was necessary to have a telephone constructed, the magnet of which should have a resistance equivalent to a considerable portion of the total resistance of the telegraph line between here (Cambridge) and Philadelphia. The resistance of the line is over 5000 ohms. Now I have had two magnets made, the coils of which offer a resistance of 3250 ohms both together. It would require a battery of many cells in order to operate a Morse sounder through such resistance. It is as great a resistance as 325 miles of

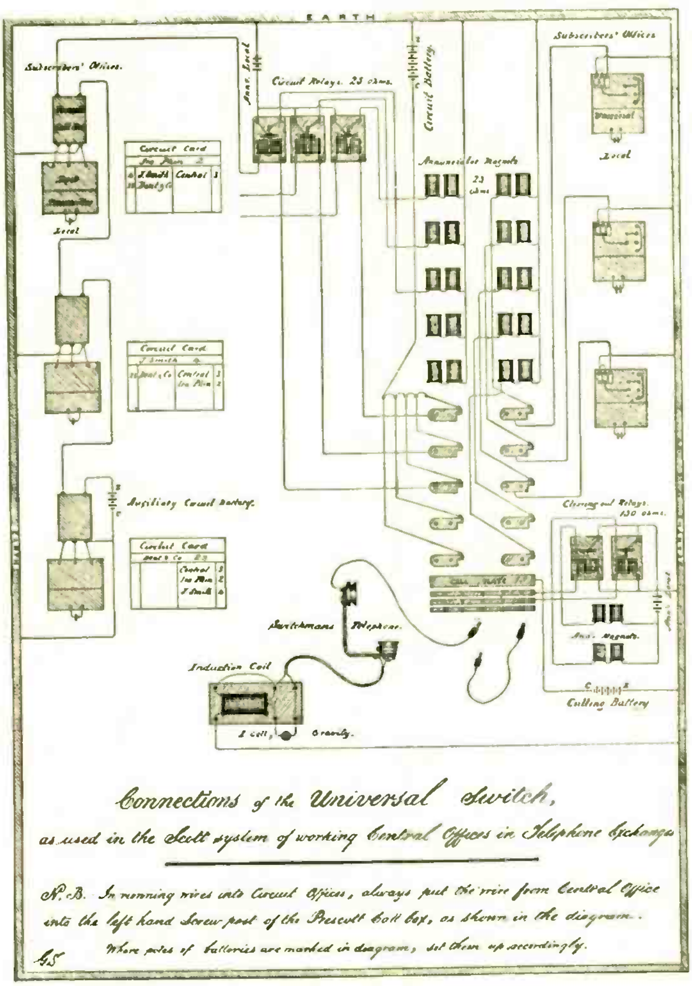


Fig. 1—Schematic circuit of a central office of 1879

well-insulated telegraph wire. My discovery was that I could work my apparatus with *one cell of battery* through this resistance. I am sure by substituting a *permanent magnet* for the pole of the electromagnet, I could work it *without a battery at all*."

This hope was strengthened by Watson's adaptation of a new quick-acting magnet to the transmitter circuit; and Bell seems to have thought, probably with a considerable amount of relief, that a transmitter battery would no longer be needed. The pamphlet which was used to solicit business for the first commercial exchange, which opened January 28, 1878, in New Haven, Connecticut, prominently advertised at the top of each page that there was "No Battery Used," thus expressing Bell's attitude. Soon, however, the battery transmitter proved to be the better type; and "gravity" cells with an initial discharge voltage of one volt, and Leclanché cells with an initial discharge voltage of 1.5 volts were the first "standards" used for closed and open circuit applications. The gravity cell (sometimes called the "crowfoot" because of the shape of its electrodes, or "blue vitriol" because of its copper sulphate) consisted of a copper electrode at the bottom of a glass jar and an amalgamated zinc electrode suspended from the top. The lower part of the jar was filled with a copper sulphate solution, which acted as a depolarizer, and the upper with a zinc sulphate solution, which was the electrolyte—the separation of the two resulting from the difference in their specific gravities. The Leclanché cell consisted of a glass jar in which carbon and zinc electrodes extended from the top into a solution of ammonium chloride (sal ammoniac) which was the electrolyte. The carbon rod electrode was surrounded with granular manganese peroxide which served as the depolarizer. Figure 1, with its amusing cir-

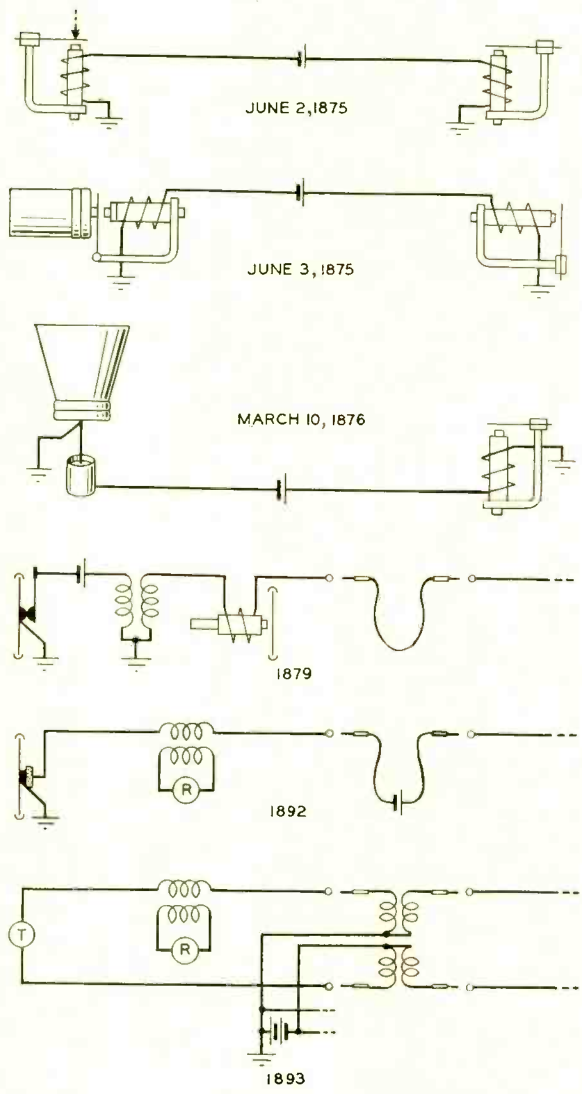


Fig. 2—Graphical history of the talking circuit over the first twenty years of the telephone

cumambient "EARTH," is a schematic circuit of an 1879 "exchange" in which the "switchman's telephone" was supplied by "one cell gravity" and each transmitter by one or two cells of either the gravity or Leclanché type.

Thus, "talking battery" had an initial value of one volt. The telephone lines were rapidly reaching out, however, and the standard voltage was destined to go through many changes. Soon, for example, the problem was encountered of making the Blake (carbon button) transmitter powerful enough for long-distance work. Thus, in March, 1880, for a comparative test of Edison (variable resistance carbon block) and Blake transmitters on a line between Boston and New York, Watson's instructions were:—"Use two cells Leclanché in each local battery and have about half a dozen on hand as Mr. Vail wishes to try the effect of increased battery"; and again, when the Hunnings (carbon granule) transmitter, the invention of an English Episcopal rector, was under test in May, 1883, "Mr. Vail wants to try the effect of a large battery." In June, 1883, two cells of Leclanché were used in conjunction with the Blake transmitters on the Hudson River cable tests.

Although, as early as January, 1885, Blake had exhibited an improved transmitter capable of operating on voltage supplies ranging from 1.5 to thirty volts, several years of intensive laboratory work by G. K. Thompson and others, having to do with the effect of higher voltages on the heating of the transmitter's carbon button, were necessary before a commercial form of the Blake transmitter was capable of operating from primary batteries of from six to eight volts.

In April, 1890, Thompson constructed a transmitter with four buttons in series and tested it with a thirty-two-volt battery of sixteen Fuller cells, an improved chromic acid type. A report of other tests in the same year of an arrangement for talking directly to the line without induction coils indicates that eighty gravity cells (eighty volts) were used in one trial, 160 in another, twenty-three storage cells (forty-six volts) in a third, and 84 Leclanché (126 volts) in a fourth. It was concluded that "above a certain value of battery voltage, no gain is obtained by increasing the number of cells of battery on a line."

About 1891 a significant trend began. With a central office signalling battery of twenty volts and charging generators for it, the question was asked as to why this could not be used to charge four-volt storage batteries at the subscribers' stations, which would replace the primary cells. This scheme was followed for a time, at least, in Chicago, and appeared again later in the P.B.X. floater batteries, many hundreds of which are today maintained from the twenty-four-volt central office supply. At about the same time, it was decided that a "centralized battery" system for supplying subscribers' transmitters would be practicable and would eliminate the maintenance difficulties of local primary or storage batteries. Thus, at Winthrop, Massachusetts, each cord circuit was provided with its own primary battery of five Fuller cells (ten volts). As the number of cord circuits increased, however, the space and maintenance required by the increased number of primary cells become objectionable; and, to make matters worse, the ever-lengthening lines demanded higher voltages, so that later this system used ten Fuller cells for each cord circuit.

Carty had already employed an early form of storage cell in a common battery for operators' transmitters; and consideration had been given for a number of years to a common battery supply for several subscribers' lines. Tests at one time with as much as 42 volts were made, although three Fuller cells comprised the more usual test battery. Crosstalk proved a difficult obstacle, however, and speech transmission was poor until Hayes' repeating-coil circuit was ready, an improved transmitter designed, and suitable low-internal-resistance storage cells became available. Then in December, 1893, the first common-battery central office circuits were put in service in Lexington, Massachusetts, with a battery of eight storage cells, the product of The Electric Storage Battery Company, which still is the main supplier of storage batteries for the Bell System.

Tests were immediately made to see what benefits could be realized by increasing the voltage; but it was found that a ten-cell battery, while giving slightly better transmission than a sixteen-volt battery, nevertheless gave some objectionable heating in the transmitters. Other voltages—twenty, thirty, thirty-two, forty-two, and one hundred—were tried but it was found that "the transmission increases more and more slowly as the voltage is increased"; and the sixteen-volt supply was adopted for the No. 1 relay switchboard. Operators' sets, which had been supplied from two, four, or six-volt batteries, were modified first for sixteen-volt and then for twenty-volt operation when the talking battery was shortly increased to that voltage.

The new manual central office at Worcester, Massachusetts, in 1896, used twelve cells in the common talk-

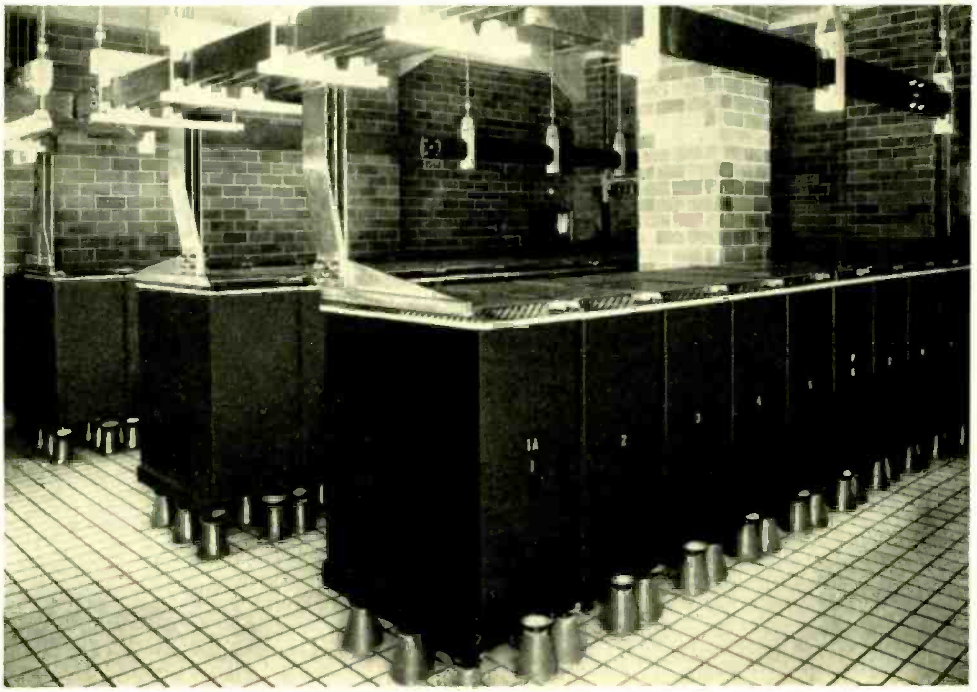


Fig. 3—A modern central office talking battery

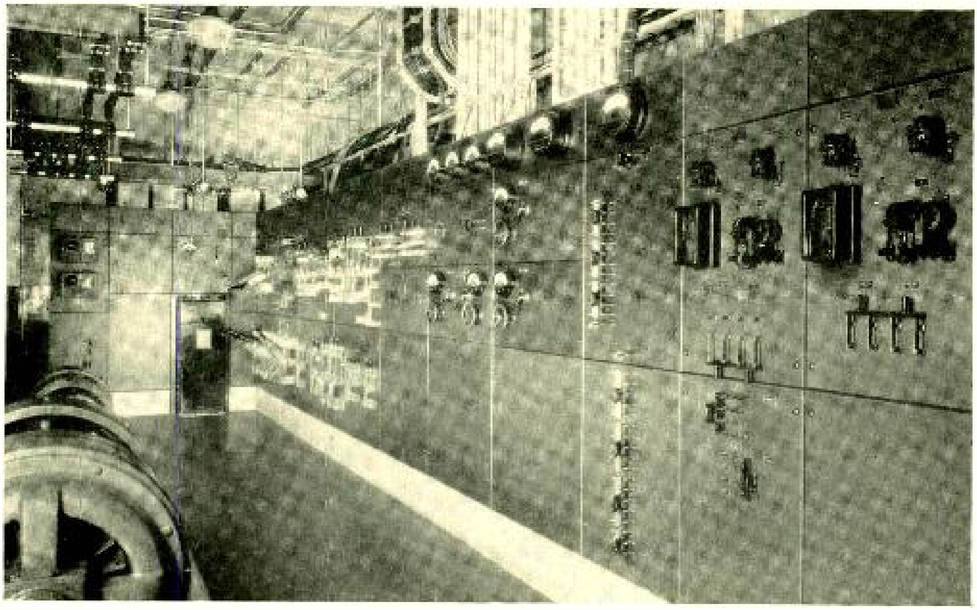


Fig. 4—The modern power board of a large central office is in striking contrast with the board of 1893 shown at the beginning of this article

ing battery and here, probably for the first time, the phrase "twenty-four volts" was employed, although it was realized that the battery voltage varied during charge and discharge. From this date, the phrase was generally applied to the common talking battery whether it was composed of ten, eleven, or twelve cells. The change to the common talking battery system came slowly and, because of their large loads, was applied first principally in the large cities. In the smaller exchanges the dry cell—employing the same elements as the Leclanché—replaced the earlier primary batteries of the subscribers' stations soon after 1900, and there are still about a million dry cells in this service in the Bell System.

