BELL LABORATORIES RECORD

WELDING LABORATORY
J. R. Townsend

MOVING-COIL MICROPHONE
A.L.Thuras, L.W.Giles, B.Leuvelink

DO OUR EARS GROW OLD?
H. C. Montgomery

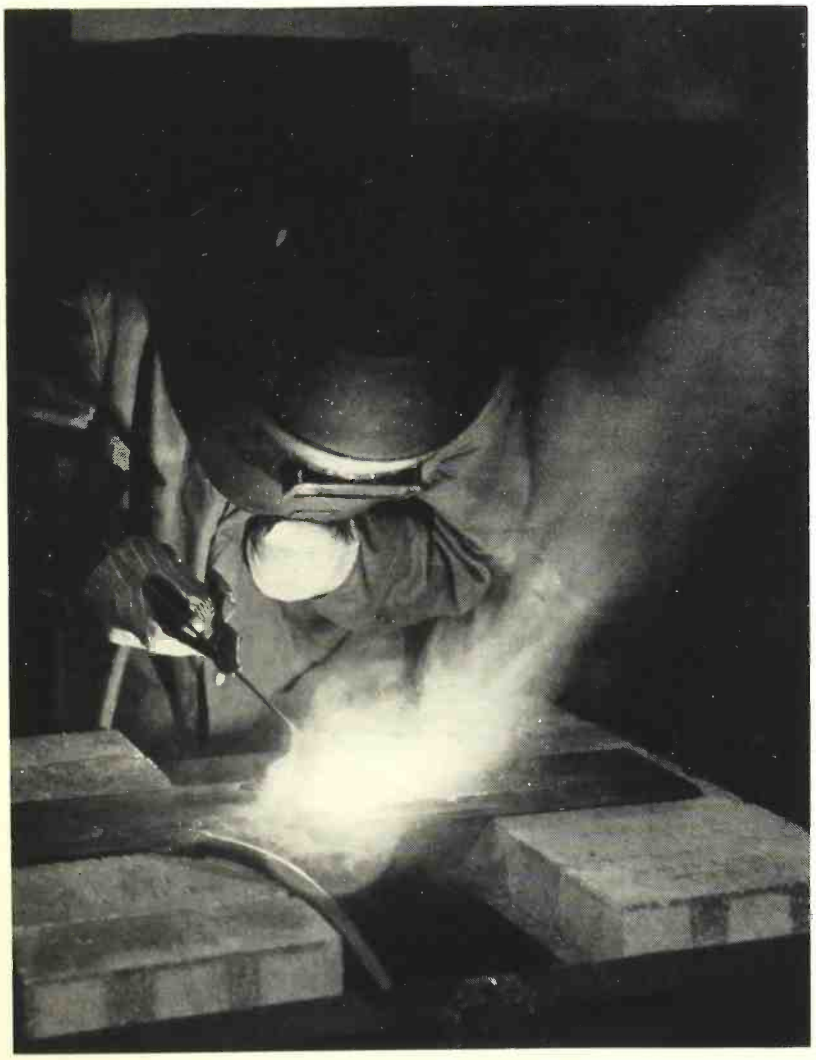
MAY 1932 VOL. 10 NO. 9

Bell Laboratories Record

Bell Telephone Laboratories, Incorporated
463 West Street, New York, N. Y.

In this Issue

BELL LABORATORIES RECORD



VOLUME TEN—NUMBER NINE

for

MAY

1932

Laboratory for Welding Studies

By J. R. TOWNSEND
Materials Development

WELDING is one of the most ancient practices of the metal arts. In the colonial times of our country, hand-wrought iron work which involved the welding of parts together by hand was much in evidence. The ornamental iron work on the porches of houses in the *Vieux Carré* of New Orleans, and in Savannah and Charleston, was practically all hand welded. Much of it was originally fabricated on rough forges by negro slaves. Locks and hinges used throughout the colonies were also made by forge welding.

Later welding was more or less supplanted by cast iron. Many parts could be made by casting more easily and at a less cost, than by the old hand-wrought process. With recent developments in electric and gas welding the tables are now turned. In increasing numbers of instances welding is replacing casting, with great savings in the cost of fabrication. In addition welding in some instances is supplanting bolting and riveting in structural steel and iron work. Here a saving in weight of approximately 20 per cent is possible with no loss in strength. Tests have shown that the welds when properly made are even stronger than the surrounding material. A further economic advantage of welding for structural purposes is that cheap hot-rolled structural parts may be sheared out and welded together without elaborate punching or the use of forming tools and gauges. Repairs are easily made and may be done on the job.

Modern attention to the possibilities of welding dates from the repair of the engines of the *Leviathan* following their damage at the time of America's entrance into the war. Broken parts were welded together and the engines were repaired on the spot by electric and gas welding. A great impetus was given to welding during the war period when it was widely used to meet the need for quick construction work. With the development of automatic and semi-automatic welding machines, welding came to be applied to production work. Automobile manufacture is now largely dependent on welding to achieve low production costs. Welding is being used more and more in building and structural work. Welded pipe lines for gas and oil extend half way across the continent.

In telephone work welding has been employed for years to attach precious metal contacts to relay springs. It has been also used for years to weld pole pieces of the telephone receiver by the electrical-resistance method. A recent application of modern arc-welding methods is in connection with steel loading-coil cases. The old cast-iron case has been replaced by a new design in which two sections of steel are pressed into a U shape and then welded together by an automatic arc-welding machine.*

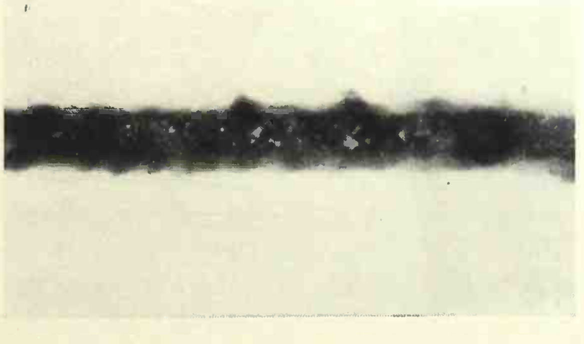
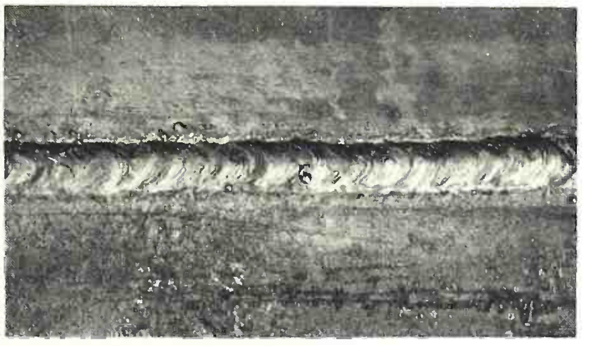


Fig. 1—X-ray photograph of weld

In Bell Telephone Laboratories a new laboratory has been recently established to study welding. Its purpose is to obtain engineering information necessary to the design of welded parts, to experiment with new welding methods, to adapt the design of telephone apparatus to welding technique, and to experiment with new welding materials. It contains automatic, semi-automatic and hand arc-welding equipment, oxyacetylene gas welding equipment and atomic hydrogen welding apparatus; and an X-ray machine has been set up to ex-



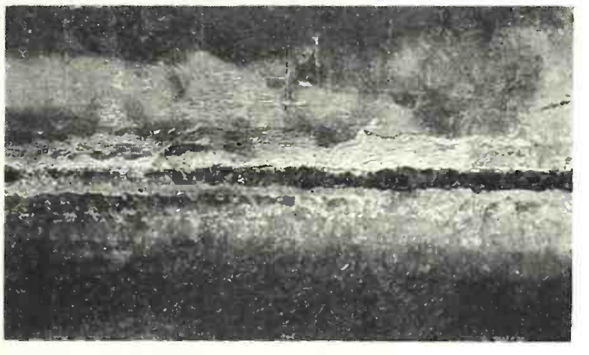


Fig. 2 (above)—Welded seam (top side) produced by the automatic arc welder. Fig. 3 (below)—The under side of the seam

*Record, *July*, 1931, *p.* 517.

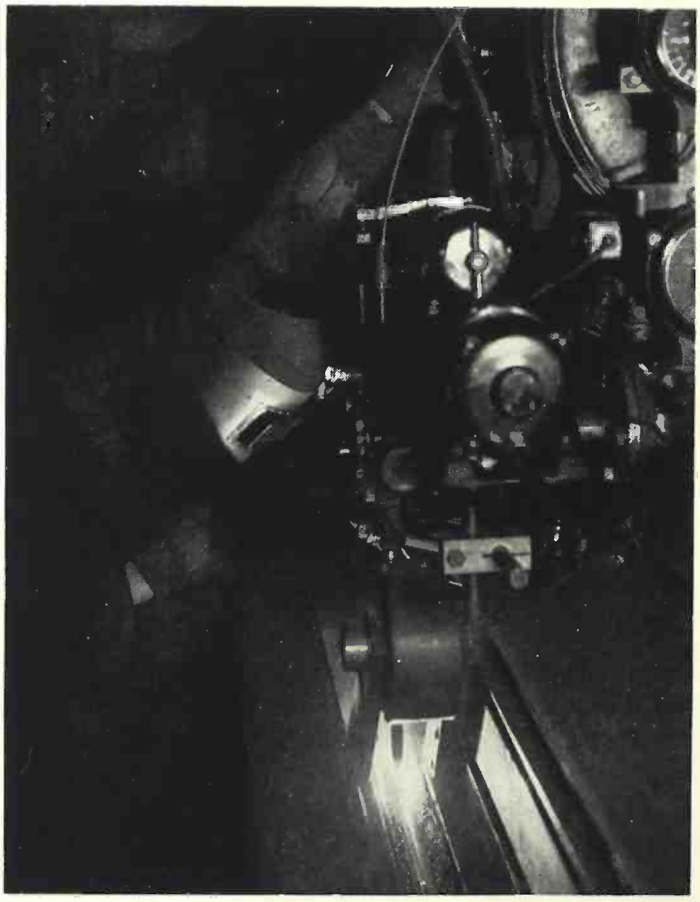


Fig. 4—Automatic seam welder in operation

amine the quality of the welds. In short, all equipment necessary to study the applications of welding has been included.

The appearance of a seam such as that produced by the automatic arc welder on loading-coil cases is shown in Figure 2. In this instance two plates of hot-rolled structural steel commonly known as fire box steel have been welded together. The abutting edges of the steel were cut at an angle of 30°. The plates were than laid flat and the space between the beveled area was filled with metal deposited by the arc. The arc was formed between a metal electrode, or welding rod, and the plates. As the welding rod melted, the hot metal deposited on the plates below filled up the beveled groove and, since the heat also melted the surfaces of the plates slightly, the two plates were thus welded together. Figure 3 shows the bottom of the two plates. The bead down the center was formed by some of the molten metal seeping between the two abutting plates. This is the appearance of a satisfactorily welded plate.

These welds were made by the automatic arc-welding machine shown in Figure 4. The electrode material comes down from a reel mounted on the top of the carriage of the machine and passes through an apparatus which guides it and automatically regulates the arc formed between electrode material and the beveled steel. This automatic welding machine not only continuously supplies electrode material to the arc and adjusts the position of the arc, but also by means of a traveling head lays a bead of metal between the plates. All that is necessary in making a seam weld with this machine is to make minor adjustments to suit the particular work at hand.

In the frontispiece the arc welding is accomplished in much the same way except that the arc is guided and directed by hand. Here it will be seen that one electrode is connected to the work whereas the other electrode is carried in the hand of the operator. The operator views the arc through a glass screen that eliminates most of the glare. It is also necessary that the operator protect his hands and face and body from the burning effects of the ultra-violet light which is generated by the arc.

The oxyacetylene gas torch used for cutting structural shapes is shown in the headpiece. After marking out with chalk the shape of cut that is desired, it is then a simple matter to guide the torch by hand. When the shapes are put together to form a structure, any inaccuracy in the cutting can be taken care of by filling in voids with weld metal.

The temperature of the oxyacetylene cutting torch is about 5800° F. This is also true of the oxyacetylene welding torch. In welding the gas flame is brought near to the two abutting metal surfaces, causing the metal to melt slightly. At the same time a welding rod is brought into the flame and melted on to the abutting pieces of metal. The temperature in electric arc welding is approximately the same.

Many metals are difficult to weld together by these methods since they have a tendency to oxidize rapidly. For example, trouble is encountered in welding stainless steel or aluminum because of this tendency. The oxide film that forms is so tenacious that it is difficult to get the two pieces of metal to fuse together. A method of overcoming this is to produce with the gas torch an excess of acetylene which reduces the atmosphere surrounding the arc and prevents oxidation of the metal. This method is successful for welding aluminum. In the case of the stainless steel, however, its much higher melting point combined with its tendency to oxidize renders it necessary that other means be employed.

The atomic-hydrogen torch consists of two tungsten electrodes between which an arc is formed. Hydrogen is forced along each of these electrodes and the two streams meet at the point where the arc is formed. The heat of the arc converts the hydrogen into nascent hydrogen which re-forms into ordinary hydrogen as it proceeds away from the arc. This molecular change raises the temperature of the arc to approximately 7250° F. and at the same time produces an envelope of highly reducing hydrogen gas at the outside of the flame. The atomic-hydrogen welding torch was developed three years ago by Dr. Irving Langmuir of the General Electric Company. With this torch it is possible to weld stainless steel, high-speed steel, aluminum alloys and practically every metal that shows a tendency to oxidize. In the atomic-hydrogen torch, instead of employing welding rod, usually two pieces of metal are caused to melt and fuse together.

The only suitable method of determining whether a weld is satisfactory, without actually destroying it, is by means of the X-ray. An X-ray ma-

Fig. 5—The X-ray apparatus is controlled from an outer chamber. A lead-glass window permits the operator to view the interior of the X-ray room as he stands at the controls

from the X-rays. The machine is controlled from a small antechamber which permits the operator to view the work through a lead-glass window (Figure 5).

The exposure room with the X-ray tube in place is shown in Figure 6. The tube has a capacity of 200,000 volts at a current of 5 milliamperes. Figure 1 shows a typical X-ray photograph of a weld. The gas pockets formed between the collecting drops of electrode material on the weld are plainly discernible. With some experience it is possible by examination of the X-ray shadowgraph pictures to estimate the quality and strength of the weld.

The equipment described enables us to carry out all of the necessary investigational work in adapting welding methods to telephone apparatus design. The work not only offers the means of improving upon present methods, but should likewise prove invaluable in bringing out more extensive applications of welding in telephone apparatus. That it constitutes a prominent contribution to the materials development program seems assured.

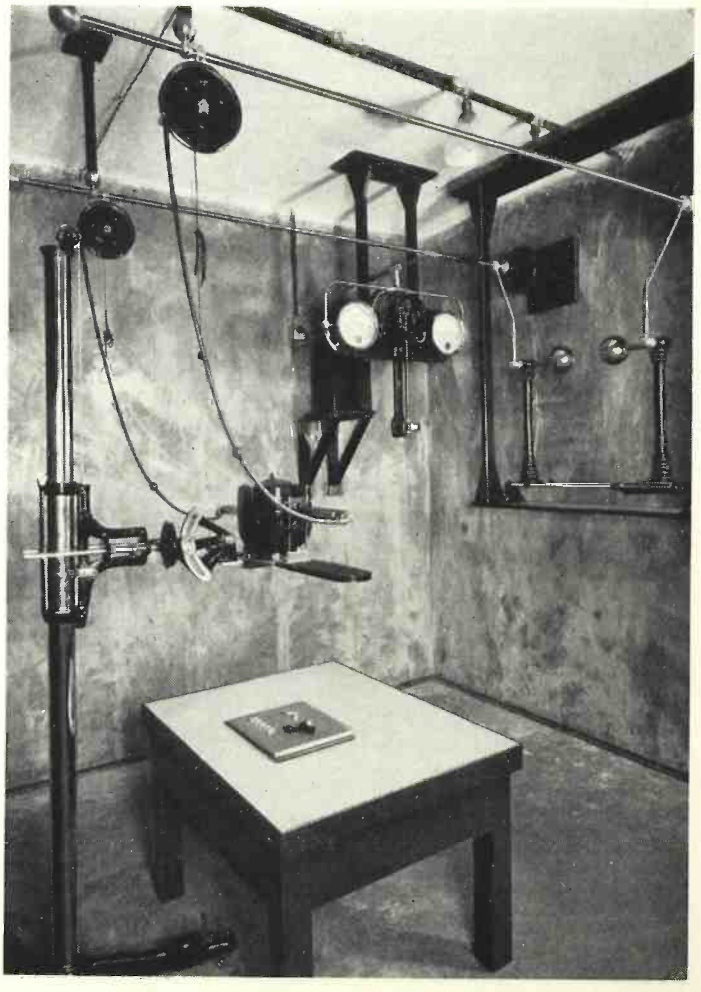


Fig. 6—The X-ray exposure room. Parts to be X-rayed are lying on a plate holder which contains the X-ray film. The sphere gaps shown in the background are used to regulate the voltage

chine capable of making photographs of steel parts up to 3 inches thick has been installed in the laboratory for this work. The whole apparatus is placed inside of a room lined with ¼-inch lead to protect the operator

Do Our Ears Grow Old?

By H. C. MONTGOMERY
Acoustical Research

"WELL, I guess I must be getting old." Such expressions as this on the part of people who find that their hearing ability is somewhat below normal indicate the popular belief that hearing deteriorates with increasing age. A recent investigation has led to the conclusion that there is some basis for this belief, but that the deterioration is small.

This investigation was conducted with the aid of the Western Electric 2-A audiometer. It consists of an oscillator which will produce any one of eight different pure tones varying in octave steps from a frequency of 64 cycles to 8192 cycles. These frequencies cover the useful hearing range, and correspond to the C's on the piano, omitting the lowest, and adding one above the highest. The intensity may be gradually reduced by an attenuator to the threshold of audibility, the point where the observer can no longer detect the sound.

Measurements of the threshold of audibility at various frequencies, together constitute an audiogram. As a standard, the normal threshold of audibility has been determined by averaging the thresholds of a number of young observers who had been examined by an otologist, and whose hearing appeared to be normal. This normal threshold is used as the standard of hearing acuity, and individual acuities are expressed in terms of decibels below the normal. Thus Figure 1 represents the audiogram of a person with good hearing, and of one whose hearing is sufficiently impaired to cause him some difficulty in understanding ordinary conversations. The dotted curve represents the level at which a sound is intense enough to cause pain, and may thus be taken as the limit of serviceable hearing.

About 200 audiograms were available, mostly of Laboratories employees ranging in age from 20 to 60 years. The subjects were selected in such a way that the proportion having defective hearing is about what might be found in any normal group of people. These audiograms were divided according to the age of the subject into

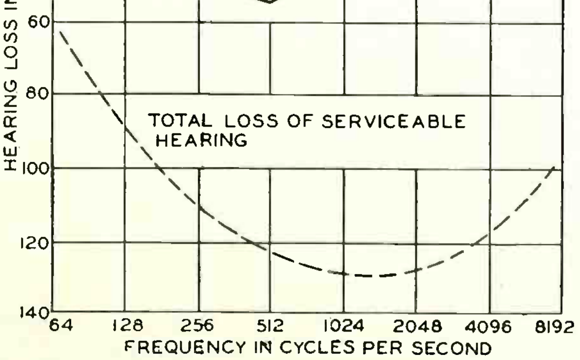


Fig. 1—In cases of moderately impaired hearing, nearly half the useful range of intensities may be lost

four groups, each group including ten years. The hearing of each age group was summarized (Figure 2) by finding the median value of the hearing loss at each frequency. The median was used rather than the average because it is not so much affected by extreme cases.

It is noteworthy that the difference between the thresholds of the youngest and oldest age groups is quite small compared to the difference between the normal and hard-of-hearing ears shown in Figure 1. In fact, at frequencies below 2000 cycles the differences are negligible, but at frequencies above 2000 cycles the differences become appreciable. This decrease in average hearing ability with increasing age might be the result of either of two causes: a considerable impairment of the hearing of only a

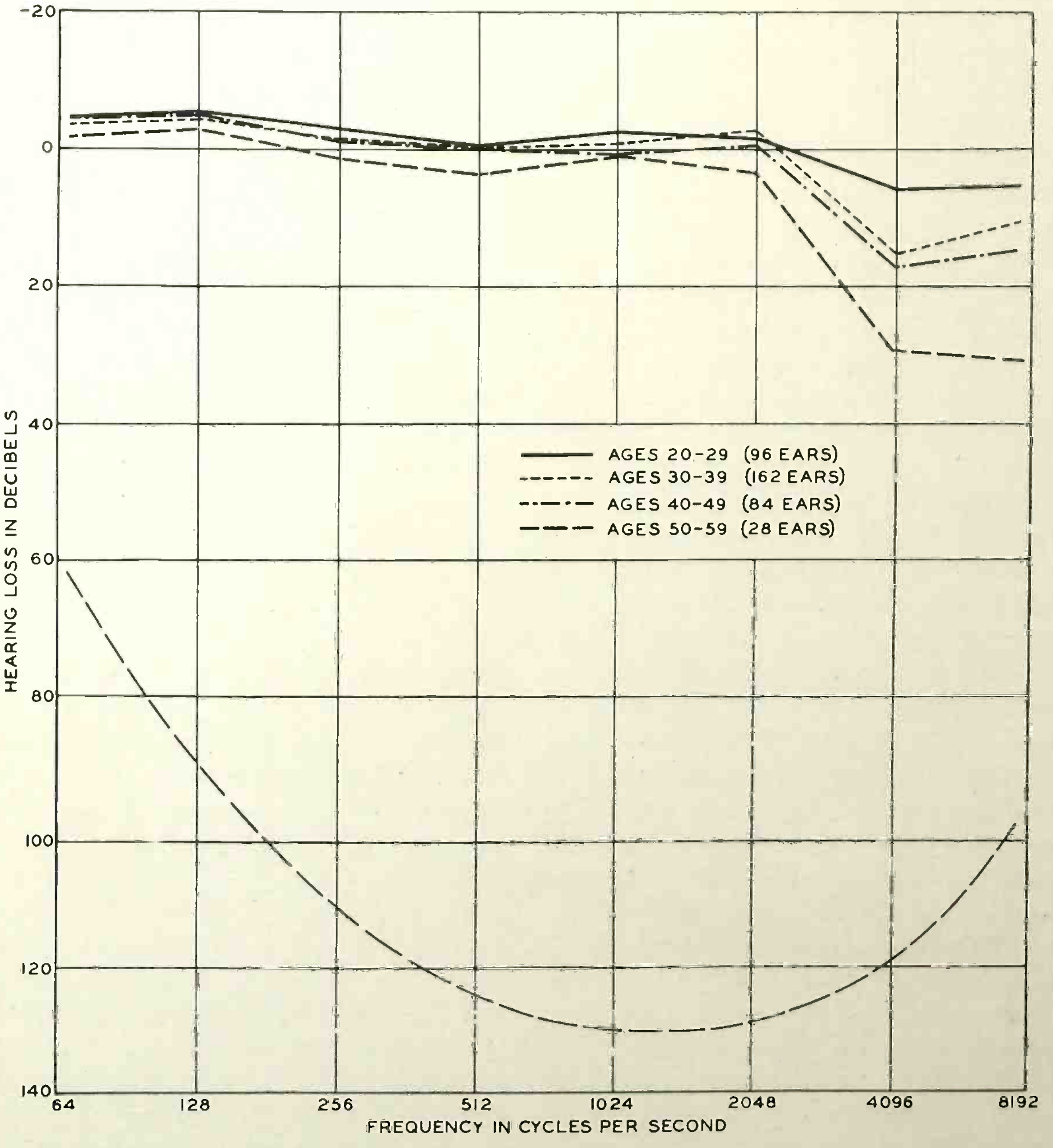


Fig. 2—Investigation showed that with advancing age little impairment of hearing normally takes place except at high frequencies

portion of the older group, or a slight impairment of the hearing of the whole group. Reference to the original data indicates that the latter is the more nearly correct explanation, for the average deviation of the cases from the median is practically the same for all the age groups.

A very common form of hearing difficulty is known as "nerve deafness," a typical case of which is shown in the audiogram of Figure 3. It is well known from individual case studies that this form of difficulty usually becomes progressively worse with increasing age. Its resemblance to the average type of impairment shown in Figure 2 immediately suggests that both are caused by the same sort of physiological changes. What those changes are and what causes them are matters upon which physicians are not yet agreed.

A question of practical interest is what effect the indicated change in hearing acuity will have on the ability to hear and understand in actual situations. The upper part of the frequency range, the only part sensibly affected, is of importance chiefly in distinguishing certain consonants and in appreciating the timbre or quality of musical sounds. In ordinary conversation, where speaker and listener are close to each other, no difficulty would be experienced by the 50–60 group, because the level of sound at the ear is high enough so that the falling off at the high frequencies would not be noticed.

The theatre or lecture hall presents a different situation. Here the level of sound at the ear is often quite low. Moreover, the higher frequency components are usually relatively weak by the time they reach the ear, due to selective absorption in the room. Under these circumstances the 50–60 group might experience some difficulty in distinguishing consonant sounds, and mistake "thin" for "sin," "famish" for "vanish," and the like.