In the use of these higher voltages it was found that the apparatus contacts were subject to arcing, and unless precautions were taken a fire hazard might be introduced. This, together with the more complicated switchboard wiring which had developed up to 1899, and the insulation difficulties, "made it inadvisable to use a battery much greater than twenty-four volts difference of potential at the terminals." It was recognized, however, that higher voltages were required for long-distance work; but it was felt that these must be applied without being present in the switchboards.

With improvements in switchboard cable and wiring methods, further tests were made on higher voltages of talking battery for long-distance work. In 1902, after experimenting with supplies ranging from twenty-four to 110 volts, it was decided that fifty volts gave the desired results and that twenty-two cells should be used—this number of cells probably being selected because it was twice that of the eleven-cell twenty-four-volt battery in common use. This new supply, which gave somewhat less than the desired fifty volts, came to be known as the forty-eight-volt talking battery. In some of the smaller boards, a compromise value of thirty-six or thirty-eight volts nominal value was employed. In 1904, sixty volts was considered but its benefits did not appear to warrant the increased battery cost.

Quite paradoxically, neither the twenty-four-volt nor forty-eight-volt talking battery supply has ever operated exactly at its nominal numerical value for any great length of time during the whole day. A laboratory memorandum by H. E. Shreeve on June 25, 1899, recording perhaps the first complaint of varying battery voltage, states that the eleven-cell laboratory testing battery was down to twenty-two volts and he had been asked to bring it back to "the customary twenty-four volts." He explained how hard it was to keep it exactly at twenty-four volts; and showed that the tests for which it was used could be made with a range of twenty-two to twenty-six volts.

For many years, the eleven-cell talking battery was standard for the low-voltage supply in manual central offices; its voltage range was nominally twenty to twenty-eight, the value twenty-four occurring only during a portion of the charging, which was usually done every day except Sunday. With the introduction of panel dial equipment, about 1920, and the adoption of the continuous floating system for the operation of the central office storage batteries, twelve cells (the number which had been tried in 1896) were once again used for the twenty-four-volt supply; and an additional twelve in series gave the forty-eight-volt supply. The twenty-one to twenty-five-volt range of the lower voltage was further narrowed by automatic regulators to approximately 24.75 ± 0.25 volts and that of the upper voltage to 49.50 ± 0.5 volts. The latest modification reduces the total number of regular cells in the modern telephone power plant battery to twenty-three, the first twelve still supplying the lower voltage whose range was then slightly raised to twenty-two to twenty-six volts and regulated to 25.75 ± 0.25, the upper voltage range remaining the same.

This, then, is the story behind "talking battery"—from the first commercial transmitter with its individual one-volt gravity cell, through the days of central office power equipment actually mounted on "boards" as shown in the photograph at the head of this article to a modern talking battery installation made up of a single string or parallel strings of enclosed glass jar cells or lead-lined wood tank cells, as shown in Figure 3. Each of such cells may weigh as much as three and one-half tons; and the several batteries are controlled from power boards such as that shown in Figure 4.

How Pitch Changes With Loudness

By A. R. SOFFEL
Physical Research

FEW people realize that the pitch of a sound changes with its loudness, although this auditory phenomenon has been recognized by some musicians. In recent years it has been studied quantitatively by several physicists including those in Bell Telephone Laboratories.

If two tones physically of the same frequency, which are sounded alternately, differ in their intensities, the ear may perceive them as of different pitch although the same number of waves reach it in each second. If the frequency is low and the difference in intensity is large the tones may appear to differ in pitch by as much as an octave.

For quantitative study of this phenomenon a single tone is varied in intensity and its apparent pitch, corresponding to each intensity, is determined by comparison with a sine-wave reference tone of a constant and low-loudness level.* For each intensity of the tone under test a series of observations is required to determine the frequency of the reference tone which has the same apparent pitch.

*The loudness level of this tone is 40 db., where zero represents the threshold of audibility for an observer with very acute hearing and 120 the point at which a sound starts to be "felt" rather than heard. Conversational speech when heard at a distance of 100 feet has a loudness level of approximately 40 db.

Observers differ as to their observations; and the same observer may also arrive at contradictory judgments, particularly when the pitch of the test tone appears to him very near that of the reference tone. The test procedure, therefore, is to present for judgment pairs of tones formed by the tone under test and a reference tone of known frequency. The latter is varied through a range of frequencies; and its equal pitch value is taken as that for which in half the pairs it appears higher and in half lower.

In making these tests it was found convenient to use automatic apparatus to select and present the pairs of tones in random order. Since observers differ greatly in pitch perception, however, the same set of tone pairs could not be used in all the tests. Greater accuracy was obtained by first approximately locating the point of equal pitch by manual selection of the reference tone frequencies, and then by having the automatic apparatus choose frequencies in a restricted range on both sides of the approximate balance point. The automatic circuit presented in random order thirty-five pairs of tones in which the reference tones were seven frequencies, differing from one another by three cycles per second. Each frequency appeared five times during a series. With this apparatus data was obtained at a rapid rate, with a minimum of error on the part of the operator, and with a minimum of fatigue to the observer.

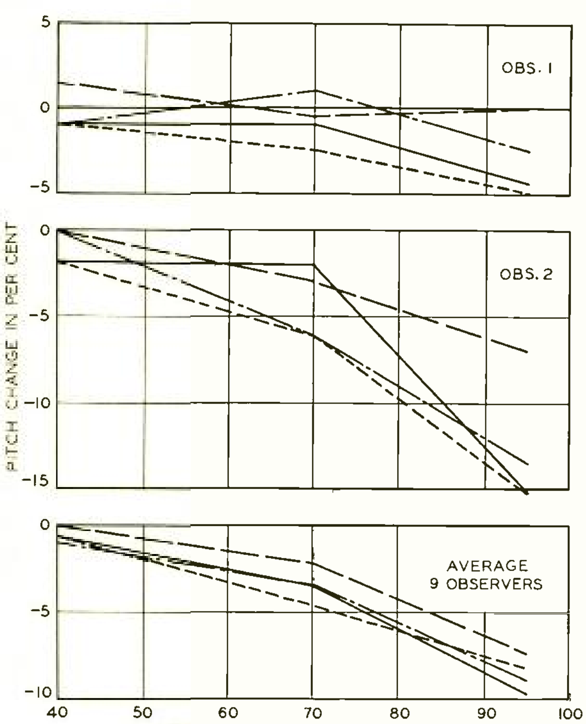


Fig. 1—The change of pitch of a pure tone with loudness varies with the observer. The pitch change is expressed in per cent of the frequency as the loudness level is changed from 40 *to the value in question*

Two different types of sound source were used in these tests: loudspeakers capable of producing very intense sound fields at low frequencies with very small harmonic distortion; and dynamic telephone receivers. Disturbing noise was eliminated by conducting the tests in soundproof rooms and by having the operator and equipment in a different room some distance away.

A crew of nine observers was used in most of the tests. After some preliminary trials a series of measurements was made using telephone receivers to determine the pitch of a 100-cycle pure tone at loudness levels of 40, 70 and 95 db. Four runs were taken successively with the crew of nine. These tests were made to show the consistency of an observer's judgments and to give practice at this type of balance. Some of the results of

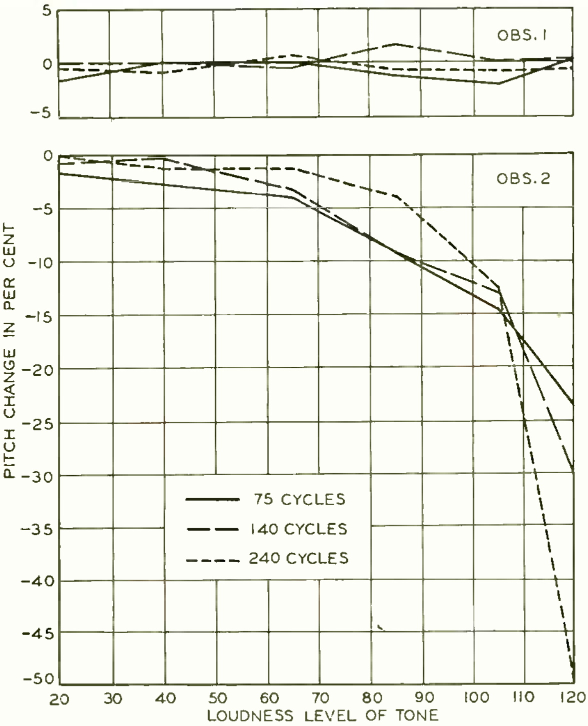


Fig. 2—Changes of pitch with loudness at three different frequencies using a loudspeaker as a sound source based on results of two observers.

this group of tests are shown in Figure 1. The observed change in pitch in each of four successive runs is plotted in per cent of the frequency of the unknown tone against its level for levels from 40 to 95 db. The negative sign indicates that the pitch of the 100-cycle tone was lowered as its loudness was increased. It may be seen that an observer's perception varies between wide limits from time to time and that some observers perceive much greater changes in pitch with loudness than others. The averages of the results of the nine observers are stable and may be taken as fairly representative.

Following this another series of tests was made using the loudspeaker as a sound source. Pure tones of three different frequencies, 75, 140, and 240 cycles, were tested in this series at loudness levels of 20, 40, 65, 85, 105 and 120. Results obtained by two members of the same crew of nine observers are shown in Figure 2. It is evident that one observer perceived no change in pitch as the loudness of a tone was increased, and that when a change was observed the pitch was lowered as the loudness increased. In this extreme case a shift of a whole octave was observed at 240 cycles while at the same loudness level the other observer perceived no shift at all. However, as shown by Figure 3, the average of the result of nine observers shows a consistent downward shift of pitch for increased loudness. From the averages of the results shown in Figures 1, 2 and 3 and from data obtained elsewhere a family of curves which give the change of pitch with frequency has been deduced. These are shown in Figure 5

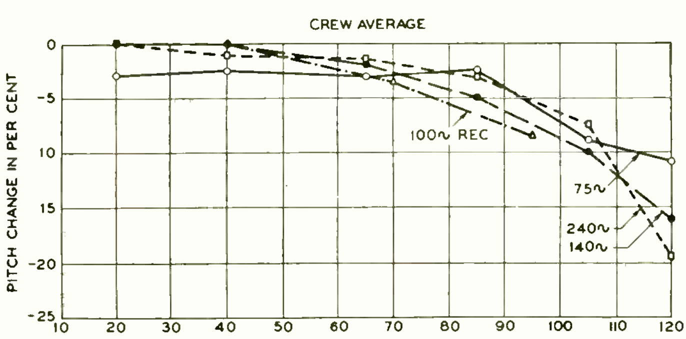


Fig. 3—Average pitch change with loudness for a crew of nine observers shows a consistent downward shift of pitch

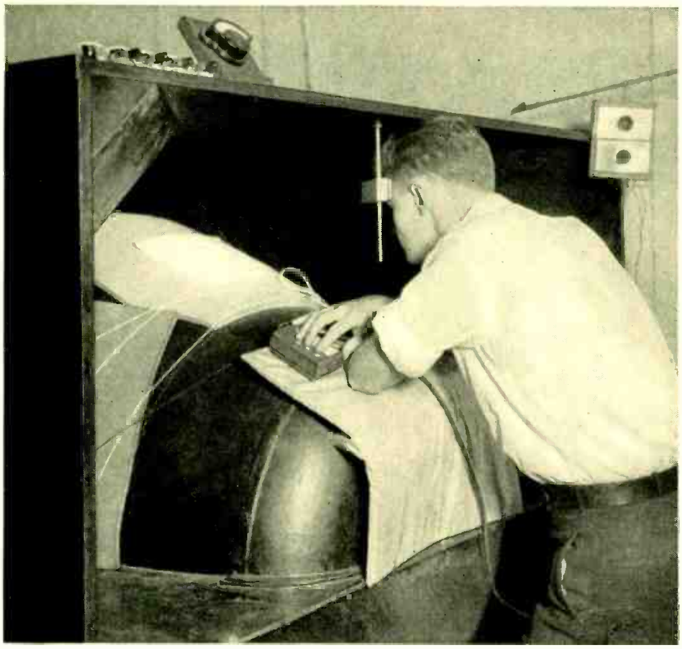


Fig. 4—R. W. Buntenbach observing the pitch of a low-frequency pure tone produced by a loudspeaker

where it may be seen that for loudness levels below 110 there is a maximum of pitch shift in the neighborhood of 100 cycles. At the loudness level 120 the region of maximum shift is just above 200 cycles. Beyond the maximum points the pitch shift decreases with frequency and becomes zero at 2000 cycles. Although no data have been taken at the Laboratories at frequencies above 2000 cycles, there is reason to believe that the pitch increases with increased loudness at higher frequencies. Evidently, before a pitch can be assigned to a pure tone of low frequency both its frequency and loudness must be known.