Music would probably sound somewhat different to members of the older group, but it is doubtful whether they would be aware of this difference because they would lack a standard of

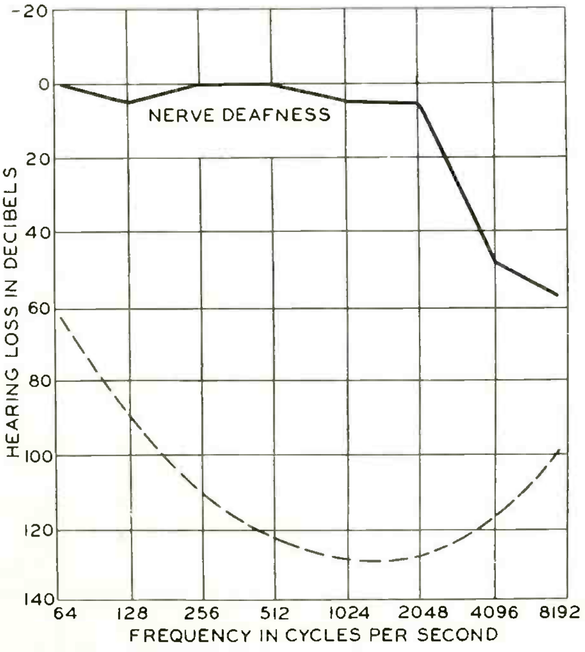


Fig. 3—In a typical case of nerve deafness, hearing at high frequencies is considerably impaired

comparison. Melody and rhythm they would appreciate as well as anyone. But the tones would lack brilliance, and differences between the instruments would not seem so pronounced to them as to younger persons.

Thus the average difference in hearing ability between a person aged 25 and one aged 55 is relatively small, but there is a tendency for hearing to deteriorate with increasing age. A study including more advanced age groups would probably uncover marked differences in hearing ability.

A Sensitive Moving-Coil Microphone of High Quality

By A. L. THURAS
Acoustical Research

IT is a common occurrence in the history of inventions that a perfectly operative device finds no commercial application until many years after the conception of the idea by the inventor. Other developments must be awaited before the new invention may be used advantageously. The moving-coil microphone very well illustrates such a situation. A microphone of this type was invented by Siemens as early as 1877, but only since the development of amplifiers has it become of practical use.

In its essentials, the moving-coil microphone consists of an acoustic diaphragm to which is attached a coil of wire that projects into a radial magnetic field. When the diaphragm is set in vibration by sound waves, a voltage of the same pitch or frequency is generated in the coil by magnetic induction. In general, therefore, it transforms sound to electrical vibrations as did the first telephone of Alexander Graham Bell, and might have become a serious competitor of it but for the advent of the carbon microphone which soon became the universally used transmitter.

The moving-coil microphone is handicapped by its inability to deliver to an electrical circuit more power than it derives from the actuating sound waves. It resembles Bell's transmitter in this respect. The carbon microphone, on the other hand, can deliver much more power than it receives from the sound wave. It acts as an electric valve to control, in accordance with the actuating sound wave, the release of much greater amounts of power supplied by an electric battery. The carbon microphone thus serves as a combination of transmitter and amplifier, and it was exactly the amplifier feature that was needed to make the moving-coil microphone of practical value.

Suitable amplifiers were not available at the beginning of the telephone era so that the carbon microphone had an impregnable advantage in early commercial telephony. Even today no type of microphone has been devised that can compete with it in a field where simplicity is of great importance. Where simplicity and efficiency are not so essential, however, the moving-coil microphone has the great advantage of being free from carbon noise, which may become objectionable when the sounds to be picked up are of low intensity. For sound recording, for radio broadcasting, and for other similar fields, therefore, the moving-coil microphone has a distinct advantage.

In its design another important difference between the two types of microphones had to be considered. In the carbon microphone the change in resistance, which gives rise to the microphonic action, is proportional to the displacement of the diaphragm. In the moving-coil microphone, on the other hand, the voltage generated is proportional to the velocity of the coil, which in turn is proportional to the product of displacement by frequency. The design of a moving-coil microphone thus resolves itself primarily into the problem of controlling the diaphragm so that its velocity per unit of force is the same at all frequencies. Under these conditions faithful reproduction will be secured.

Under applied forces a diaphragm vibrates with an amplitude which depends on both its stiffness and mass. At low frequencies stiffness is the controlling factor but at high frequency, mass has the greater influence. At some intermediate frequency—known as the resonance frequency—a balance exists between stiffness and the mass, or inertia effect, and a relatively large amplitude of vibration results. At low frequencies where stiffness predominates, the velocity is proportional to frequency while at the higher frequencies, with inertia controlling, the velocity varies inversely as frequency.

To make the velocity independent of frequency, resistance must be added in sufficient amount to make it the controlling element. A familiar example of the use of resistance to obtain constant velocity is the parachute. Without a parachute the speed of a man falling under the constant force of gravity would be governed almost entirely by inertia; his acceleration would be constant but his velocity would continuously increase. With a parachute, however, enough air resistance is introduced to become a controlling factor, and the velocity of fall becomes constant. Air resistance performs a similar function in the new moving-coil microphone.

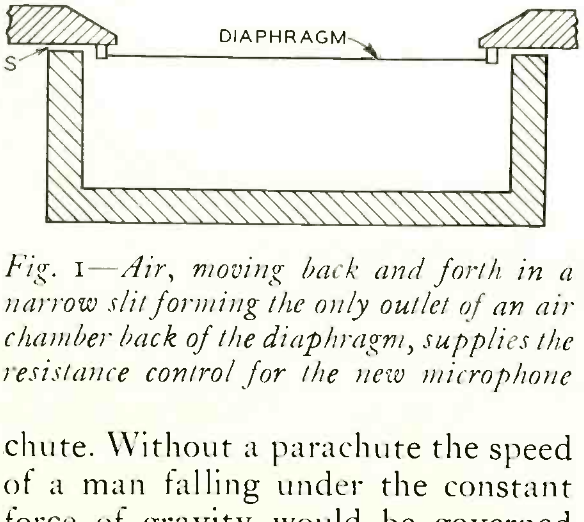


Fig. 1—Air, moving back and forth in a narrow slit forming the only outlet of an air chamber back of the diaphragm, supplies the resistance control for the new microphone

If a diaphragm is made to form one wall of a small enclosure provided with a narrow annular slit, as shown at S in Figure 1, air will be forced to and fro in the slit as the diaphragm vibrates. This rapid motion of air in the narrow slit provides a resistance load on the diaphragm. The amount may be varied over a wide range by adjustment of the various dimensions.

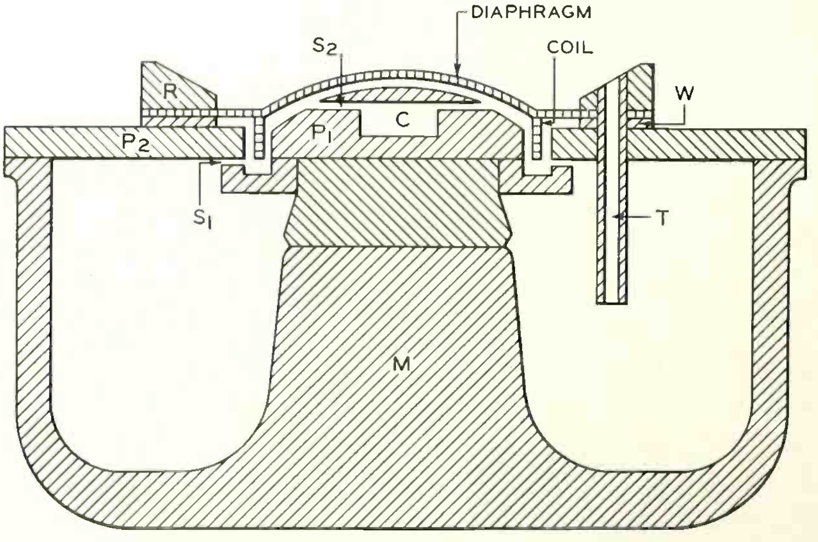


Fig. 2—A cross-section of the laboratory model shows the slit furnishing resistance control and the tube furnishing compensation for stiffness at low frequencies, as well as other features of the construction

As previously stated the voltage generated by the moving coil is proportional to the velocity of the diaphragm, and to have the voltage independent of frequency it is necessary to have resistance the controlling element. Velocity, however, is inversely proportional to resistance, when resistance is the controlling factor, so that to obtain high sensitivity, or large velocity per unit force, the resistance must be kept as low as possible. To keep the resistance low and at the same time to make it the controlling factor, requires that both the stiffness and mass of the diaphragm be kept as small as possible, and that by some means the stiffness at low frequencies and mass at high frequencies be compensated or partially offset.

The chamber and narrow slit construction of the new microphone partially secures this compensation for the mass, or inertia, of the diaphragm at high frequencies. If the slit were closed, the air in the chamber would be compressed and rarefied as the diaphragm moved back and forth during a cycle. The air chamber would then act as a cushion and so add to the stiffness of the diaphragm, and thus to a certain extent offset the mass. At high frequencies precisely this action takes place in the actual microphone because the period of one cycle is so small that the time is insufficient for any but a very small quantity of air to flow back and forth in the slit. The conditions are practically the same as though the slit were closed. This stiffness added at high frequencies, by counteracting the inertia effect, tends to produce a velocity that is independent of frequency, and thus allows a lower value of controlling resistance to be used.

A Laboratory model of the moving-coil microphone is shown at the head of this article and a cross-section of it, in Figure 2. The central portion of the diaphragm is dome shaped, making it rigid. A light aluminum ribbon coil,* fastened to the diaphragm at the base of the dome, projects into the radial magnetic field between the

*Record, *March* 1928, *p.* 205, and *August* 1928, *p.* 409.

pole-pieces, P_1 and P_2, of a permanent magnet which forms the frame of the microphone. By the ring R and washer W the diaphragm is clamped to, but held a short distance from, the pole-pieces. The small air space back of the diaphragm is closed except for the narrow annular slit S_1 which connects it with the larger space within the body of the magnet. This slit serves to control the response of the diaphragm as already described.

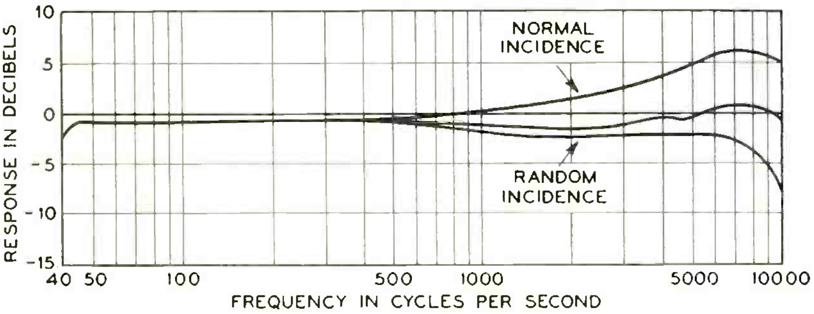


Fig. 4—The response of the microphone in actual use varies with the direction of the incident sound as indicated by the upper and lower curves of this illustration

The first models of these microphones showed an irregularity in the response in the neighborhood of 6,000 cycles, which was probably caused by some form of resonance oscillation within the air chamber under the diaphragm. To correct it, an additional cavity C was formed within the central pole-piece and connected to the air chamber by the narrow annular slit S_2. This construction gave sufficient damping to eliminate the irregularities in the response previously observed.

As already pointed out the stiffness of the diaphragm would control its motion at low frequencies—producing a velocity that decreased with frequency—except for the resistance element. Such stiffness control begins at about 200 cycles. Below this frequency the sensitivity of the microphone would tend to fall off. If the force on the diaphragm, however, could be increased at a rate corresponding to the falling off of velocity due to stiffness, a uniform response would be obtained. This action is secured by an air connection from the front of the diaphragm to the air chamber within the magnet made through the tube T. By proportioning the length and diameter of this tube, it is possible to exert a suction—which increases as the frequency decreases—on the rear of the diaphragm at the same time that pressure is applied to the front. At low frequencies this suction increases the velocity, and thus by producing an additional force tends to offset the increasing effect of stiffness at low frequencies.

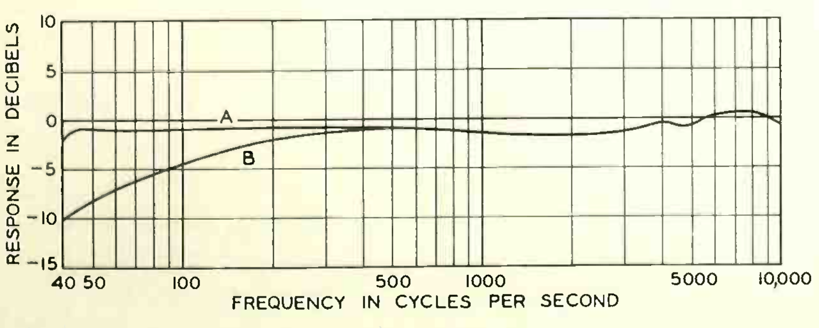


Fig. 3—The response of the complete new microphone with a constant pressure acting on the diaphragm, curve A, is practically flat from 40 *to* 10,000 *cycles*

The effect of this arrangement in improving the uniformity of response is shown in Figure 3. Here curve B indicates the response without the tube T, and shows the falling off in response at low frequencies. With the tube connected, the response is given by curve A, and varies only a few db from 45 to 10,000 cycles. The curves of Figure 3 show the frequency response of the microphone for a constant pressure applied over the surface of the diaphragm. The response when the microphone is used as a sound pick-up is somewhat different due to the distortion of the sound field caused by the microphone and because the sound pressure over the surface of the diaphragm is not uniform nor in phase at all frequencies. The response was therefore obtained with the microphone placed in a sound field of known intensity, and certain of the results obtained are shown in Figure 4. The upper curve shows the calibration when the incident sound is perpendicular or normal to the diaphragm. The random incident curve shown in the same illustration was calculated from measurements taken when the microphone was placed at various angles to the direction of the sound source. The response of the microphone under most conditions of operation will fall somewhere between these two curves. The pressure calibration of Figure 3 is also shown with these curves for comparison.

A transformer is normally employed to connect the microphone to a vacuum tube amplifier, and under this condition the microphone delivers about 10 db more voltage to the grid than the condenser transmitter, which was designed to operate at maximum efficiency up to about 7,000 cycles. It is better adapted, therefore, for uses where the source of sound is at some distance from the transmitter, since with the smaller amplification required, mechanical and electrical disturbances—and amplifier noises in general—may be kept at a relatively lower level. A commercial form of this instrument, in which are incorporated the fundamental principles described in this paper, is now being used for radio broadcasting, sound recording, and public address.

Economic Control of Quality of Manufactured Product

The publication of "Economic Control of Quality of Manufactured Product" by W. A. Shewhart, another text in the Laboratories' series, is announced by D. Van Nostrand Company. It is based upon investigations carried on by Mr. Shewhart in the Laboratories to develop the most efficient uses of statistical methods in solving problems that arise in the quantity production of complex assembled products, such as in telephone apparatus.

The material in the text was originally organized for presentation in the Out-of-Hour course given by Mr. Shewhart. It was later revised for use in a course of lectures presented by him at Stevens Institute of Technology. The book outlines means of effecting economies through the statistical control of the quality of manufactured product in all stages from raw material to finished article.

Adapting the Moving-Coil Microphone to Commercial Use

By L. W. GILES
Transmission Instruments Engineering

CERTAIN of the basic ideas underlying the moving coil microphone were conceived during the early stages of the development of the telephone. As long ago as 1877 it was suggested that the performance of Bell's microphone could be improved by making the diaphragm of non-magnetic material and attaching to it a coil, preferably of aluminum, arranged to vibrate in a magnetic field. Such an arrangement had several inherent advantages, but at that time there were many obstacles in the way of its accomplishment. Besides certain fundamental difficulties, pointed out in an accompanying article* of this issue, which retarded the early use of the moving coil microphone, there was available at that time neither the accumulated research in acoustics nor the long experience in the design of transmission instruments that have played such an important rôle in the production of a moving coil microphone suitable for commercial use.

Among the many desirable features that could be secured by the use of a moving coil are a uniform electrical impedance and a constant force factor over a wide frequency range, the absence of static force on the diaphragm, and freedom from non-linear distortion even at large amplitudes. Even with these advantages obtained by the adoption of the moving coil principle

*A. L. Thuras, p. 314.

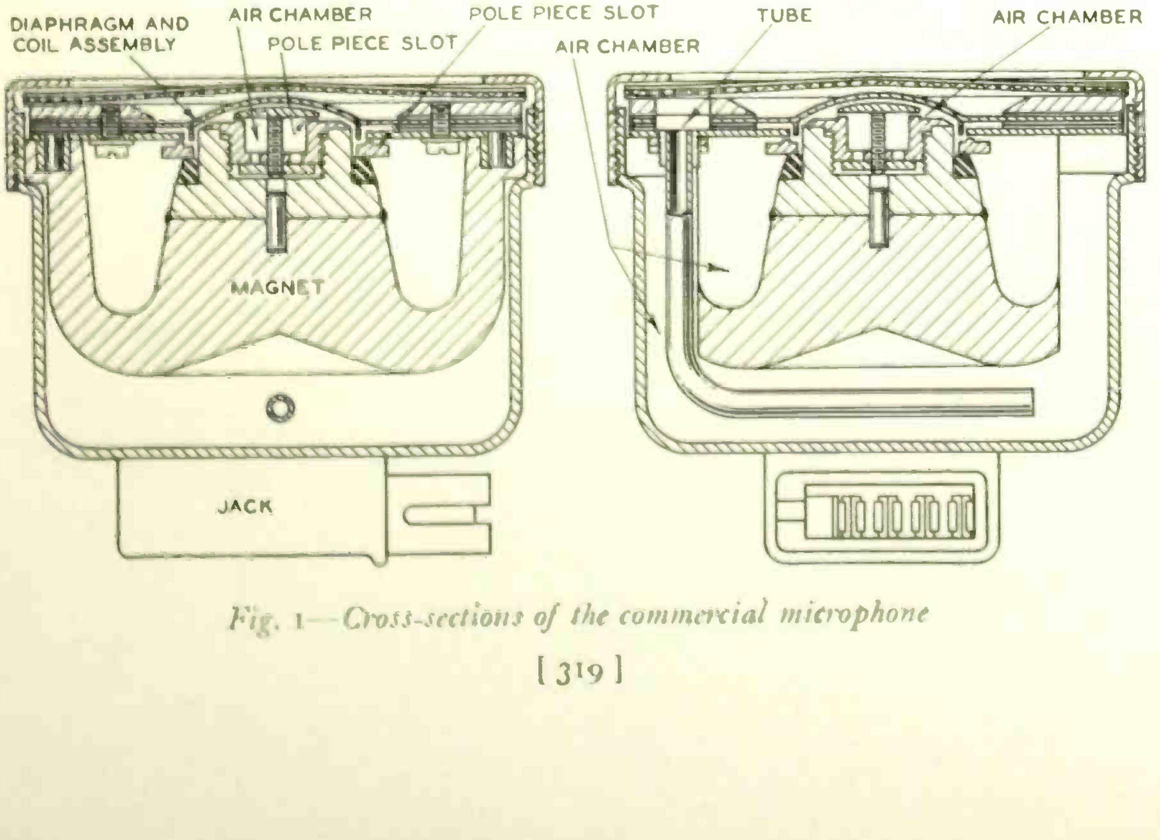


Fig. 1—Cross-sections of the commercial microphone

alone, however, the resulting instrument would not be suited for high quality reproduction of sound. To secure the uniformity of response required to make a moving coil microphone satisfactory over a wide frequency range, it has been necessary, in addition, to couple several acoustical elements to the diaphragm and coil. The success of the present moving coil microphone is due, in a large measure, to these supplementary design features.

The functions of these various elements are discussed in the article already mentioned, but the microphone there referred to and shown in cross-section differs somewhat from that manufactured for commercial use. So far as response characteristics are concerned the differences are small, but greater departures are evident in the construction since one microphone was a research model and the other is a commercial product. The major features of the commercial microphone are shown in the cross-sections of Figure 1.

To avoid the necessity of using a polarizing potential, a permanent magnet of cobalt steel is employed to establish the magnetic field in which the moving coil vibrates. The properties of cobalt steel are such that the size and weight of the magnet can be reduced to a minimum and demagnetization practically eliminated. Soft-iron pole-pieces are employed. The inner pole-piece is welded to the central portion of the permanent magnet and the outer one is secured in correct alignment by two pins which fit into soft iron inserts in the magnet.

The diaphragm is made of thin duralumin and has a dome-shaped center portion which extends to the inner edge of the moving coil. This stiffens the center of the diaphragm and insures that it will vibrate substantially as a plunger throughout the frequency range of interest. The moving coil is made of aluminum ribbon wound on edge. Varnish is employed both to insulate the turns and to hold them together, and is also used to fasten the coil to the diaphragm. The assembly is then baked to drive off the volatile material and to insure a rigid bond between the coil and the diaphragm.

A perforated metal grid protects the diaphragm from mechanical injury, and a silk screen, which covers the grid, aids in preventing dust and particles of magnetic material from accumulating on the diaphragm. Both the grid and the metal housing which encases the microphone are insulated from both moving coil and diaphragm, and form a shield which may be connected to ground through one of the three contacts in the jack located on the back of the microphone housing. The two outside contacts in the jack, described in an accompanying article,* are connected

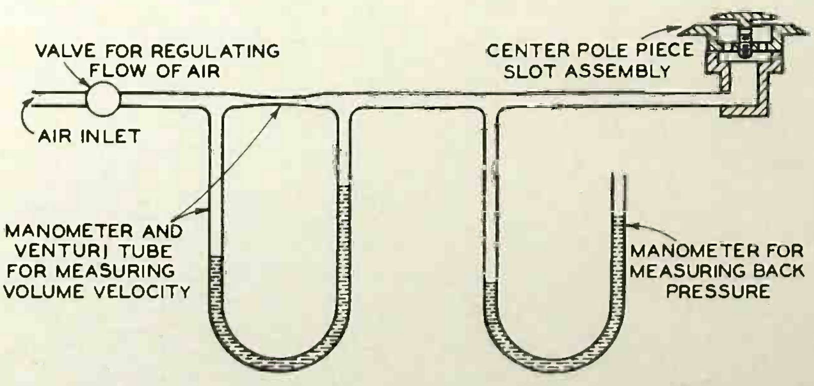


Fig. 2—By the use of such a calibrating fixture the center slot assembly can be adjusted to give the proper acoustic resistance

*B. Leuvelink, *p.* 323.

to the moving coil. The locking device on the jack, in addition to insuring a positive contact, prevents the plug from being accidentally withdrawn while the microphone is in use.

As already pointed out, various acoustic elements have been coupled to the diaphragm to control the response of the transmitter over a wide range of frequencies. It is of course essential that these elements be individually adjusted to within predetermined limits. The transmitter for commercial production, therefore, has been designed to facilitate making such adjustments prior to the final assembly of the transmitter.

The details forming the center pole-piece slot can be assembled as a unit and its acoustical resistance measured in a fixture represented in Figure 2. When this resistance has been adjusted to the proper value, the unit is screwed into the center pole-piece as shown in Figure 1. The outer pole-piece slot may also be tested by means of the fixture represented in Figure 2 and the adjustment of acoustical resistance made before final assembly. When this unit is assembled in the microphone, acoustic leakage at the base of the slot is prevented by a rubber gasket that seats on a shoulder on the center pole-piece and presses against the ring forming one side of the slot.

The third acoustical element used for controlling the response of the microphone consists of a metal tube which, as shown in Figure 1, fastens into the outer pole-piece and connects the air space behind the diaphragm to the air in front of it.

The response characteristic of a microphone under the various conditions of use encountered in sound recording, broadcasting, and similar fields cannot be expressed by any one response curve. Diffraction of the sound by the microphone, and the angle of incidence of the sound wave

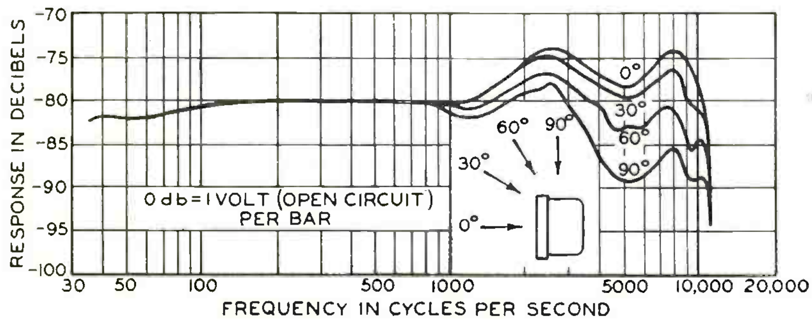


Fig. 3—Response characteristics of the commercial microphone for several angles of incidence of the actuating sound

affect the response of the instrument to a marked degree. These effects are represented in Figure 3, which shows the response for several angles of approach of the sound wave when the microphone is placed in a sound field of constant pressure. It will be noted that these curves differ considerably from that shown in the accompanying article where the response of the instrument when subjected to a constant pressure on the diaphragm is given. The conditions most likely to be encountered in the use of the microphone are such that the effective angle of incidence is generally between 0 and 90°. In the design of the moving coil microphone for commercial production, the various elements have been adjusted, therefore, to give an overall response characteristic which is substantially uniform for an angle of incidence approximately midway between 0 and 90°. In all cases, where the microphone is to be used for precise acoustic measurements, it should be calibrated under the actual conditions of use, if possible.