The observations given above were for pure tones. Most musical tones are complex and do not exhibit such startling changes in pitch with loudness. When a tone composed of five harmonic components (200, 400, 600, 800, 1000) of equal intensity was changed in loudness level from 40 to 114, a decrease in pitch of only two per cent was observed.

On the other hand, when a pure tone at a frequency of 200 cycles was carried through the same change in loudness level its pitch was found to decrease eleven per cent. From this it might be considered that the perception of pitch for the complex tone described above was probably influenced to a considerably greater extent by the character of the several overtones involved than by the loudness itself. A discussion of this aspect of the subject, however, is beyond the scope of the present article. The complete understanding of the workings of the human ear awaits further studies of this type on the complex reactions of hearing.

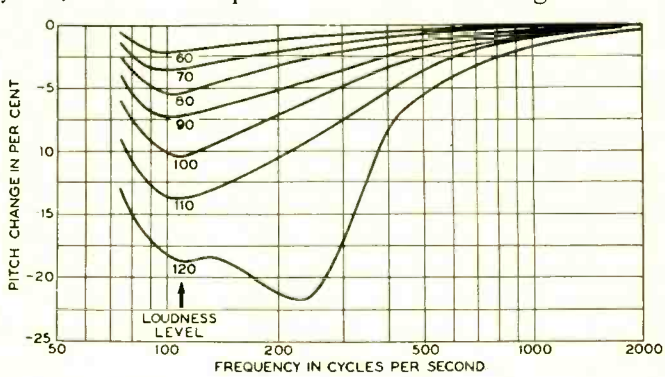


Fig. 5—Pitch change contours for various loudness levels

Non-Spreading Lubricating Oils

By W. E. CAMPBELL
Chemical Laboratories

IF a drop of any of the oils in general use for lubricating purposes is placed on a horizontal metal surface and left for a week or two, it will be found to have spread out to a thin film of irregular shape several square inches in area. For a large majority of industrial applications the spreading tendency of an oil is not a property of great importance, and has therefore been given comparatively little attention by oil manufacturers. It is, however, a serious disadvantage in the lubrication of certain types of telephone apparatus, since it causes bearings to run dry too frequently, drives oil to parts where lubrication is undesirable, and promotes the collection of dust. The development of oils which do not spread therefore becomes a matter of great interest.

The loss of oil from bearings by spreading is of more than usual importance on machine switching apparatus because of the extremely small amount of oil which can be held in many cases by relatively small bearings. Since it is not practicable to use a central oiling system, each little surface must be oiled periodically by means of a hand operated tool and it is desirable to lengthen the interval of application to a maximum. An appreciation of the lubrication problem

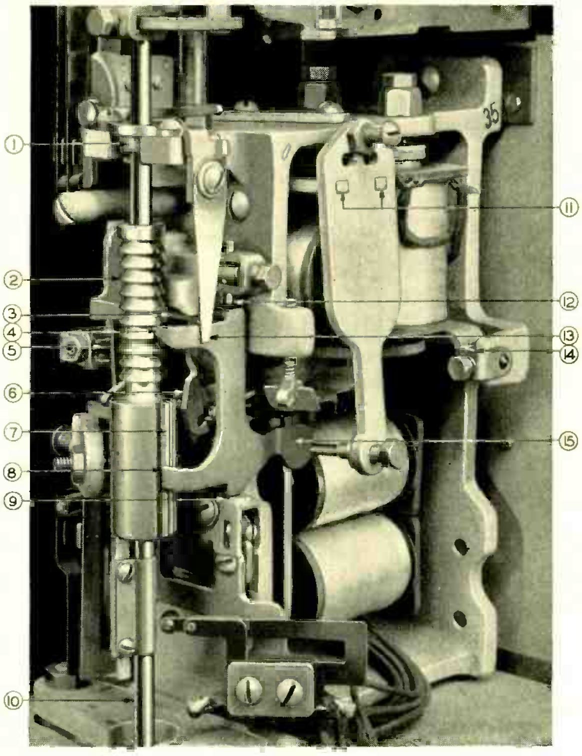


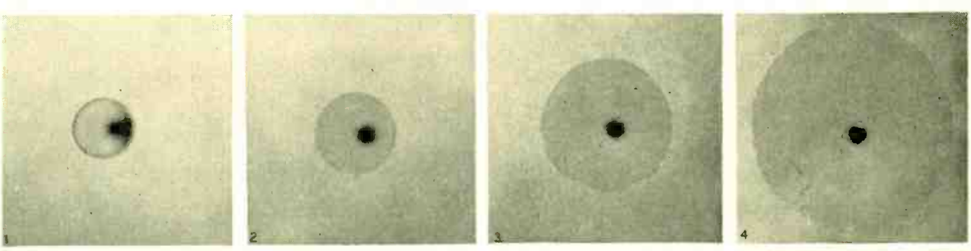
Fig. 1—Machine switching apparatus has numerous small bearings which have to be lubricated by hand

on some of this apparatus may be obtained by referring to the accompanying illustration where the parts of a step-by-step switch which require periodic oiling have been numbered.

Other apparatus in which similar problems are encountered includes dials, rotary selectors, and trip rod bearings.

For some time investigations of the factors which influence the spreading of oils on horizontal metal surfaces have been under way at the Laboratories with the object of developing a non-spreading oil of high oiliness. The work on oiliness has been described in an earlier article,* where a fundamental difference between mineral oils and fatty oils of animal and vegetable origin was pointed out. The same general distinction holds for the property of spreading—the mineral oils spread, and the fatty oils do not. This difference is clearly brought out in Figure 2 which shows successive photographs of drops of light mineral oil and of a fatty oil placed on a steel plate at the same time. Figure 3 shows the spreading rates of a large number of oils. It will be noticed that all the mineral oils spread, and that the rate

*Record, *August*, 1932, *p.* 406.



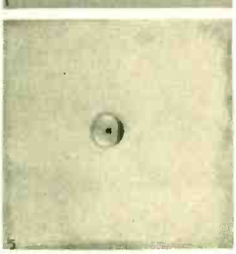
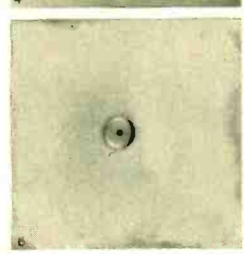


Fig. 2—Mineral oils (above) spread but fatty oils (below) do not. The elapsed time between the first and last columns is 71 hours. After several months only a microscopically visible film of mineral oil will remain, but the fatty oil drop will be essentially the same size



of spreading is dependent on the viscosity. The fatty oils, on the contrary, do not spread after initial flattening of the drop, and the equilibrium size of the drop is not related in any way to the viscosity.

It would appear from these facts that a solution of the problem would lie in the selection of a fatty oil of suitable viscosity which would provide a non-spreading oil of high oiliness. Unfortunately, however, fatty oils as a group are considerably less stable to oxidation than the mineral oils, and tend to gum and to form corrosive acids to varying degrees. The work carried out recently in the Laboratories has therefore been directed towards the development of blends of fatty oils with mineral oils or stable non-spreading organic liquids. A study has also been made of anti-oxidants or chemicals which can be added in small quantities to stabilize the blends towards oxidation. This work has resulted in the development of several non-spreading oils of relatively high stability, and has yielded fundamental information of great interest concerning the nature of surface films on various types of solids.

When a drop of liquid is placed on a solid its spreading behavior is determined by the relative values of the forces which tend to flatten it and those which try to draw it in. The former are gravity and the surface tension of the solid and the latter are the surface tension of the liquid and that of the solid-liquid interface. The difference between the solid and the solid-liquid tensions is called the adhesion tension. This is extremely sensitive to small amounts of contaminants on the surface of the solid. Under ordinary field conditions this contamination is an adsorbed film whose thickness and composition depend on the humidity and state of purity of the air. This film modifies the adhesion tension and profoundly affects the spreading behavior of

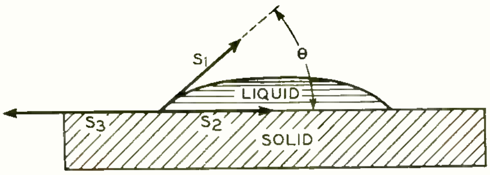


Fig. 4—The spreading behavior of an oil on a solid surface depends on the values of the surface tension of the liquid, S_1, that of the solid-liquid interface, S_2, and the surface tension of the solid, S_3

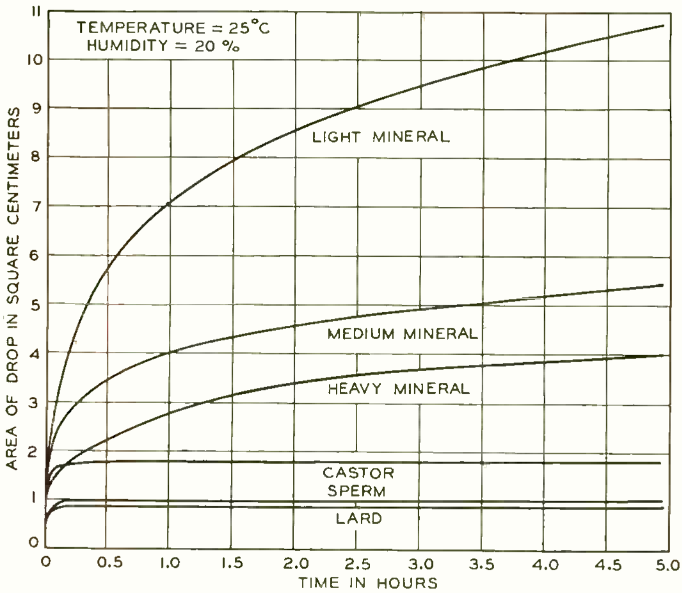


Fig. 3—The rate of spreading of various lubricating oils on steel is dependent on the viscosity of the oils

an oil. For example, a drop of mineral oil will spread much more rapidly on a steel surface which has been thoroughly freed from contamination than on one which has been exposed to the atmosphere for some time.

The thickness of the adsorbed film of moisture on a solid varies with changing humidity and this also changes the adhesion tension. This is illustrated by the behavior of a drop of white mineral oil which will spread indefinitely on clean glass in an atmosphere at 40 per cent humidity, but if placed on the same surface in an atmosphere at 70 per cent humidity, it will stop spreading after a few minutes. If the humidity is initially low and the drop is allowed to spread until it is considerably greater than its equilibrium size at 70 per cent humidity, and the humidity then raised to 70 per cent, the drop will retract to the equilibrium size. Acetic acid, on the other hand, shows exactly opposite behavior. It acts as a non-spreading liquid in a perfectly dry atmosphere, but spreads rapidly if a small amount of moisture be admitted to the atmosphere.

An interesting example of the effect of adsorbed vapor films in modifying the spreading of another liquid is shown in Figure 5. The first three pictures are of a kerosene drop spreading on a steel plate in a dry atmosphere. Just before the third picture was taken drops of a volatile organic compound of a type which is strongly adsorbed were placed on the edge of the plate. Within a few seconds the central drop started to retract as shown in the fourth and fifth photographs. Moisture was then admitted to the atmosphere, at which time the central drop immediately started to spread again as can be clearly seen from the last photograph.