By careful design, and selection of materials, the new microphone has been made practically independent of variations in temperature, barometric pressure, or humidity likely to be encountered in its use. The tube introduced to improve the response at low frequencies inherently provides the means for equalizing barometric pressure, and all metal parts of the microphone are protected from corrosion by suitable finishes. In addition to freedom from effects of temperature, humidity, and changes in barometric pressure, the new microphone, when compared on an equivalent basis, is more efficient than the conventional form of condenser microphone and, unlike it, may be used at a considerable distance from its associated amplifier. These features are of considerable practical importance and, in conjunction with the choice of mountings provided, should enable the new microphone to prove of great usefulness in a wide variety of fields.

A number of moving-coil microphones of the type described in this article are already in use and the results obtained appear to be very satisfactory.

"*Profitable Practice in Industrial Research*"

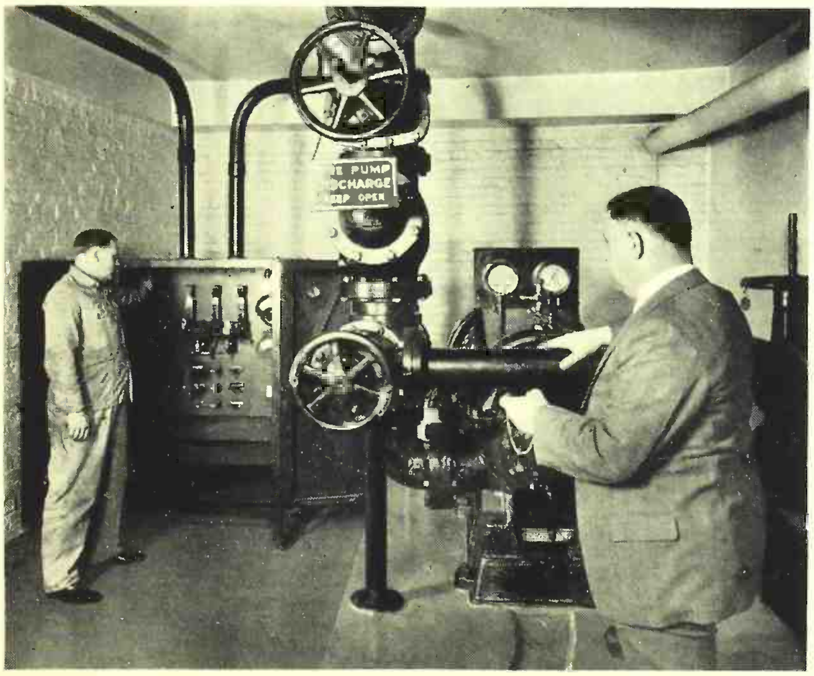
President Jewett *contributed the opening chapter to a book "Profitable Practice in Industrial Research" recently issued by Harper & Brothers. It was prepared under the auspices of the National Research Council and contains contributions by distinguished men of science on the place of the research laboratory in industry and on methods and practices that have led to success in industrial research.*

Dr. Jewett's account is entitled "Philosophy and Practical Application." He touches briefly on the nature and history of research and explains the difference between the industrial research laboratory and the university laboratory which he terms the research laboratory's senior partner. The main difference between the two, he points out, is one of motive: the institution in the university having as its objective the extension of the realm of knowledge and the development of men trained in scientific methods; the industrial laboratory of necessity directing its activities to the solution of purely utilitarian problems.

In the same book John Mills discusses methods for the selection of the Laboratory research worker and states that specifications for the man rather than for the job are paramount. Citing the main specifications which from his experience are applicable in the employment of college men for any industry, he describes an interview method which reveals to the employer the candidate's mental aptitudes, preference and personality, rather than stressing his technical ability which is easily ascertained from his former instructors.

NEWS AND PICTURES

of the Month



Making a periodic test of the 1,000 *gallon electrically driven pump. Fire Inspector William Wissel observes the pressure gauges after the switch is thrown by W. C. Somers, in charge of the power plant.*

BUILDING'S SAFEGUARDS GIVE FIRE LITTLE CHANCE

Bell Telephone Laboratories enjoys a very low fire loss, thanks to the safeguards established by our alert and energetic Plant Department and the coöperation of all members of the Laboratories. Not only are great precautions taken against the occurrence of fire, but equally thorough preparations are made for extinguishing any that may occur. In addition to the safeguards provided by the automatic sprinkler and alarm systems, fire doors completely isolate each section of the building from its adjoining section. Portable fire equipment is located at convenient places and is periodically tested to insure that it is readily available in case of any emergency that might arise.

The watch dog of the sprinkler system is the automatic head. When the air temperature surrounding the head rises above a specified maximum, a plug releases and a spray of water is thrown down uniformly over an area approximately 14 feet in diameter. The heads are placed at sufficient distance apart so that the entire area of a room is protected.

There are two types of head in use in the building. One is the fusible type in which the head operates by the failure of a soldered strut which holds a glass plug in place. In the second, a newer type, the plug is held in place by a glass capsule containing an expansible liquid. The expansion of this liquid at the danger temperature bursts the capsule. In both types the failure of the plug support permits the plug to be forced out by the pressure of the water in the system.

In tanks on the roof of the main building 62,000 gallons of water are stored to supply the automatic sprinklers. A similar service is performed by tanks holding 15,000 gallons on the roof of Section "L" for the sprinklers in the Sound Picture Laboratories and others holding 12,000 gallons for sections "J" and "K." In case of a severe fire these supplies could be supplemented by water pumped by the City Fire Department through outside connections into the sprinkler system. These Y-shaped outside connections which project from the sides of the buildings on each of the four bordering streets are dubbed "Siamese" by the firemen.

Each section of the main building shares with its neighboring section a fire standpipe. On each floor there is a valve on the standpipe with a nozzle and sufficient fire hose so that from two adjacent standpipes complete coverage of the area between is obtained. These standpipes are supplied by a reserve of 3,500 gallons in a tank on the 13th floor

A sprinkler head with its glass capsule in place.

roof. As in the case of the sprinkler system, this supply may be reinforced by water pumped through outside connections; those which reinforce the sprinklers are painted green; the standpipe connections are painted red.

A further supply of water is provided by an electrically driven pump in the basement of Section "H" which can feed 1,000 gallons of water per minute into either the standpipe or the sprinkler system. It is supplied with City water from two separate street water mains through a special type water meter only permitted on fire services.

The heads of the automatic fire alarm system are distributed on the ceilings, wired in closed circuits, and operate by the failure of a soldered electrical connection, due to high temperature. The system is installed and maintained by the Automatic Fire Alarm Company. Alarms over this system are received at the main office of the Automatic Fire Alarm Company which notifies the Fire Department.

There are several kinds of fire doors in the building. One type is constructed of corrugated iron plate fastened to an angle iron frame. Another type consists of several plies of wood completely clad with sheet metal. Still another type is the hollow metal door filled with non-combustible material. All the newer types of these doors bear the Underwriters' approval as evidenced by a metal tag permanently fastened to each door.

Outside of working hours every room in the building is visited each hour by a watchman who carries a small circular case containing a magneto which he plugs into outlets placed at the various locations on each floor. The magneto sends a current to a watchmen's clock situated on the 11th floor and perforations on a large sheet of paper record the visits to each station.

Fire protection falls within the duties of the Plant Inspection Department and is under the immediate charge of Messrs. A. M. Nicholson and William Wissel. Mr. Nicholson was experienced in inspection work for fire insurance companies

The winners of the Club's four-man team duplicate contract tournament: W. T. Jervey, R. O. Ford, R. L. Shepherd, and G. B. Graeff

previous to becoming a member of the Laboratories. Mr. Wissel is a retired member of the New York City Fire Department. In cooperation with all departments throughout the building they enforce the two prime requisites of fire prevention: order and cleanliness. They also supervise the purchase, use and storage of any hazardous materials. They organize and supervise regular fire drills where required.

MEN'S BRIDGE CLUB REPORTS ACTIVE CONTRACT SEASON

THE CONTRACT BRIDGE team composed of R. O. Ford, G. B. Graeff, W. T. Jervey and R. L. Shepherd emerged victorious in the four-man team duplicate tournament which closed early in April. First place in the tournament was decided in a special play-off between the three leading teams in each of two groups into which the tournament was divided. Second place was won by the team composed by C. H. Achenbach, I. W. Brown, W. L. Kidde and E. W. Waters. C. L. Deelwater, J. R. Reeves and A. L. Stillwell constituted the team winning third place.

On March 29 the annual match with the Western Electric Company was played at 195 Broadway and the Laboratories again won the Auction and Contract Trophy. The match was a progressive duplicate contract tournament in which twenty two-man teams from each company participated. Total score gave the Laboratories 82,865 points compared to 68,815 for Western Electric.

In the four-man team duplicate tournament matches were on a round robin basis with scoring on the match point system. Sixteen four-man teams participated, eight teams in each group.

The Men's Bridge Club, which this year has been under the chairmanship of R. Linsley Shepherd of the Bureau of

Publication, has enjoyed an unusually successful season. Fifty-two men competed in the progressive contract tournament held last fall and eighty-four men played in the special tournament on January 11.

D. H. ANDREWS AND L. H. GERMER ADDRESS COLLOQUIUM

Professor Donald H. Andrews of Johns Hopkins University spoke on *The Raman Spectra and the Chemical Bond* at the meeting of the Colloquium on March 14.

In 1928 Raman observed that when a beam of light is passed into a liquid, there is in addition to the radiation which passes directly through, a secondary radiation emitted from the light in all directions and due to the scattering of the light by the molecules in the liquid. This scattered light, Professor Andrews said, when observed with a spectrograph gives a group of rather sharp lines, displaced from the wavelength of the unscattered light by amounts which depend on the structure of the molecules in the liquid. These frequency differences correspond in general to the frequencies in the infra red region at which the different parts of the molecule are vibrating. Such frequencies are often observed as absorption band in the infra red spectra.

Since this pattern of lines caused by the scattered light is sharply characteristic of the molecule causing it, it forms an ideal means for qualitative identification, the speaker brought out. By proper interpretation of the different features of the pattern, moreover, such features in the structure of the molecules as double bonds, rings, extra heavy atoms and the like can be readily recognized.

At the meeting on March 28 L. H. Germer described recent electron diffraction experiments. Pointing out that diffraction patterns produced by the scattering of electrons by crystalline substances offer a new means of studying crystal structures, Dr. Germer mentioned that although the diffraction patterns are often similar to those of x-rays, they permit experiments which cannot be made by x-rays. Some of these experiments were discussed by the speaker, such as the determination of the size and orientation of crystals in extremely thin foils and the marked changes which are produced by hammering and annealing; the examination of films existing upon metallic surfaces as a possible aid in the study of corrosion and chemical catalysis; and attempts to discern the nature of polished surfaces.

CLUB ORCHESTRA PROVIDES EASTER MUSICAL

A rich and entertaining Easter musical was given by the Club Orchestra under the direction of L. E. Melhuish on March 24 in the Auditorium. Two of the numbers on the program, compositions for soprano solo by Gounod and Rodney, were sung by Mrs. R. J. Podeyn, accompanied by the orchestra.

The other numbers on the program included Mendelssohn's "Priests' March from Athalia" and the Triumphal March from "Sigurd the Crusader" by Grieg, played by the Club Orchestra; and Liszt's "Liebestraum" played by a violin trio consisting of R. J. Podeyn, M. H. Quell and P. F. Hoyt accompanied by W. Whitney at the piano.

ADMINISTRATION

Dr. Jewett spoke on industrial research at the annual dinner of the Engineering, Architectural and Technical Societies of Rochester on March 28. He was welcomed to the City of Rochester by Mayor Owen and introduced to the audience by W. Roy McCanne, president of the Stromberg-Carlson Telephone Manufacturing Company. Following the talk L. S. O'Roark gave a demonstration which included speech and music characteristics and vertical recording.

On the morning of the talk Dr. Jewett was guest of honor at a breakfast given by heads of various organizations in Rochester. Those present in addition to Dr. Jewett were Messrs. Bausch, Lomb and Eisenhauer of the Bausch & Lomb

Company, W. R. McCanne, J. P. Boylan, president of the Rochester Telephone Company, L. S. O'Roark and D. G. Blattner, who was in Rochester to set up and oversee the operation of the vertical reproducing equipment.

Following the breakfast visits were made to various centers of interest in Rochester and to the Bausch & Lomb and Stromberg-Carlson plants.

H. P. CHARLESWORTH has been appointed a member of the Corporation of the Polytechnic Institute of Brooklyn.

DR. JEWETT, MR. CHARLESWORTH and General Patent Attorney J. G. ROBERTS attended the celebration of the opening of the new Patent Office at Washington on April 11. At a dinner held in the Mayflower Hotel Dr. Jewett gave an address "Modern Research Organizations and the American Patent System." An excerpt from his remarks appears on page 326.

AN INDUSTRIAL saga rises out of A. F. Dixon's career in the Bell System which reached the thirty year mark on April 29. He came to the Clinton Street factory in Chicago as a young draftsman with some experience on steam boiler work. He was not without anxiety as to his fitness in handling smaller telephone details but was assured that a good draftsman would soon accustom himself to the work. Applying himself diligently to his tasks, he undertook outside studies of the mathematics involved in this new work. Soon he achieved the reputation of an expert draftsman, and was entrusted with the design of various apparatus. He was sent to New York in 1907 to work under the late E. B. Craft, at that time a young man like himself who possessed a remarkable genius in the design of intricate apparatus used in telephone work.

In 1912 Mr. Dixon was placed in charge of the printing telegraph development. He supervised this work until 1915 and within this period the Western Electric multiplex system was developed and work on the start-stop system, one of the basic features of Bell System teletypewriter service at the present time, was already well under way. The multiplex system was adopted by the Western Union Telegraph Company for use on the most important of their trunk lines.

In 1915 the first semi-mechanical machine switching installation was placed in operation in Newark. It was the panel type and the important panel bank had been designed by Mr. Dixon while he was still in Chicago. Shortly after the first semi-mechanical systems went into operation, Mr. Dixon was placed in charge of further development. The program of

A. F. Dixon

full-mechanical switching was soon under way and with it in the years that were to follow came important features of the panel system as we know it today—the link and start circuits, decoder and relay call indicator. These developments were all carried on under Mr. Dixon's supervision and guidance.

In 1919, with the addition of the equipment and toll circuit groups, Mr. Dixon's department assumed practically its present form in which it is responsible for the Laboratories' contributions to the field of telephone systems.

Since 1928 his title has been Director of Systems Development. While, as that title indicates, Mr. Dixon's activities have increasingly become those of the organizer and leader, he still retains the interest in creative engineering which has placed his name on sixty-seven patents.

PUBLICATION

John Mills and W. C. F. Farnell visited the Century of Progress, Chicago, to confer on plans for the proposed Bell System exhibit at the 1933 World's Fair.

A demonstration of the characteristics of speech and music was given at Rochester by L. S. O'Roark in connection with Dr. Jewett's talk.

P. B. Findley described Western Electric airplane radio equipment before members of the Princeton Club of New York on March 22. By means of an airplane receiving set the audience listened to the beacon signals and weather reports.

On March 25, Mr. Findley addressed the Science Forum of the Unitarian Church of Flushing, on "Sound Pictures in Education." A number of the educational films prepared by E. R. P. I. were shown with one of the recently developed 16 mm. sound picture projectors.

RESEARCH

Transmission Instruments

Equipment for the demonstration of vertical recording at a talk given by J. E. Otterson, president of ERPI at Hotel Astor was set up by D. G. Blattner, H. B. Ely, W. Kalin and T. C. Sedgwick. The occasion was a luncheon held by the New York Electrical Association. The richer tonality and increased volume of the new recording were compared with tones from phonographs of 1918 and 1925. Mr. Blattner was also at Rochester during the month for a similar demonstration given in conjunction with Dr. Jewett's talk.

W. C. Jones and L. W. Giles visited Hawthorne for conferences on transmitters and receivers. With N. Blount Mr. Jones also visited Washington where they discussed with Naval engineers problems concerning telephone equipment for the U. S. Navy.

An address *The Recording and Reproduction of Sound* was given by H. A. Frederick before the Morris County Engineers at Mountain Lakes.

Chemical Laboratories

Accompanied by H. H. Glenn of the Apparatus Development Department, C. S. Fuller visited the Northern Electric Company's plant at Montreal in connection with development of enameled wire.

Improved apparatus for micro-electroanalysis is described by B. L. Clarke and H. W. Hermance in the Journal of the American Chemical Society for March.

S. O. Morgan and A. H. White have an article *The Dielectric Constant and Power Factor of Rosin Oil and Ethyl Abietate* in the March Journal of the Franklin Institute.

Electro-Optical Research

H. E. Ives spoke on *Pictures in Relief* before the Physics Club at the University of Pennsylvania.

Transmission Research

S. A. Schelkunoff visited Massachusetts Institute of Technology to inspect the differential analyzer developed by Vice President Bush of the M. I. T. faculty. Mr. Schelkunoff has an article *Complex Numbers in Elementary Mathematics* in School Science and Mathematics for March.

Acoustical Research

Acoustic tests in the Academy of Music in Philadelphia have been made by H. Fletcher, J. C. Steinberg, W. B. Snow, A. R. Soffel and K. E. Hammer.

Radio and Vacuum Tube

In the Faraday Society Transactions, Volume 28, there is an article *The Use of Thermionics in the Study of Adsorption of Vapours and Gases* by J. A. Becker which is contributed as part of a symposium on the adsorption of gases by solids.

T. R. Griffith of the Tube Shop completed twenty years of service on April 29.

A PAPER describing experimental studies of the virtual heights of the Kenelly-Heaviside layer, by J. P. Schafer and W. M. Goodall of the Deal Laboratory, was presented at the annual convention of the Institute of Radio Engineers at Pittsburgh.

INSPECTION ENGINEERING

ON APRIL 9, W. A. Shewhart sailed for London, England, where on May 3, 5, and 6 he will deliver by invitation of the University of London a course of three lectures on *The Rôle of Statistical Method in Industrial Standardization*. While abroad, Dr. Shewhart will confer with some of the leading authorities in the fields of statistics, economics, and standardization both in England and on the Continent. He has recently been elected a Fellow in the Royal Statistical Society of Great Britain.

S. H. ANDERSON visited East Pittsburgh in connection with a quality survey on rectifiers and engines at the plant of the Westinghouse Electric and Manufacturing Company.

R. M. MOODY, in company with A. J. Boesch, Field Engineer, Philadelphia, was at Richmond, in connection with an engineering complaint on step-by-step relays.

L. G. HOYT visited the warehouse of Electrical Research Products Incorporated, Chicago, on current problems.

G. GARBACZ, Field Engineer, Los Angeles, visited Anaheim and Fontana, California, on field engineering work. H. W. Nylund, Field Engineer, San Francisco, made similar trips to Seattle and Portland.

A QUALITY survey on 600-A Transmitters was attended by L. G. Hoyt and P. H. Betts at Hawthorne.

H. F. DODGE gave a short discussion on *Use of Graphical Charts in Controlling Quality of Manufactured Products* before a meeting of the Management Division of the American Society of Mechanical Engineers held at the Engineering Societies Building in New York on April 6.

H. F. KORTHEUER's career in the Bell System passed the thirty-five year mark on April 6. Part of this time was spent in Europe where he was a member of the Commission which made the preliminary survey for the Paris to Strasbourg toll cable, one of the first in Europe to be equipped with telephone repeaters. He performed a similar service in 1920 in connection with the Stockholm-Gothenburg cable in Sweden. Following the survey for the Swedish cable he was in both London and Stockholm as equipment engineer of the project during the manufacture of the repeaters and associated equipment and during their subsequent installation.

H. F. Kortheuer

Mr. Kortheuer also supervised the manufacture of repeaters after the completion of the first transcontinental line when there arose a demand for repeaters in other long toll lines. At that time the Hawthorne plant was not in a position to manufacture repeaters so they were made by Engineering Department in New York, about 500 being manufactured under Mr. Kortheuer's direction. At about this time he was also associated with carrier development program, then in its early stages.

Following his activities in Europe which extended from 1919 to 1923 he became a member of the Inspection Engineering Department where he has since worked on surveys of Inspection Methods and Quality of Manual and Toll Equipment.

APPARATUS DEVELOPMENT

Special Products Design

T. E. Shea was in Washington to make preliminary arrangements for the S. M. P. E. convention to be held there in May. He also visited the Bureau of Standards, and Commerce and Navy Departments while in Washington.

Radio Development

Accompanied by E. W. Thurston of the Western Electric Company and O. E. Richardson of the Graybar Electric Company, F. W. Cunningham visited Station WAPI at Birmingham, Alabama.

J. C. Herber inspected the 1-kw radio telephone broadcasting equipment at station WISN owned by the Evening Wisconsin Company at Milwaukee. He also inspected the 50-kw radio telephone broadcasting equipment recently installed for the Columbia Broadcasting System at Wayne, New Jersey.

A survey for the installation of a 100-watt radio transmitting equipment and associated speech input equipment for the Independence Broadcasting Company, station WHAT, at Philadelphia was made by F. H. McIntosh.

O. W. Towner visited Los Angeles to inspect stations KRKD and KFAC owned respectively by Daltons, Incorporated and the Los Angeles Broadcasting Company. He was also at Phoenix, Arizona, to inspect the radio telephone broadcasting equipment owned by the KTAR Broadcasting Company.

The installation of 400-watt radio telephone equipments for the Police Department of New York City at stations WPEE and WPEF located respectively in Brooklyn and the Bronx, were supervised by B. R. Cole and W. P. Fisher. These stations are now in operation in conjunction with Station WPEG, the 1000-watt Western Electric transmitter at the Police Headquarters, New York.

A. R. Brooks addressed the Kiwanis Club of Bloomfield on recent developments in airplane radio. Captain Brooks, accompanied by R. J. Zilch, recently flew to Hartford, where the motors of the Ford plane were overhauled at the Pratt & Whitney factory.

A. F. Dolan, of the Whippany Laboratory, in his capacity as Hanover Township committeeman, made the first call through the new common battery switchboard recently cut over at Whippany.

At Somerville, Massachusetts, F. H. McIntosh supervised the installation and test of a 400-watt radio telephone transmitter for the Police Department. Eighteen automobiles and two traffic posts are equipped with receivers. One of the latter effected the capture of counterfeiters, three minutes after they had dashed from a store where the spurious bill had been detected. About forty "alarms" are sent out by radio, many of them having been received over the police teletypewriter network.

Sound Picture Laboratory

J. Crabtree and W. Herriott visited the Eastman Kodak Company and the Bausch & Lomb Optical Company in Rochester to confer on problems associated with the recording of sound on film.

F. L. Hunt was at the Bureau of Standards in Washington.

Transmission Apparatus

W. J. Shackelton went to the Bureau of Standards in Washington in connection with the determination of new and more precise values for international standards in electrical units.

Problems concerned with the line assembly of loading coil cases required C. R. Young's presence in Hawthorne.

E. B. Wood inspected some special cable butts in the toll office in Chicago and then went to Hawthorne to discuss distributing rings and the tinning of copper wire.

Materials

Meetings of A.S.T.M. committees held in New York, were attended by H. N. Van Deusen, J. M. Wilson, W. A. Evans, W. W. Werring, R. Burns, J. J. Martin, K. G. Coutlee, J. D. Cummings, I. L. Hopkins, and J. H. Cox.

J. R. Townsend attended a meeting of the Special Research Committee on

Mechanical Springs of the American Society of Mechanical Engineers, of which he is chairman, held at the Society's Headquarters in New York.

H. N. Van Deusen and J. M. Wilson visited the Western Electric Company at Hawthorne in connection with phenol fibre problems.

H. L. Coyne was also at Hawthorne on corrosion studies of wound apparatus. Mr. Coyne and C. W. Bowler visited the 13th Street Exchange in connection with this work.

F. F. Lucas spoke on high power photomicrography, both with visible and ultra-violet light, in an address before the District of Columbia branch of the Sigma Xi at Washington.

Manual Apparatus

In connection with the development of a new jack and jack-panel for use with a combined test and cable terminal, J. F. Baldwin and P. Neill visited the trial of cable carrier equipment which is being conducted by the Laboratories in the New Jersey Bell Telephone Company office at Morristown.

H. T. Martin visited Hawthorne for discussion of new types of telephone sets and telephone station appliances. On April 22 Mr. Martin completed twenty years in the Bell System.