Observation of the spreading rates of oils consequently requires exceed-

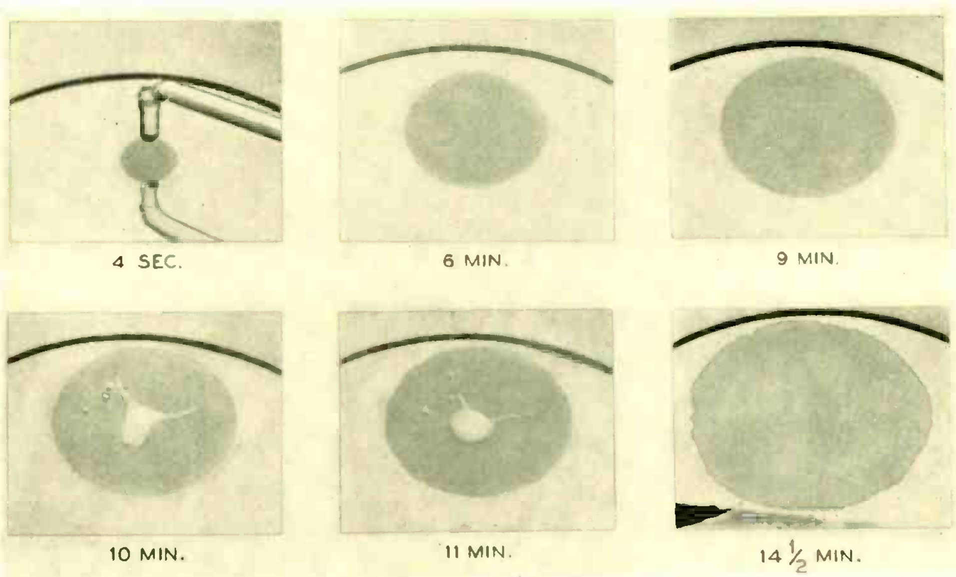


Fig. 5—Adsorbed films affect the spreading behavior of oils. The fourth and fifth photographs show the retraction that is caused by the addition of a volatile vapor and the last photograph shows the return of spreading when moisture was added

ingly careful cleaning of the surface and control of the atmosphere, for slight contamination of the surface during spreading may alter materially the spreading rate or the equilibrium size of the drops, causing them to assume irregular shapes which are difficult to measure. In studying non-spreading oils it has therefore been necessary to develop a technique for measuring the spreading rate of oil drops on clean highly polished metal plates. To obtain circular drops of reproducible size it is necessary to form and deposit them by a controlled method on an accurately flat and carefully leveled surface.

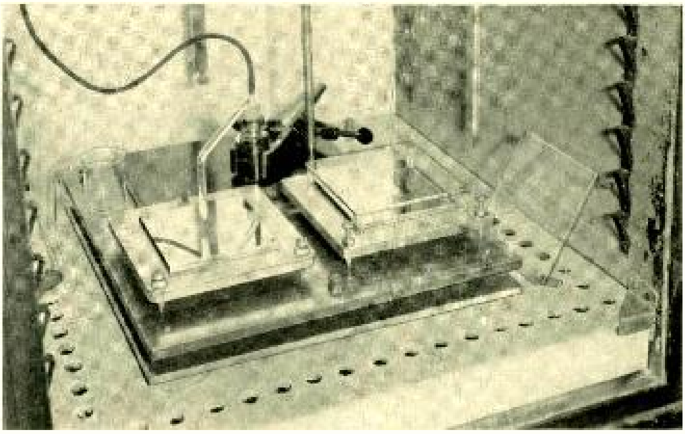
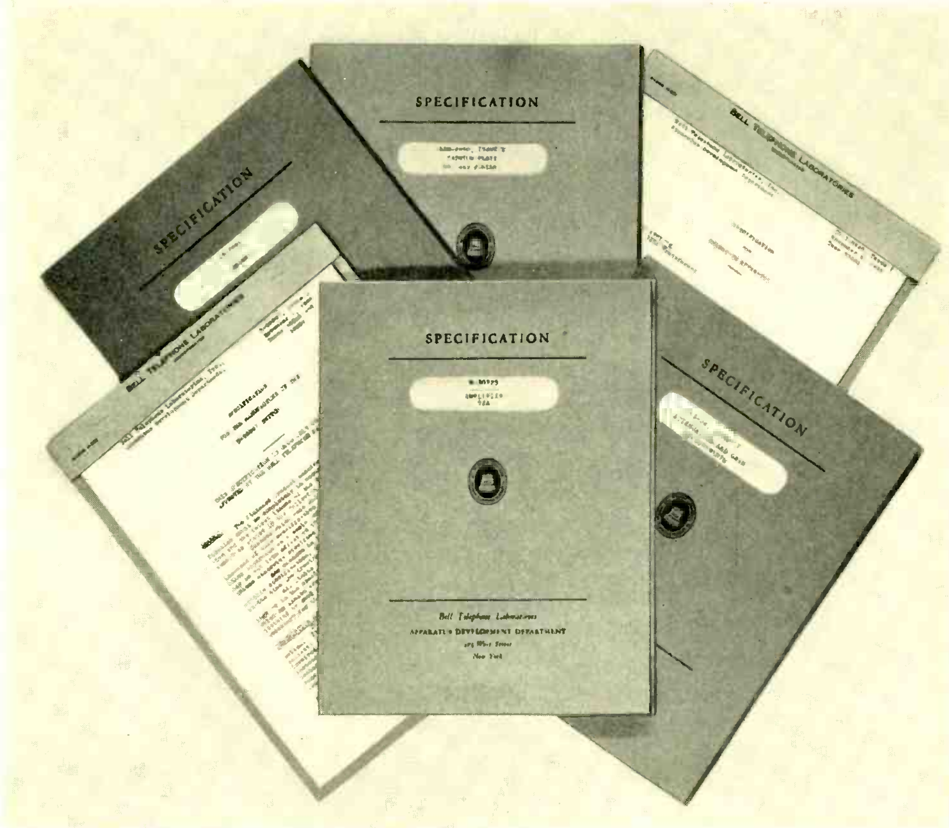


Fig. 6—The spreading behavior of lubricants is studied by making a series of photographs of oil drops on a polished steel plate which is accurately flat and carefully levelled

The apparatus used for routine testing is shown in Figure 6. A capillary tube with an accurately ground circular tip is mounted one centimeter above a polished steel plate which is maintained horizontal by means of a leveling platform. A drop of the liquid to be studied is formed slowly at the tip of the capillary by applying pressure to the liquid in the attached bottle and is then allowed to fall of its own weight on the steel surface. The measurements are made by determining the diameter of the drop at intervals with the aid of two parallel steel rods placed on a glass plate about five centimeters above the drop. The first measurement is taken five minutes after the drop has been deposited and then others are made every hour thereafter for the duration of the experiment. The steel plate is cleaned by polishing it with a fine abrasive followed by a thorough rinsing with water and redistilled alcohol. It is then dried in purified air. This cleaning method gives a high and reproducible coefficient of static friction between steel surfaces which indicates freedom from surface contamination. The results shown in Figure 3 were thus obtained.

A photographic method has been developed for making more precise measurements and for recording certain types of irregular spreading behavior. In this case, the camera is mounted almost directly above the center of the drop and adjusted so that the image on the plate is a definite known fraction of the size of the drop. Photographs which were taken in this manner at definite intervals are shown in Figure 2.

These investigations of spreading have resulted in the development of lubricating compounds which are now under test for the lubrication of telephone equipment. Incidentally, fundamental information on spreading has been revealed which will find use in many other fields.



Apparatus Specifications

By W. H. SELLEW
Specification Department

IN Bell Telephone Laboratories, stored in banks of metal filing cabinets, there are some two hundred thousand "Apparatus Specifications" including various kinds of supplementary specifications. These specifications portray in detail the telephone apparatus used throughout the Bell System, and also many other types of apparatus developed as by-products of research in the art of communication, and used outside of the industry.

A typical apparatus specification consists of a brief statement of the type of apparatus and the use for which it is intended, together with complete manufacturing information for the apparatus, including a list of drawings and any supplemental data required by the factory where the apparatus will be made. The tests that this apparatus must meet to insure satisfactory performance in service are specified in detail.

The principal drawings, such as the assembly and wiring diagram, are bound in the specification to facilitate use of the specification for general information, and blueprints of the others are forwarded separately to the factory. Commercial information, such as the probable demand for the apparatus, is also included for the benefit of the various planning and control branches of the Western Electric Company.

A specification is a condensed form of description; to the engineer it constitutes a complete picture of the apparatus, to the machine shop manager it is all the technical information he needs to manufacture the apparatus. In one case the specification may contain all the information that is necessary for the production of certain telephone apparatus, in another may cover materials and processes used by Western Electric Company in the manufacture of apparatus, and in still another it may describe standard methods of making tests, such as insulation-break down tests, measurements of inductance, phase displacement, or cross-talk, and other precise tests which are frequently required on apparatus developed for the Bell plant.

The number of copies distributed is commensurate with the size of the manufacturing and distributing organization required to supply the extensive equipment needs of the Bell System. A study of the last ten-year period shows that an average of over 200,000 copies of new specifications have been distributed each year by the Apparatus Development Department. A typical distribution of a specification covering the manufacture of a piece of telephone apparatus is shown in Figure 1, which also gives some idea of the Western Electric Company's plan of organization for the handling of specifications for manufacture. In addition to the copies of specifications distributed at the time of issuance, many re-

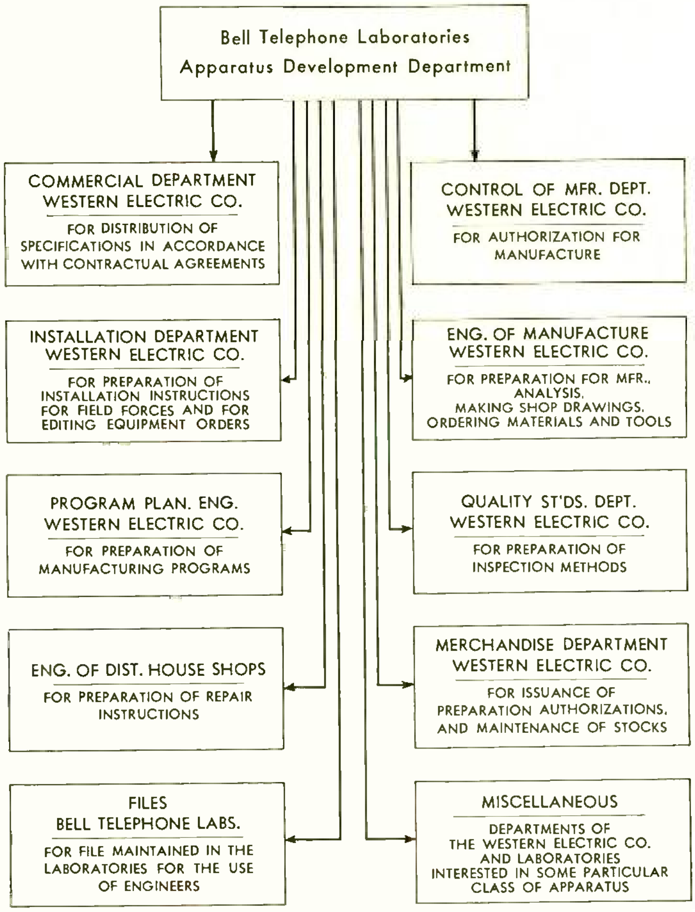


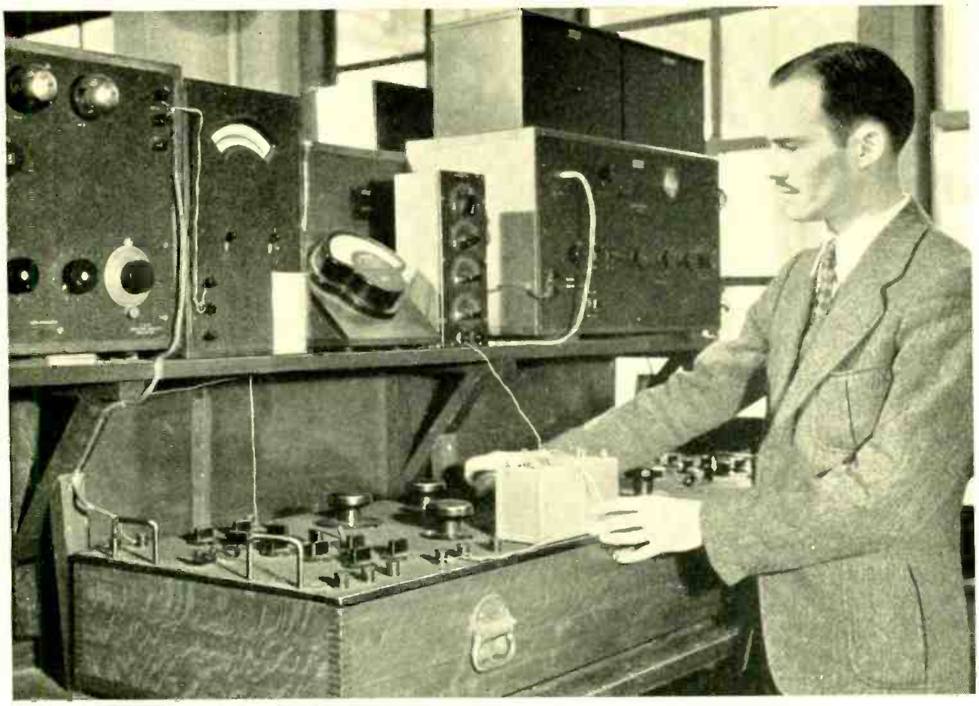
Fig. 1—Distribution of specifications varies somewhat with the type of apparatus described. A typical distribution for specifications covering a piece of telephone apparatus is indicated by the above diagram

quests are received for additional copies of specifications and drawings. Some idea of the magnitude of this phase of distribution can be gleaned from the fact that in one year alone, in addition to the copies sent out at the time of issuance, over 120,000 extra copies of specifications and drawings were needed.

The various functions which the apparatus specifications must perform, and the numerous requirements which they must fulfill, involve the combined work of all the departments of the Laboratories concerned with the design of apparatus. These specifications present in detailed form the engineering information which is the principal output of that part of the Laboratories. They constitute an account of the Laboratories' achievements in the field of apparatus development in a form suitable for use in manufacture. They are a record of past developments, and the starting point for further improvement studies.

Executive Officers of Bell Telephone Laboratories

In anticipation of the retirement of Vice President E. H. Colpitts, which will take place early in 1937 under the age provision of its pension plan, the directors of the Laboratories have elected as executive vice president Oliver Ellsworth Buckley, who has been Director of Research. Otto B. Blackwell, formerly Manager of Staff Departments, was elected vice president.



New Carrier System Filters

By A. R. D'HEEDENE
Apparatus Development

To provide additional service on existing open-wire toll circuits without stringing new lines, carrier telephone systems are often used. These installations have been limited in the past to medium and long-distance circuits but a new system, type G1, has now been developed which has been simplified to the point where it can be used to advantage over distances as short as ten miles and possibly less in some cases.*

An important factor in the success of this new development is the use of simple and inexpensive filters of special construction to separate wanted from unwanted frequencies. This simplification has been possible because the same carrier frequency is supplied for both directions, and both sidebands as well as carrier are transmitted. This allows the filter requirements to be more lenient. Since short distances are involved carrier-frequency amplification is not required and consequently large differences of level are not encountered. This permits grouping the filter elements closely together without introducing noise or cross-talk. These several advantages are obtained at the cost of one complication over other systems. Since both sidebands are transmitted and carrier is supplied at one terminal only, phase-shifting networks are consequently required at one terminal.

The carrier circuit is obtained by

*Record, *August*, 1936, *p.* 393.

modulating the voice frequencies with a carrier frequency of 10.3 kilocycles which is supplied at one terminal and transmitted over the line for modulation and demodulation at the distant end. The terminal at which carrier current is supplied is called the active terminal while the other is called the inert terminal. Figure 1 (left) shows the networks required at the active terminal and Figure 1 (right) those required at the inert terminal. These networks are further subdivided into four groups designated as A, B, C and D. Group A consists of a filter which transmits voice frequencies without appreciable distortion and prevents carrier frequencies at the modulator-demodulator element (modem) from reaching the voice-frequency terminals of the carrier circuit. At the active terminal the system may occasionally be connected to a voice repeater equipped with a compromise balancing network for general applications. To satisfy this need the impedance of this filter must match that of the balancing network in the repeater. At the modem end it must also provide a low impedance path to carrier frequencies and have a direct current resistance of 600 ohms to increase the efficiency of the modem. At its other end, the filter must be an open circuit to direct currents to prevent such currents present at the switchboard from reaching the modem. All of these conditions have been fulfilled in the design. The discrimination against carrier frequencies is shown in Figure 2. The condenser C3, Figure 1, provides the required low impedance path to carrier frequencies. The coil L3 has a direct current resistance of 600 ohms and is

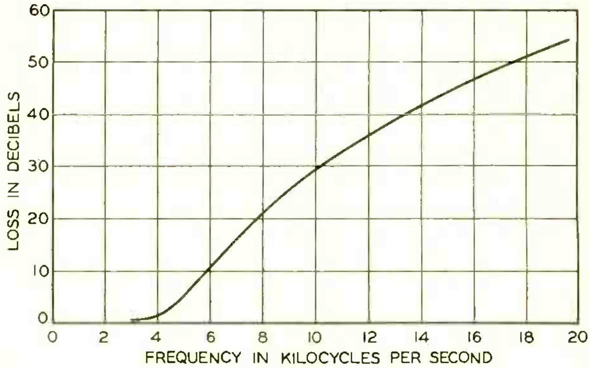


Fig. 2—The Group A filters prevent the carrier frequencies from reaching the voice input of the carrier circuit without distorting the voice frequencies

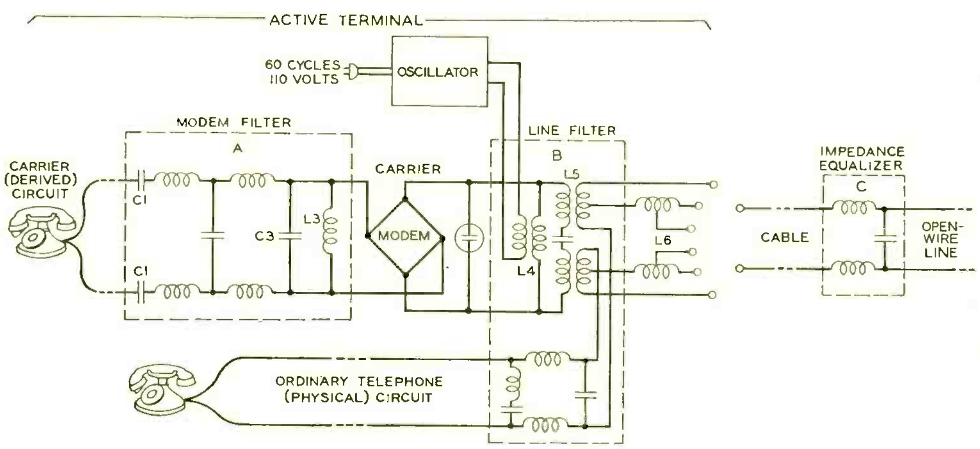


Fig. 1—Schematic of the G type carrier telephone system

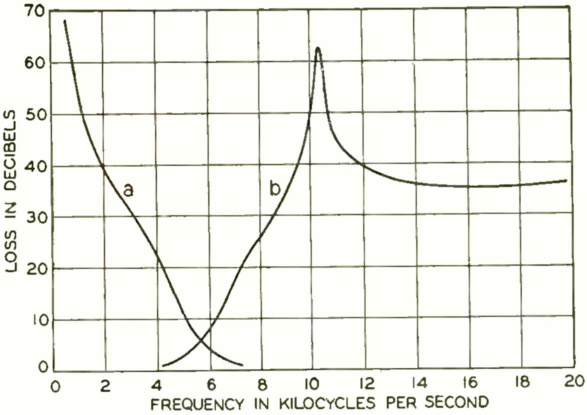
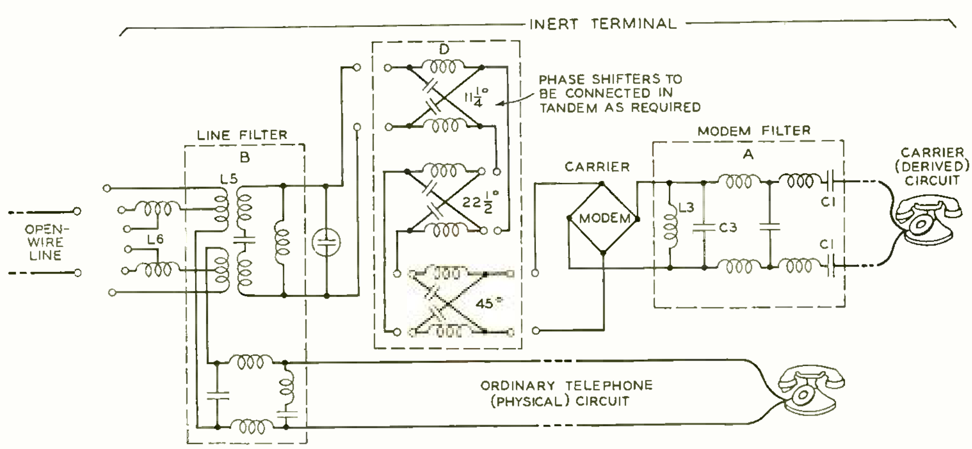


Fig. 3—The Group B filters comprise a high-pass filter "a" which prevents the voice frequencies from entering the carrier frequency input circuit, and a low-pass filter "b" which keeps the carrier frequencies from the voice frequency input circuit

designed to have an impedance sufficiently large over the voice frequency band to prevent noticeable bridging loss. The condensers C1 serve to block direct current from the switchboard and, at the same time, provide the capacitive reactance that is required to match the reactive component of the balancing network impedance.

Group B comprises a pair of filters which are used to separate the voice frequencies of the ordinary telephone circuit from the carrier frequencies. An outstanding and original feature of these filters is the coil L5. This coil, which has four windings, permits the high-pass filter to be connected in series with the low-pass filter without any sacrifice in either discrimination or balance. In this particular design, the coil makes it possible to eliminate three condensers, which would be required if the previous method of interconnecting pairs of balanced filters in parallel were used. In addition, the coil is provided with a tapped winding, by means of which the high-pass filter can be made to face the modulator with a 500-ohm resistance over its pass band whether the other end of the filter is connected to an open-wire line or to a non-loaded toll-entrance cable. Such a four-winding coil for connecting two filters in series is being used here for the first time. Additional economy was obtained by designing the oscillator-output transformer L4 so that it also functions as one of the coils in this filter.

A design problem arises from the fact that the impedance of non-loaded



which is designed for use on lines only a few miles long entrance cable differs from that of open-wire line. In general, where short lengths of such cable are encountered the effect of the cable is not important at voice frequencies. At carrier frequencies, however, the transmission loss due to the impedance mismatch is appreciable. Evidently, a simple impedance matching network is required which will provide an impedance transformation only at carrier frequencies but will freely transmit voice frequencies.

An impedance matching network was designed for the G1 system, which modifies the impedance of the cable at carrier frequencies so that it will match both the impedance of the office apparatus at one end and that of the open-wire line at the other without appreciably affecting the circuit at voice frequencies. Physically, the results are realized by the proper combination of an impedance equalizer (Group C) which is connected between the open-wire line and the cable; the cable itself, which provides the desired shunt capacity in the network; and the coil L6. With an arrangement of this kind, it is possible to use cables that are as long as one mile and still obtain satisfactory impedance transformations.

The three phase-shifters shown as Group D consist of series coils and lattice condensers. This type of network introduces a phase shift of 90° at its critical frequency, which is that at which the coil reactance equals the condenser reactance. By properly selecting these critical frequencies, the sections were designed to shift the phase of the 10 kc. carrier by 11¼°, 22½° and 45°, respectively. Any phase

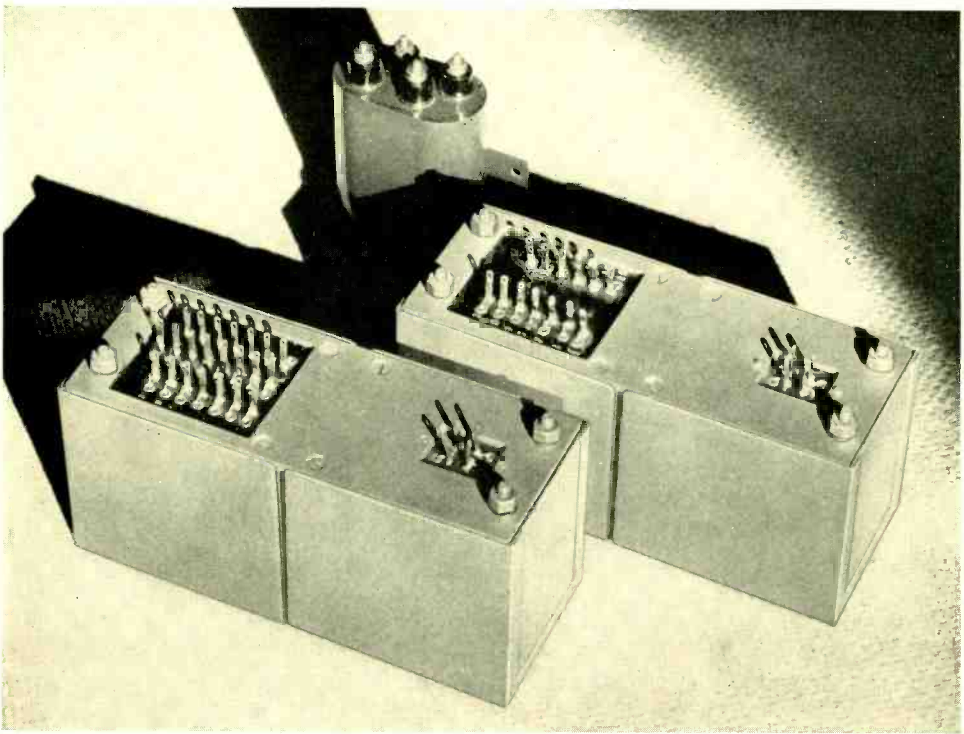


Fig. 4—The filters and the equalizers of the new carrier system are simple and compact

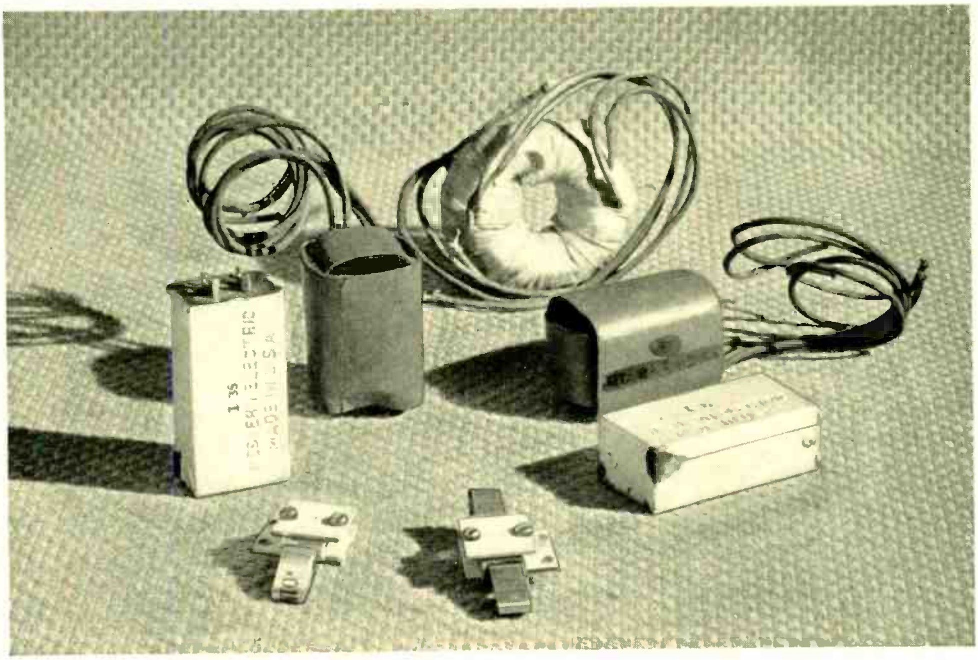


Fig. 5—Permalloy dust core coils (at the rear) and precision paper condensers, also a few small mica condensers (in front), are used in the filters of the G1 carrier system

shift between 0° and 90° can be obtained in steps of 11¼° by a combination of these sections. When the equipment is installed the number of sections required to give the most efficient transmission are strapped into the circuit.