Forty-one members of Mr. Martin's organization held a dinner and sociable evening at the Elks' Club in Union City, New Jersey. After dinner, bowling and other games were enjoyed for the remainder of the evening. The affair was in charge of a committee consisting of S. T. Curran, R. W. Davis, D. H. King, F. Lohmeyer, W. J. Means and J. M. Peabody.

F. R. McMurry visited the Teletype Corporation in Chicago for a discussion of development problems on printing telegraph apparatus.

Dial Apparatus

H. F. Dobbin visited Hawthorne for conferences on new dial developments.

C. I. Baker was twenty years a member of the Bell System on April 1.

M. E. Seager rounded out twenty years in the Bell System on April 22.

SYSTEMS DEVELOPMENT

Equipment Development

In an engineering advisory capacity J. R. Stone attended the installation in Louisville of centrifugal exhausters for pneumatic tube systems in the new toll office.

J. H. Sole visited Lynn and Boston in connection with the development of improved voltage regulators.

Toll Development

Tests on teletypewriter switching developments were conducted by A. B. Dickinson and R. A. Vander Lippe in Atlantic City.

R. L. Case, G. C. Crawford and M. R. Kleist were at Princeton to observe the operation of the return loss measuring equipment which is being used there in connection with the B-88 cable circuit trial.

R. A. Brader spent a week in Pittsburgh, observing the performance of a new remotely-controlled test panel for testing and adjusting toll-line signalling circuits.

H. I. Romnes in Chicago, initiated a series of tests on the stability of long toll cable circuits.

Local Central Office

The thirtieth service anniversary of J. A. Frey occurred on April 27. He is in

J. A. Frey

charge of the power supply for the Local Systems laboratory.

His first work with the Western Electric Company was in the cable department where he worked nearly four years. He was engaged in switchboard installation for more than ten years, working chiefly in the New England Territory for the Western Electric Company. He came to the Engineering Department to perform layout work on high frequency bridges.

In 1922 he transferred to the Local Systems laboratory where he was largely engaged in wiring circuits of new or changed design for engineer's test. Lately Mr. Frey has taken over charge of power supply for the wiring laboratory.

J. L. Dow completed twenty-five years with the Western Electric Company and

J. L. Dow

Laboratories on April 28. As Laboratories Engineer for the Local Systems Department he is in charge of laboratory analysis and testing, of the determination and compiling of apparatus requirements for central-office maintenance, and of compilation of Bell System practices. He was graduated from Kansas State Agricultural College in 1906 (B.E.) and started on the student course at Clinton Street, Chicago, shortly thereafter.

After being successively associated with the equipment engineering on central office apparatus, non-associate sales engineering, and returning to equipment engineering, he came to New York in 1916. He worked on the development of manual circuits until 1919 when he was assigned to panel dial system development. Soon afterward he was placed in charge of the testing of step-by-step circuits and later panel circuits.

Mr. Dow became Laboratories Engineer in 1921. The Laboratory group of which he is in charge analyzes from the standpoints of manufacture, installation and operation, all circuits and systems, proposed by the Local Systems circuit design group and tests out these circuits under the most stringent conditions of actual operation.

In 1913 E. H. Clark, at that time an equipment engineer at Hawthorne, came to New York to work on the development of circuits for machine switching. The next year he took part in testing the first semi-mechanical installation in Newark. When the plans for the Metropolitan toll semi-mechanical tandem office were projected, he was assigned to the development of circuits and had a prominent part in the ultimate circuit design for that office which was cut into service in 1920. Associated closely with this project was the development of circuits for the relay call-indicator and later the key-indicator circuit, with both of which he was closely

E. H. Clark

identified. This work stands out prominently in Mr. Clark's career in the Bell System which reached the twenty-five year mark on April 1.

On the Metropolitan toll project he also had an active part in the design of test circuits for senders. During the war period he spent some time in Pittsburgh expediting the completion of much needed equipment. He has 46 patents to his credit, mostly related to machine switching systems. At the present time he is a member of the Fundamental Development group.

FORTY YEARS of service in the Bell System were completed by E. R. Lundius on April 1.

Mr. Lundius is supervisor of one of the groups handling Manual Development

E. R. Lundius

work. Extensive experience with several operating companies as well as nearly a score of years devoted to engineering activities ably fit him for this work. He worked as cable tester with the former New York and New Jersey Telephone Company and on switchboard maintenance for the New York Telephone Company. In 1905 he became division wire chief in the San Joaquin division of the Sunset Telephone and Telegraph Company. Later he was wire chief of the Inland Division of the Pacific Telephone and Telegraph Company and Equipment Superintendent in Portland, Oregon and Seattle.

In 1914 Mr. Lundius returned east to the Engineering Department of the New York Telephone Company. The following year he became associated with the then Engineering Department of the Western Electric Company and since has been chiefly occupied with Manual Systems engineering.

ON THE OCCASION of W. L. Dodge's twenty-fifth anniversary in the Bell

W. L. Dodge

System, a biographical note in the RECORD for November, 1931, concluded with the hope that he might be restored to health and soon rejoin his associates in the Laboratories. The hope was not to be realized; Mr. Dodge's vitality slowly ebbed and his death occurred on April 7. Sincere regret at the passing of a friend is mingled with gratification that he was permitted to see the successful outcome of so many of the projects to which he contributed in the field of circuit development for dial systems.

COMMERCIAL SERVICE

COMMERCIAL SERVICE Manager K. B. Doherty completed his twenty-fifth year in the Bell System on April 1.

On entering the employ of the Western Electric Company he worked on Material Inspection and slightly more than a year later he went to the Records Division where he helped to institute the first engineering filing system. For a number of years he was associated on special work with the late E. B. Craft and during the war period he was at New London on production work for the submarine detection program on which the Western Electric Company was concentrating a large part of its energies at that time.

Following the war he was given charge of the Central Office Files and later the

K. B. Doherty

Office Service work including mails, telegraph and messengers was added to his supervision. In 1926 he assumed his present duties as Commercial Service Manager in charge of commercial activities associated with engineering projects.

PATENT

In connection with various patent duties during the month E. W. Adams visited Atlanta, Richmond and Washington; T. P. Neville was in Washington; and A. G. Kingman was in St. Louis, Indianapolis, Kansas City and Chicago. Mr. Kingman also attended a hearing before the Examiner of Interferences in Washington.

At a patent Department luncheon during March, H. A. Burgess spoke on new developments in carrier transmission.

J. J. Hart was admitted to the New York State bar on March 3.

PLANT SHOPS

On April 10, Otto F. Vollheim of the Development Shop completed his thirtieth

Otto F. Vollheim

year in the Bell System. For the Western Electric Company Mr. Vollheim worked on the assembly of relay coils and the inspection of deskstands. In 1914 in the Model Shop he assembled coils and later transferred to work on the heat treating of steel. Recently he has been placed in charge of the work of impregnating coils in the Development Shop.

Mountings, Connectors, and Amplifier for Moving-Coil Microphone

By B. LEUVELINK
Special Products Design

WITH the advent of broadcasting and sound pictures, a need arose for a microphone of high efficiency and good response. It was met by the condenser microphone which for a number of years has been used with success. Because of its high impedance, however, the condenser microphone required an amplifier very close to its terminals. Although the amplifier designed, already described in the RECORD*, was of very small dimensions, it was large enough with the microphone, to be not entirely satisfactory for certain sound picture uses. Development work was undertaken, therefore, to secure a microphone which, by not requiring an amplifier immediately adjacent to it, would be smaller and more readily handled.

As a result of this work a sensitive,

*BELL LABORATORIES RECORD, *June*, 1928, *p.* 324.

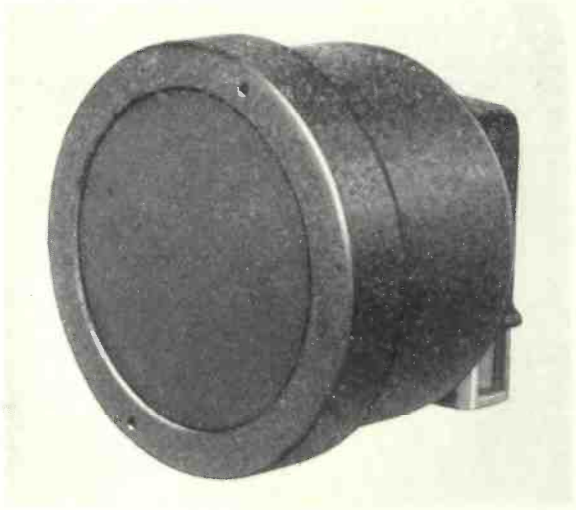


Fig. 1—*The new moving coil microphone, known as the* 618-*A, is only some three inches in diameter*

high-quality microphone of the moving-coil type has been developed and is now available for use. As already pointed out in the Record,* its impedance is low enough so that its amplifier may be located at some distance from it. This leaves only the microphone itself which, with its small diameter, permits a maximum of concealment in sound-picture sets.

Since the new microphone may be used for broadcasting and public address, as well as for sound-pictures, a variety of mountings had to be provided. In motion picture studios the microphone is usually suspended from an adjustable boom and for this purpose a suspension mounting was designed. A simple ring-clamp holds the microphone firmly in place and permits it to be raised or lowered to the desired position by the boom. The clamping ring is supported by trunnions so that the face of the microphone may be tilted to any vertical angle desired, and by rotating the support on the shaft of the suspension eye any desired horizontal angle is readily obtained.

For broadcasting and public-address systems it is ordinarily required that stands for either floor or table mounting be supplied. The accompanying photographs show the apparatus provided. In both of these stands the clamping ring is attached to the upper end of a short shaft that slides into the top of the stand. These upper sections, or heads, are alike for both types of stand: a feature which is expected to be desirable since it permits quickly transferring a microphone from one type of stand to the other. In neither of the mountings is provision made for tilting the microphone. Although the suspension mounting is intended primarily for

Fig. 2—*Stands have been provided for both floor and table mounting. R. L. Hanson is demonstrating the equipment in the Sound Picture Laboratory*

*Bell Laboratories Record, *p.* 319.

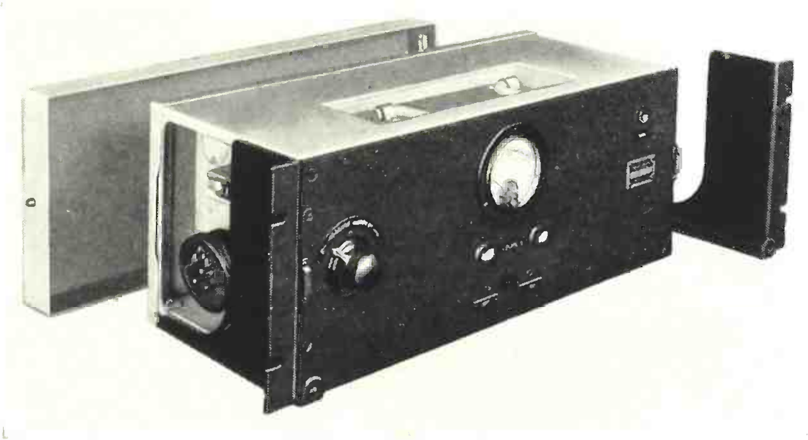


Fig. 4—The amplifier, but seven inches high, may be either mounted on a rack or used as portable equipment

sound-picture work and the other two supports for broadcasting and public address, any of the forms provided may be employed wherever they seem most suitable.

Because of the low operating level of the circuit, which under extreme conditions may be in the neighborhood of -90 db, and of the low impedance of the instrument, a very high grade contact is necessary at the detachable connection between the microphone and the amplifier. To provide it, a special plug and jack were developed. Three contacts are required so that the plug is equipped with three flat prongs, each of which fits between double clips in the jack. Positive contact is obtained by applying heavy pressure through a cam lever on one side which fits snugly along the side of the plug in the closed position. The construction is shown in Figure 3. One of the jacks is arranged for fitting directly on the back of the microphone and a plug is mounted on the amplifier designed for use with the microphone. A cord with a jack on one end and a plug on the other is used as the connecting link.

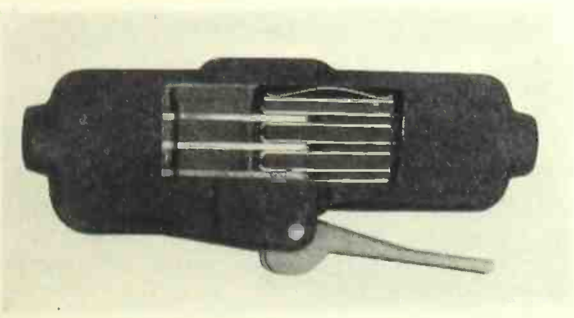


Fig. 3—An important accessory of the new microphone is a plug and jack in which the contact pressures are high

The amplifier, shown in the accompanying photograph, was designed principally to permit field trials of the new microphone under sound-recording and broadcasting conditions. Although the amplifier was proposed primarily as a portable unit, brackets have been provided which allow it to be mounted on a rack where that method is preferable. Under these conditions it is held in place by only two screws so that it may quickly be removed and carried to other locations for temporary use. A back cover permits ready access to the interior of the amplifier and a front cover is provided for protection when the amplifier is being carried. A handle used for carrying the amplifier drops below the top of the box when not in use. This permits the amplifiers, when mounted on a rack, to be placed one above another with a minimum of space. In addition to the jack for the connection from the microphone, the amplifier is provided with a six-conductor plug for the power and speech output circuit. Soldering terminals are also provided for use when the amplifier is permanently mounted on a rack.