When a phantom circuit is derived from two side circuits by using each pair as a single conductor for the phantom system, it is necessary that the impedance of the phantom connection of the two side circuits be nearly the same in order to avoid introducing noise into the phantom circuit. If a carrier system is applied to one side circuit of a phantom group, it is usually necessary to introduce into the other side circuit a network, known as a phantom balancing network, which has an impedance equal to the phantom impedance of the carrier system. In the Type G1 system the filter coils are few in number and these were designed to have a small impedance to phantom currents so that this system may be used on one side circuit of a phantom group without using a balancing network in the other side.

The coils and condensers used in these filters are shown in Figure 5. Although the coils are small, it was possible to obtain high efficiencies by the use of permalloy as the core material. A few of the condensers are of mica but most of them are precision type paper condensers. In these condensers, precise initial adjustment is obtained by adding a low-capacity unit to the main condenser.

The number of coils and condensers required in the equipment as a whole having been reduced by careful electrical design, and the coils and condensers themselves having been made small and inexpensive, the last step was to provide a compact and inexpensive assembly. To secure this all of the active terminal networks are assembled in a double unit container. That is, the two low-pass filters, the high-pass filter, the demodulator networks, the oscillator output transformer and the impedance correcting coil at the active terminal, comprising eight coils and seven condensers, are assembled as a unit. Similarly, at the inert terminal this apparatus and, in addition, the three phase-shifting networks, comprising in all 11 coils and 13 condensers, are assembled as another unit. The impedance equalizer is assembled in a small can designed to be mounted in a cable terminal box at the junction point between the open-wire line and the toll entrance cable. The two filters and the equalizer are shown in Figure 4.

The development of the relatively inexpensive type G1 carrier system extends the field of usefulness of carrier telephony to shorter distances than have been economical in the past. The simplicity, small size and low cost of the filters of this carrier system have been important factors in the success of this development.

Coaxial System Demonstrated

Successful conversations over the coaxial cable system were held on November 30, when President Jewett in New York talked with members and officials of the Federal Communications Commission in Washington. Between New York and Philadelphia the circuit was looped back and forth twenty times, giving a talking path 3800 miles long in the coaxial system. In Washington were Commissioners Prall, Stewart, Sykes, Case and Payne, and in New York with Dr. Jewett was Commissioner Walker. On the following day a demonstration was given for the press.

While the present experimental coaxial system is designed for 240 channels in each direction, terminal equipment for only 36 channels is installed. To link enough of these channels to form 3800 miles of talking circuit, it was necessary to modulate from one carrier frequency to another (or to voice frequency) seventy times—a far more severe test of the system than an equal straightway circuit which would require only four modulations. In each of the twenty round trips, the transmission path passed through repeaters a total of 400 times to make up the line loss. This was an average of 4.5 decibels per mile or a total of 17,000 db.

"In this preliminary experiment," said Dr. Jewett, "our main purpose is to reveal the telephone possibilities, not television. The performance has been up to expectations and no important technical difficulties have arisen to cast doubt upon the future usefulness of the coaxial cable system. Much work remains to be done, however, before coaxial systems suitable for general commercial service can be produced."

A Modernized Hearing Meter

By R. NORDENSWAN
Special Products Development

BECAUSE of its importance in telephony, the ability of people to hear has been a subject of study by the Laboratories for a great many years, and apparatus has been developed with which measurements could be made. The use to which the measurements are to be put affects to a considerable extent the type of apparatus provided, and several forms of audiometer, as the apparatus is called, have been built and successfully used for a wide variety of purposes. A comparatively simple form of audiometer, used for making hearing measurements on a number of people simultaneously, such as school children or factory workers, was described in the RECORD* some years ago. For more complete measurements of hearing, as would be used for studies in these Laboratories or by physicians, the 2A audiometer was employed, which permitted measurements of hearing loss to be made at eight frequencies from 64 to 8192 cycles. Developments in a number of fields in recent years have indicated that an improved audiometer for this type of use could now be made, which besides having better characteristics, would be smaller, simpler to operate, and less expensive. The 6A audiometer, shown in the photograph at the head of this article, is the result.

Instead of having a number of fixed frequencies at which measurements may be made, the new audiometer incorporates a heterodyne oscillator, which permits readings to be taken at any frequency up to 10,000 cycles.

*RECORD, *January*, 1928, *p.* 159.

The heterodyne unit includes a 110-kilocycle fixed-frequency oscillator and an adjustable-frequency oscillator covering the range from 100 to 110 kilocycles. The output of these two are fed to a copper-oxide modulator, which produces the difference frequency—from zero to 10,000 cycles. An attenuator in the output circuit gives control of the volume, and the output level of the oscillator is such that hearing losses from − 15 to + 110 db may be measured in the range from 1000 to 4000 cycles. The audiometer is designed for operation on the ordinary commercial 110-volt lighting supply, either direct or alternating current. This arrangement is more satisfactory than the battery supply employed with the 2A audiometer.

Other changes incorporated in the new audiometer extend its usefulness and widen its field of application. One of these features, which is optional with the purchaser, is a microphone, mounted just behind the front panel of the audiometer, with which the physician may talk to the patient directly through the receiver used for the test. Where there is a large hearing impairment, this is of great convenience. The microphone is cut into or out of the circuit by a switch on the front of the cabinet. The audiometer is also arranged for use with either an air-conduction or bone-conduction receiver, so that the patient's hearing may be measured for both types of reception. Such a double measurement may give valuable information as to the cause of any hearing impairment that exists. A dynamic receiver is employed for the air-conduction measurements instead of the electromagnetic type formerly used. This gives somewhat higher efficiency and better characteristics than the former type.

The appearance of the 6A audiometer is shown in Figure 2. The cabinet is eight inches high, fifteen inches wide and eight inches deep. It encloses a metal chassis, shown in Figure 1, which carries all the apparatus. The large dial at the right in Figure 2 controls the attenuator, and is marked in db from − 15 to + 120—the loss being read opposite an index marked on the panel at the edge of the dial. Since the sensitivity of the ear varies over the audible frequency band, the volume level at the receiver for a given amount of hearing loss is different for various frequencies. If a single index for reading the loss were employed for all frequencies, there-

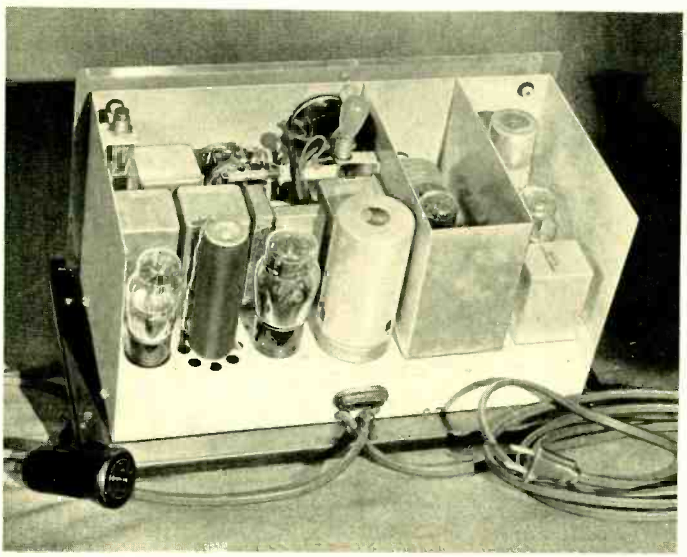


Fig. 1—All the apparatus for the Western Electric 6A Audiometer is mounted on a metal chassis that slides inside an outer cabinet carrying the front panel

fore, the losses so read would have to be corrected in accordance with the threshold of hearing. To avoid this, and also to equalize the overall frequency characteristic of the audiometer, a number of indices have been marked along the edge of the dial to indicate the reference points for the various frequencies. These reference indices, evident in Figure 2, are marked for the octaves and quarter octaves from 128 to 9747 cycles inclusive. The loss at any frequency is that indicated on the dial opposite the index marked for that particular frequency.

The large dial to the left of the attenuator dial is for setting the frequency of the oscillator, and like the indices of the attenuator, is marked for octaves and quarter octaves from 128 to 9747 cycles, or 6¼ octaves. The small dial at the extreme left is employed for adjusting the frequency of the oscillator so that small frequency variations may be corrected when they occur.

In the top of the cabinet is a lamp, which lights when the set is turned on and remains lighted except when the push-button, held in the patient's hand during test, is pressed. As long as the patient hears the tone, he leaves the light burning, but when he ceases to hear it, he extinguishes the light as a signal to the physician. Along the bottom of the front of the cabinet are three toggle switches. The one at the left is used to interrupt the tone; the center one substitutes the microphone for the tone, so that the operator may speak to the patient; and the one at the right controls the power circuit to the audiometer. The microphone is mounted just behind the three narrow openings in the upper center of the panel.

The acuity of the ear is not the same for both bone and air-conducted

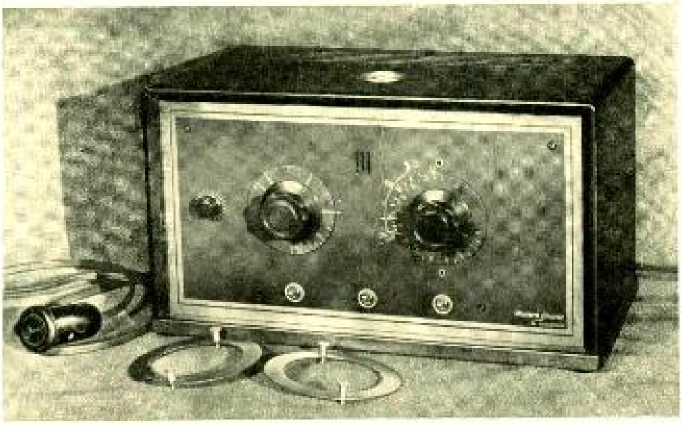


Fig. 2—The 6A audiometer with the 125A and 126A Audiometer Index Rings

sounds, and as a result a different set of indices is required if the attenuator dial is to indicate true hearing loss. This is provided by a separate index ring that plugs into the two sockets just above and below the attenuator dial. It is called the 126A audiometer index ring and goes completely around the dial, covering up the indices used for air-conduction tests. In making a simple bone-conduction test, in which the 126A Index Ring is employed and a bone-conduction, in place of the air-conduction, receiver, the hearing loss obtained may not be that of the ear being measured alone because some of the sound is transmitted through the head and picked up by the other ear. To make it possible to obtain the true bone-conduction hearing for a single ear, the 100A audiometer masking attachment and the 125A audiometer index ring are available as additional attachments.

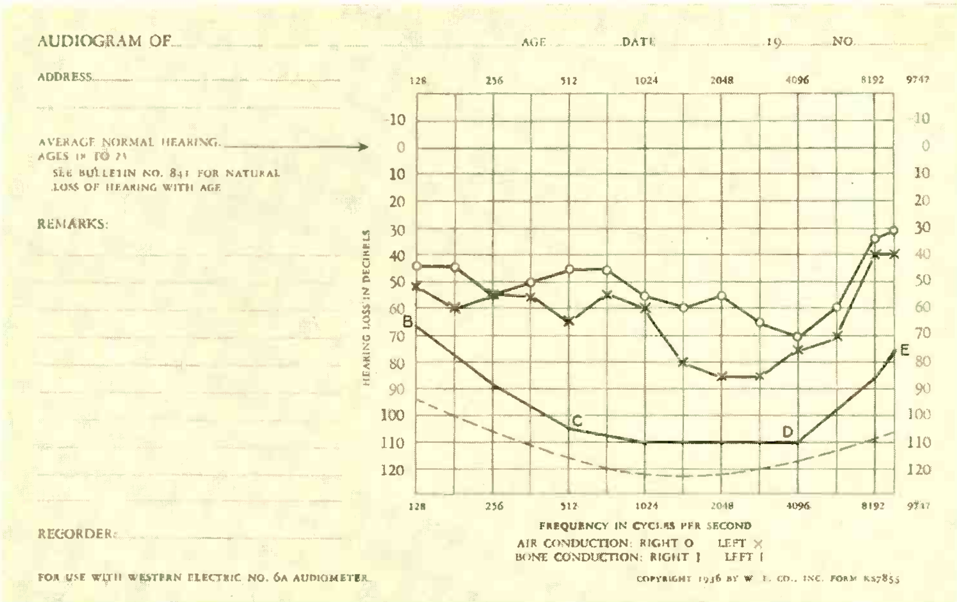


Fig. 3—An audiogram chart used for recording hearing loss

This masking attachment includes a cord that plugs into the receiver jack of the audiometer, and has two jacks—one for the air-conduction, and one for the bone-conduction receiver. A push-button is also provided to be used by the physician instead of the interrupter switch on the front of the panel. The bone-conduction receiver is placed just behind the ear to be tested, and the air-conduction receiver is held to the other ear. Tone of the same frequency is applied to both receivers, but the volume of that to the air-conduction receiver is made slightly greater than that of the tone conducted to that ear by bone-conduction from the bone-conduction receiver. In this ear, therefore, the tone from the air-conduction receiver completely masks bone-conduction hearing in that ear. If the tone to the bone-conduction receiver is interrupted, therefore, the interruptions cannot be detected by the ear with the air-conduction receiver.

To make such a test, the physician interrupts the tone to the bone-conduction receiver two or three times a second by the push-button provided him, and the patient signals by the regular push-button and lamp when he does not perceive any interruptions of tone. The reading of the attenuator dial when the patient ceases to hear, using the 125A ring, gives the loss for bone-conduction hearing in the ear which is under test.

To simplify the recording of loss determined, audiogram charts, as illustrated in Figure 3, are provided. The loss at each frequency is recorded for both ears, and the two resulting graphs drawn through these points are the audiograms determined. On the chart in Figure 3, two actual audiograms are drawn in, and also a curve representing the limits of loss that can be recorded by the 6A audiometer. A curve representing the threshold of feeling is printed on the card as a reference for hearing loss.

Decibel Meters

By F. H. BEST
Transmission Development Department

DURING the present century there has come into existence a new unit known as the decibel. It was employed originally as a measure of loss and gain in telephone transmission, but because of its wider utility, it has more recently been adopted by other electro-acoustic fields such as broadcasting and sound pictures, and is also used in the measurement of noise and sound in general. Regardless of its field of use, however, it remains a measure of an increase or decrease in power, but it is a unit of an unusual type, and in spite of its wide employment has remained more or less of an enigma to all but those who are initiated in its use.

In the ordinary affairs of life a change in anything would be measured either in the same units as the original quantity, or in per cent of the original. If, for example, a man buys a bond for \$1000 and sells it for \$900, his loss might be said to be \$100 or 10 per cent. Both of these measures of loss are significant: the first giving the actual amount of money lost, and the second the ratio of loss to original principal. Such methods of measuring loss are also used in many other fields, such as in electric power transmission, for example.

Neither of these methods, however, is entirely satisfactory for measuring losses in telephone circuits. Such circuits are designed so that a given circuit element produces the same percentage loss between its input and output terminals regardless of the part of the circuit into which it is inserted. Since the input in watts to such an element varies with the location of the element in the circuit, the loss in watts produced differs for each position of the element, and so to measure the loss in watts would be to lose the advantage of a single and constant expression for the loss occasioned.

While an expression of the loss in per cent would not be open to this objection, it becomes inconvenient when the effect of a number of such ele-

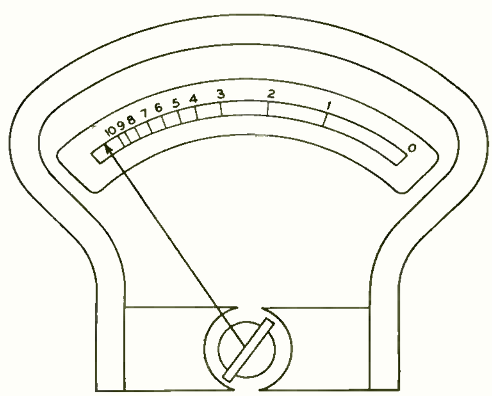


Fig. 1—Arrangement of a d-c ammeter for use as a db meter without other modification than a change of scale

ments in series is to be considered. If R, for example, be allowed to represent the ratio of capital after investment to capital before, or of power at the output terminals of a circuit element to power at the input terminal, the per cent loss is given by the expression 100(1-R), and where several losses are suffered consecutively, the combined loss in per cent becomes $100[1-(R_1 \times R_2 \times R_3)]$ where R_1, R_2 and R_3 are the loss ratios for the various elements. The calculation of such a combination of losses is complicated by the series multiplication.

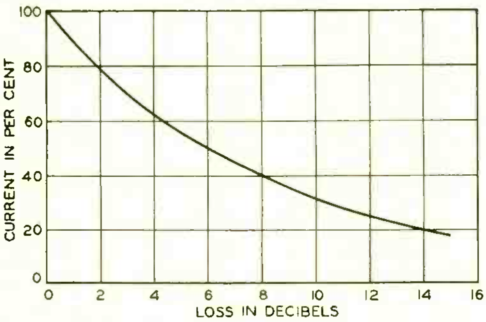


Fig. 2—Current in per cent of the reference current (corresponding to zero loss) for various losses in db

In the db system the same loss ratio R is employed, but the series multiplication is avoided by using the logarithm of R as the unit of loss instead of the ratio R itself. It takes advantage of the simple mathematical fact that the $\log (R_1 \times R_2 \times R_3)$ is equal to $\log R_1 + \log R_2 + \log R_3$. A circuit element producing a loss ratio R is said to produce a loss of X bels, where X is the logarithm of R. The total loss produced by a number of elements is thus the sum of the losses of the individual elements. More commonly the decibel is used instead of the bel, and since a decibel is 1/10 of a bel, the loss in decibels is 10 log R instead of simply log R. The logarithm of ratios of 0.1, 0.01, 0.001, etc., are whole numbers, and thus the db loss for these respective loss ratios are 10, 20, and 30 db which correspond to percentage losses of 90, 99, and 99.9.

If, for example, three circuit elements produced loss ratios of 0.5, 0.4, and 0.3, the combined ratio would be $0.5 \times 0.4 \times 0.3$ or .06 and the resultant loss would be 94% or $100(1-.06)$. Expressed in the db systems the individual losses would be 3.01, 3.98 and 5.23, which are ten times the respective logarithms of 0.5, 0.4, and 0.3. The overall loss would simply be the sum of the individual losses, or $3.01+3.98+5.23=12.22$.

In the telephone plant, losses are commonly determined by sending a predetermined amount of power over the circuit and determining the received power by measuring the amount of current flowing into a fixed terminating impedance, since with fixed input power and fixed terminating impedance, the received power is proportional to the square of the current. The output current is rectified and measured with a d-c ammeter, and the logarithm of the ratio of the squares of the currents under the two conditions is the loss in bels, and ten times the logarithm of this ratio is the loss in decibels. These measurements are facilitated by attaching a special scale to the meter so that the loss in db may be read directly. A meter is selected that reads full scale for the amount of current corresponding to the fixed input power, and this full scale on the meter is marked zero loss. Because of the logarithm that defines the db, however, the points on the scale for subsequent units of loss in db are not evenly spaced, but are crowded together as shown in Figure 1.

The ordinary d-c ammeter is designed to have equal spacing on the scale for equal increments of current. This is secured by having the moving coil, to which the pointer is attached, rotate in an air gap of equal flux density throughout. Since the flux is constant, the torque on the coil will be proportional to the current, and since the pointer acts against a spring providing a restoring force proportional to the deflection, equal deflections are obtained for equal increments of current.

This evenness of scale is very convenient in any meter, and it was felt desirable, therefore, to develop a db meter that would have equal increments of scale for equal increments of loss in db. It was decided to modify the ammeter previously employed to bring this about. This was accomplished by varying the width of the air gap from one extreme position of the coil to the other, so that the flux, instead of being the same at all positions of the coil, would increase towards the positions of greater loss.

The right-hand end of the scale of such a meter, the position for maximum current, would be marked zero db loss. If the current corresponding to this indication be considered as unity, then the currents for various losses in db will be as shown in Figure 2. As the current decreases the loss increases, but the decrease in current for successive db steps in loss becomes less and less. Thus from no loss to 1 db loss, the current changes 0.11 while from 14 to 15 db loss the change is only 0.02 or less than one-fifth as much. Since the movement of the pointer along the scale is to be the same for each db, the air gap must be proportioned to make the flux correspondingly larger toward the large loss end to offset the decreasing increments of current. The flux in the air gap, in fact, should follow the reciprocal of the curve of Figure 2. The construction of such a meter would be as indicated in Figure 3.

Since the narrowest air gap is at the position of maximum loss, this value of current and loss must be decided upon first, and from it the amount of necessary widening of the gap can be readily determined. As may be observed from the form of Figure 2, the amount of widening of the gap increases rapidly with the range of db to be measured. Thus for a meter to read up to 10 db the narrow end of the gap would have to be such as to give more than three times as much flux as at the wide end, while for a meter with a 20 db scale, the narrow end of the gap would have nearly ten times as much flux as the wide end.

Such a meter requires a higher operating current than the ordinary ammeter because the flux is less at maximum current. The varying width of the air gap also causes a variation in the damping at various positions of the scale. At zero loss, where the flux density in the air gap is least, the damping will be least, while at large loss, where the flux density is the greatest, the damping will be greatest.

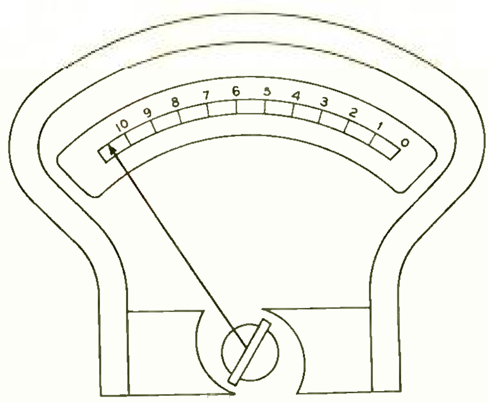
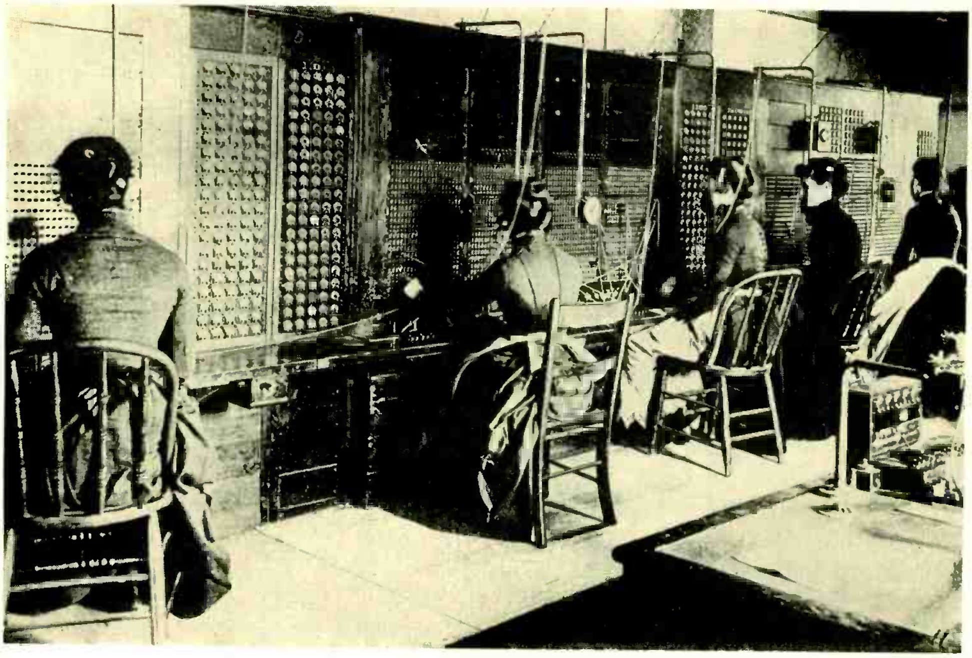


Fig. 3—A d-c ammeter used for measuring db loss with the air gap modified to give an evenly spaced scale

Meters of this type have been designed and have been made for Bell System use by the Weston Electrical Instrument Company. They have proven very satisfactory in service, and have already come into wide use.



A New Chair for Operators

By B. M. BOUMAN
Equipment Development

THE chair is the most varied and familiar article of domestic furniture. It is of extreme antiquity, although for many centuries and indeed for thousands of years it was a symbol of state and dignity rather than an article of ordinary use. It was not until the 16th century that it became common anywhere. The chest, the bench, and the stool were until then the ordinary seats of everyday life. It was owing in great measure to the Renaissance that the chair ceased to be an appanage of state and became the customary companion of whosoever could afford to buy it. Once the idea of privilege faded, the chair speedily came into general use, and almost at once began to reflect the fashion of the hour and locality.

No piece of furniture has ever been so close an index to sumptuary changes. It has varied in size, shape, and sturdiness with the fashion not only of women's dress, but of men's also. Thus the chair which was not too ample during the several reigns of some form or other of hoops and farthingale, became monstrous when these protuberances disappeared. Again, the costly laced coats of the dandy of the 18th and 19th centuries were so threatened by the ordinary form of seat that a "conversation chair" was devised which allowed the wearer to sit with his face to the back.

The advent of the telephone switchboard toward the end of the 19th century again made it necessary to develop a "conversation chair," this time for the switchboard operator. This, however, did not come about immediately after the advent of the telephone switchboard. Pictures of early switchboards and operating rooms of the eighties reveal the fact that little attention was paid to operators' chairs. They were of the kitchen variety with no provision for adjustment and very little for comfort, as may be seen in the photograph at the head of this article. It was during the decade beginning with the year 1900, when the switchboards became larger and less subject to change, that chairs specially designed for operators made their appearance. As shown in Figure 1, they employed an attractive bent wood construction with a rigid back and with a round cane seat that could be adjusted as to height. While experience of many years with this type of chair proved the soundness of the general design, it did not entirely meet all the changing conditions of more modern requirements.

The idea gained ground that when man directs and uses a machine to serve an end of his own, he is in a very definite sense combining himself with it. The telephone operator and the central-office switchboard system form such a combination of men, machines and devices—an intricate system of human, electrical, and mechanical parts all of which must function harmoniously if a highly efficient service is to be the result. The operators' chairs are an integral part in this system, for they are a direct means of preserving and sustaining the energy and efficiency of the human part or the mind of the system. It was from this point of view, that a further study was undertaken some years ago of what an operator's chair should be. The data obtained were then used in connection with redesigning the chairs

Fig. 1—Switchboard chairs of the early 20th century indicated the trend that was to be followed in later years

described in this particular article.

In formulating general requirements for the new chairs, it was decided that their size and general shape should adhere closely to those of the existing operators' chairs, which had been reasonably satisfactory, but that the construction should be such as to result in some improvement as regards assembly, materials, seat, and back rest. These general requirements had to be coördinated with practicability in service, reasonable production costs, and low repair and maintenance expense.

Ideas of how to design chairs that would promote the purposes desired varied widely. They usually assumed a seat modeled after a saddle, and a back rest that was adjustable both horizontally and vertically so that it could be fitted to each individual. On the other hand, practicability in service means a minimum of adjustable parts, or in other words, simplicity in construction. This also was a requisite for low production, repair, and maintenance costs. No data were available to indicate whether there was enough range in the requirements of different operators to make an adjustable back rest desirable.

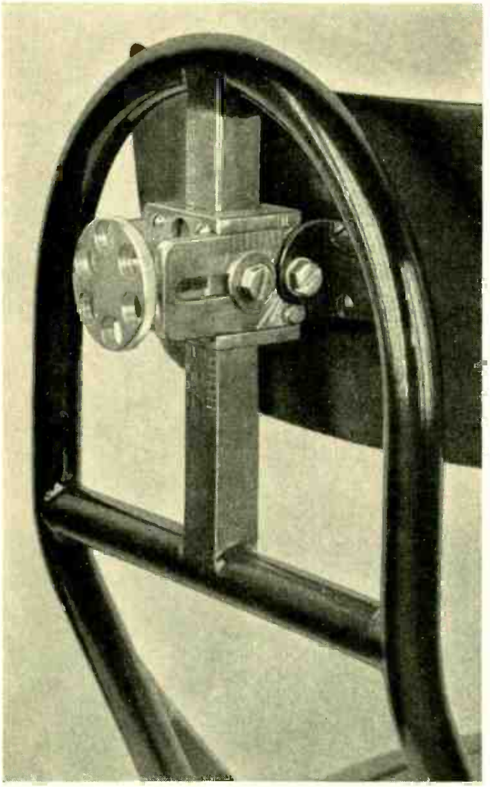


Fig. 2—Back rest adjustment features used on experimental chairs

To find the answer, it was decided to build a number of experimental chairs, and to try them out in the field over an extended period under regular service conditions. These chairs had a type of back rest that could be moved both vertically and horizontally, and that permitted each adjustment to be recorded on a suitable scale, as shown on Figure 2. The backs were then adjusted to suit the individual requirements of many operators and readings were taken from the scales.

After plotting and studying the results thus obtained, it appeared that an adjustable back rest was not required, and the exact position of a back rest that would be satisfactory to a large proportion of the operators was determined. A simple swivel was then added as a further means of compensating for the heights of different people. To verify these conclusions some of the chairs so equipped were sent to a number of central offices for trial. The trials also indicated that there is a marked preference for a cane seat in a circular frame with a narrow straight front slightly saddle shaped.

The information obtained as described above was then used in the final design of the chairs, one of which is shown in the middle picture in Figure 3. It meets the specific requirements for telephone operating as revealed by extensive experimentation and field trials at different types of toll and local switchboards, with varying heights of keyshelf and multiple reach, and with and without switchboard platforms.

As is shown in the photographs, the framework of the chairs is made of tubular steel members, and the seat and back rest are of wood. The foot ring is made of hard rubber reënforced by a steel ring embedded in the rubber. Bakelite disks swiveled to the legs of the chair provide ample bearing surfaces for the legs and prevent denting of floors that are covered with linoleum.

Fig. 3—One of the new chairs is shown between two of an older type at the Laboratories PBX

The four legs are welded to the hub which consists of heavy steel tubing. The cane seat rests on a punched steel plate structure to which the spindle and the posts for the back rest are welded. The back rest is swivel connected to the back rest posts, the swivel-joints being so tensioned as to allow the back rest to assume readily and retain the position best suited to the occupant. The cane seat and the back rest can be readily replaced by the maintenance forces in the field. Furthermore the strong welded steel construction of the chair is not subject to climatic influences, and prevents the various parts from getting out of alignment. While the use of a metal construction helped to solve some problems it created a problem of another sort, that is, the provision of a durable finish. Fortunately the recent developments of synthetic enamels for the automobile industry provided the answer, and it was possible to develop the synthetic enamels in the three desired colors—mahogany, walnut, or dark oak. The wooden parts are finished in the usual manner to bring out the natural grain.

Four chair heights have been made available, one 18 inches, one 20 inches, one 24 inches, and one 28 inches as in the past. This range of height is required to make the chairs suitable for various switchboards having different keyshelf heights above the floor or switchboard platforms.

Contributors to This Issue

F. H. Best joined the Engineering Department of the American Telephone and Telegraph Company in 1911 immediately after graduating in Electrical Engineering from Cornell University. He was transferred to the Department of Development and Research upon its formation in 1919 and became a member of our Technical Staff when the organizations were consolidated. Mr. Best has been engaged principally in the development of testing methods and arrangements used in transmission maintenance work.

R. P. Martin, Jr., received the A.B. degree from Yale University in 1915 and B.S. degrees in electrical engineering from M. I. T. and from Harvard University in 1917. He immediately entered the Engineering Department of the Western Electric Company but left early in 1918 to enter the Signal Corps of the Army, from which he was discharged in December, 1918, as a second lieutenant. After two years as assistant purchasing agent of Perin and Marshall, Consulting Engineers, and three months as assistant engineer of Gahagan Construction Company, he joined the power group of the Department of Development and Research of the American Telephone and Telegraph Company. Here his principal work was in connection with storage batteries, emergency gasoline engine sets, and telephone power-plant noise problems. On coming to the Laboratories in 1934, he at first continued his power work, but in 1935 transferred to the Transmission Development group where he has since been engaged in the development of control terminals for radio-telephone circuits.

W. E. Campbell was graduated from the University of Witwatersrand, South Africa, in 1923. After three years teaching chemistry, he entered the Chemical Research Department of these Laboratories. Until 1929 he conducted research in electroplating and corrosion, in the course of which he developed a method of accurately measuring the corrosiveness of the fumes from wooden cable duct on the lead sheath of the cable. Meanwhile he continued his studies of chemistry at Columbia, receiving the A.M. degree in 1929. He then carried on fundamental studies in the field of lubrication for a period of six years. Since 1935 he has been engaged in

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studies in the mechanism of tarnish and its relation to contact behavior.

A. R. SOFFEL joined the Research Department of the Laboratories in 1928. He has been engaged in various studies on the fundamental properties of hearing and has also been concerned with problems relating to the transmission and reproduction of speech and music. He has completed the Laboratories' Student Assistant Course and is now attending New York University.

A. R. Soffel

A. R. D'heedene

A. R. D'HEEDENE graduated from New York University in 1924 with the degree of B.S. in Mechanical Engineering and immediately joined the Laboratories. He was assigned to the group in the Apparatus Development Department which is responsible for carrier system filters and equalizers. While engaged in this work, he developed many of the networks now used in commercial carrier telephone systems. The networks described in the paper in this issue of the RECORD are those which he devised for the Type "G" carrier system. He is now responsible for the development of crystal filters.

R. NORDENSWAN joined the Engineering Department of the Western Electric Company in 1913 to engage in apparatus drafting. The following year he transferred to the transmission instruments engineering group, where he was concerned with the development of receivers and handsets. In 1922 he transferred to the apparatus development group where he has since been engaged in developing receivers, loud speakers, phonograph reproducers, audiphones, and audiometers.

W. H. SELLEW received the A.B. degree from Columbia in 1909, and two years later, the degree of Mechanical Engineer. The next eight years he spent chiefly with the General Electric Company, the Edison Laboratories, and the Ford Instrument Company, but in 1919 he joined the

R. Nordenswan

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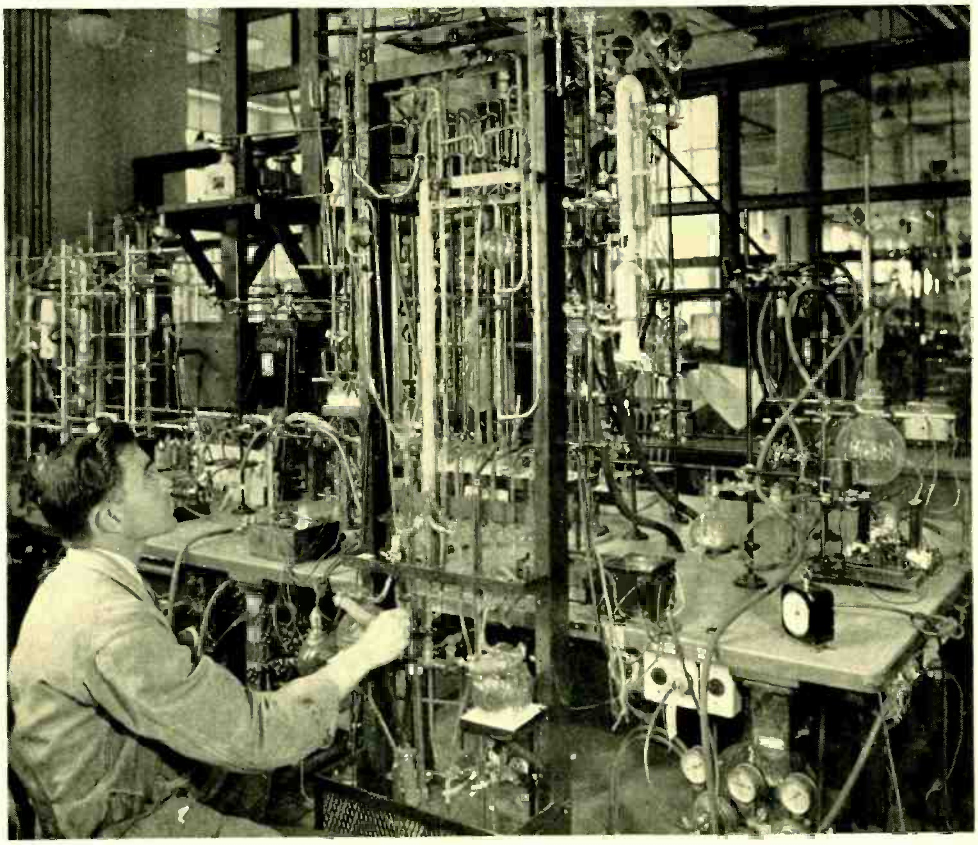
Technical Staff of the Laboratories—then the Engineering Department of the Western Electric Company—as supervisor of the design of household appliances. Three years later he became supervisor of the group preparing specifications on machine-switching and printing-telegraph apparatus. In 1929 he assumed responsibility for specifications on radio, sound pictures, and other special products, and two years later he took over, in addition, the supervision of distributing apparatus specifications and drawings to the Western Electric Company and to other companies in the Bell System.

B. M. BOUMAN graduated from the University of Minnesota with the degree of E.E. in 1904. He spent a year and a half with the Stromberg-Carlson Telephone Manufacturing Company and then joined the Equipment Engineering Department of the Western Electric Company in New York. In 1907 he was transferred to Hawthorne and later was associated with the Equipment Development Department. For three years, beginning in 1913, he was with the American Telephone and Telegraph Company in New York, engaged in general standardization work for Central-Office Equipment. In 1916 he returned to Hawthorne and three years later came to the Laboratories in New York where he has since been engaged in equipment development.



E. W. Kern analyzing gas from specimen of evacuated graphite