Two stages of resistance-coupled amplification are provided. A six or twelve volt battery is required for the filament, and a 135 or 200 volt battery for the plate supply. The amplifier has a gain of 45 db and is intended to work from an impedance of 25 ohms into either a 50 or 200 ohm balanced circuit.

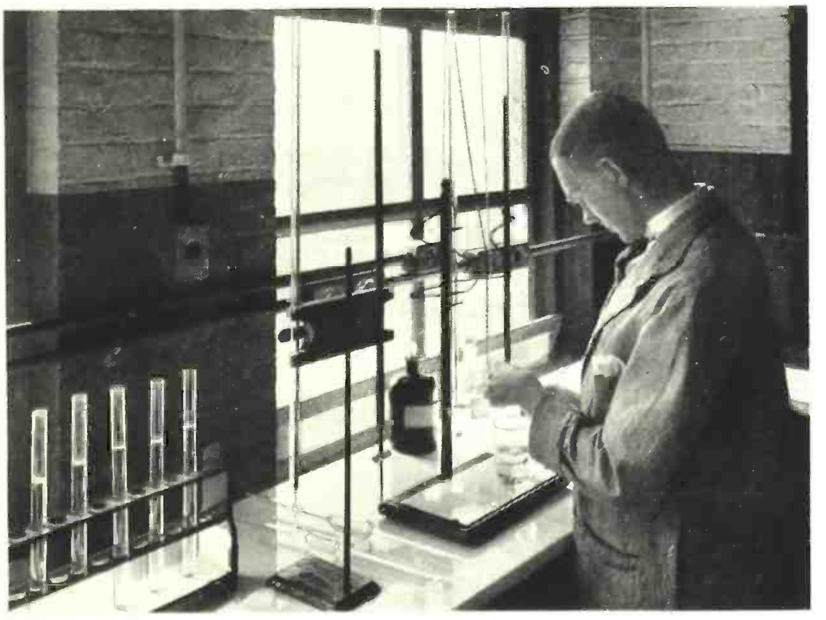
This new microphone with its high quality and small size, and with its variety of interchangeable mountings should prove a valuable adjunct to sound picture studios. For all broadcasting and public address purposes its advantages in size and quality would seem to predict a widespread use.

The Patent System

"Thanks to the workings of the patent system, there has been placed in the hands of our people, during this past century and a half, a vast array of new tools. For the most part labor saving in character, these tools have enabled a new and relatively sparse population to subdue and develop a wilderness and at the same time to do it under conditions which have raised the average standards of living and enjoyment of life to heights far beyond anything theretofore conceived possible or elsewhere obtained. That we have not always in the past and are not now utilizing the things of our creation to the maximum advantage of the people in the matter of greatest happiness, contentment or release from drudgery, is no basis for valid criticism against the patent system or its continued maintenance. Rather, it is an indictment of our rate of progress as human beings in our social and political relations as regards the elements of greed and avarice, of lust for power, and of a just regard for the common decencies of living together.

"In this respect our urgent problems of the present and the future are not concerned with stopping or diminishing the flow of new things into the current of life's activities, but are rather the problems of finding the best way of utilizing these things and of distributing the benefits of that use to the best advantage of all our citizens. To me the idea that there should be a holiday in scientific research, in the quest for new and useful applications of science, or a weakening of the forces such as those which result from the urge of our patent system, as many now urge, is an abhorrent thought. Instead I would seek to stimulate increase of activity, since to me there is nothing repugnant in the idea of a goal which has for its aim the minimum of human drudgery and the maximum of human enjoyment in living. To me the great problems ahead are the problems of so distributing the benefits of our human ingenuity and of so educating people in the profitable use of these benefits and of the time salvaged from the mere daily operation of securing food, shelter and raiment, that the sum total of our effort will be a happier world for our descendants than the one we now know."

—From an address by Dr. Jewett at a dinner celebrating the opening of the new United States Patent Office.



The Service of Analytical Chemistry to Research

By B. L. CLARKE
Chemical Research

A SAMPLE of a supposedly novel and useful product was recently submitted to the Analytical Division of the Chemical Department for their opinion as to its value. It is common for new commercial materials to pass under the hopeful scrutiny of the Laboratories, and nearly always a chemical analysis is the first step taken. After careful examination the analyst reported that the material, far from being a new discovery of extraordinary properties, was in fact an exceptionally low grade product, not only greatly inferior to that in use by the Bell System but possessing strong potentialities of hazard. Analysis revealed a chemical composition failing entirely to confirm the extravagant claims made for it. Thus it came about that a relatively simple chemical analysis saved the System the bother and expense of elaborate service tests.

While such clear-cut instances are not frequent, it is nevertheless true that analytical chemistry is indispensable to research and engineering in its continual checking of the compositions of materials. For composition is an important factor in determining performance, and satisfactory performance is the goal of all our efforts. As the number of different materials in the telephone plant is enormous, so also is the diversity of types of determination the Analytical Division is called upon to perform. There are few things one could mention that have not been submitted, at one time or another, to these Laboratories' analysts. The following list, selected at random, is illustrative of this diversity, though far from exhaustive:

alloys of every type, oils and waxes, phenol plastics, textiles and paper, paints and varnishes, atmospheric dust and gases, adhesives, acetone-air mixtures, corrosion products, water, soaps, woods, milk, ink.

The importance of accurate chemical analysis to research will be manifest to the thoughtful engineer. The composition of a material is like the finger-print of a man: a nearly infallible means of identification and classification. Chemical constitution offers the most practicable means of correlating new knowledge of the performance of materials with previously discovered knowledge.

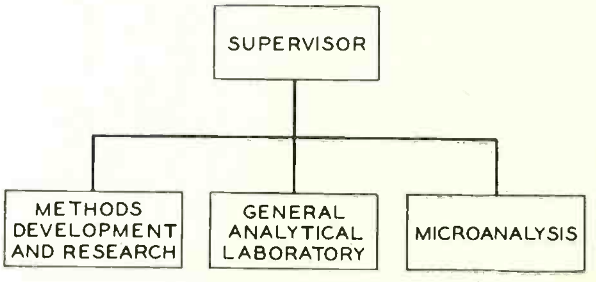


Fig. 1—The organization of the Analytical Chemical group

A magnetic alloy of definite electrical specification is required, for example. The engineer refers to a graph showing the desired properties plotted against composition—the concise summary of, it may be, years of research. He selects the suitable composition and has his alloy made up by the metallurgists. At every point here *composition* is the medium, the universal language, that links the several steps of the project and makes possible their synthesis and successful culmination. Without a knowledge of the composition of magnetic alloys, this almost routine project would become a research of major proportions.

Adequate recognition of the important rôle played by analytical chemistry in industrial research has not always been accorded. Neither has it been universally realized that the technical skill required for the proper performance of any save the most perfunctory of analytical operations is comparable with that required elsewhere in research. Laboratories otherwise soundly conceived sometimes use an analytical method discarded by analytical specialists a decade ago; and entrust to an inexperienced laboratory assistant an analysis that may be the most momentous step in a research expensively prosecuted by doctors of philosophy. Where research on new analytical methods has been unavoidable these specialists in other fields have been compelled to undertake it, resulting always in costly detours from their main interest and often in the publication of analytical methods inexpertly devised.

If the analyst has suffered thereby from loss of dignity, research itself has been equally the sufferer from loss in efficiency. It is seldom indeed that when a new material, such as an alloy hitherto unknown, is submitted for analysis, a method can be found in the literature that is applicable without modification. As the divergencies from standard compositions in new materials developed by research may vary from slight to profound, so varies the investigatory skill required of the analyst who is called upon to adapt or develop his methods. The expert and versatile master of modern analytical chemistry unquestionably deserves a status parallel with that of other research workers.

In the modern science of analytical chemistry are properly included not only the classical separations and systematic analyses familiar to most from undergraduate years, but also many novel methods which utilize tools un-

Fig. 2—The General Analytical Laboratory performs those analyses which do not require extensive use of special methods

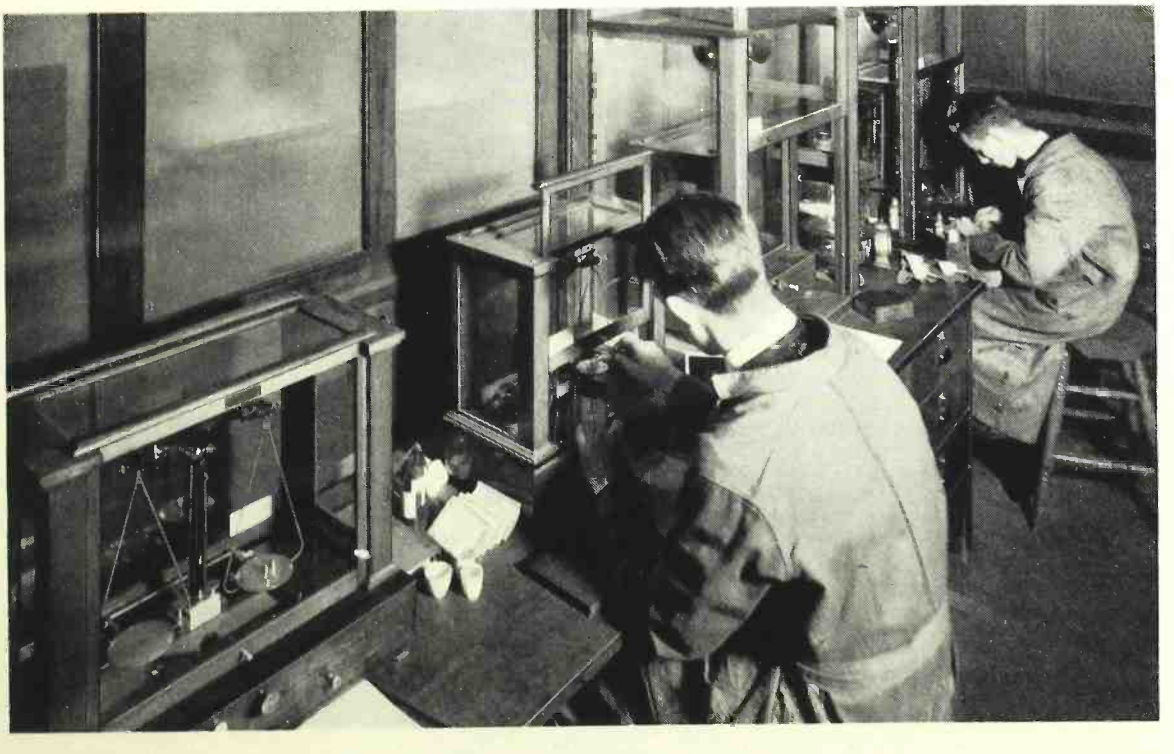


Fig. 3—The balance is an indispensable adjunct to much quantitative analysis

known or unperfected in the days of the pioneers. Microanalysis, for example, reduces the scale of all operations and strives to extract from a minute sample the largest possible amount of analytical information. Electrometric analysis applies electrochemistry in various ways to analytical problems. Spectrometry determines small traces of impurities by measuring the intensities of their spectra. Polarimetry permits the accurate determination of a class of organic substances whose solutions rotate the plane of polarized light. Nephelometry measures the turbidity of a liquid caused by suspended particles of other substances. In an up-to-date analytical organization there must be, in addition to skilled "old line" analysts, experts in the technique and theory of all these newer methods and of many others.

The Chemical Department for several years past has been making intensive efforts to increase the efficiency of its Analytical Division so that analytical chemistry might perform its full service to research. The analytical unit in a research organization functions at maximum efficiency only when it is able to carry out all required analyses with the desired precisions at the maximum speed. Continually closer approach to this ideal is the prime objective of the Chemical Department.

There are, however, two supplementary objectives which are important: performance of fundamental research in analytical chemistry; and acting as a liaison agency for assisting groups outside the Chemical Department, and therefore presumably without detailed chemical knowledge, to make contacts conducing to the efficient service of chemistry to general research in communication. This latter function is based on the conviction that many entirely unneces-

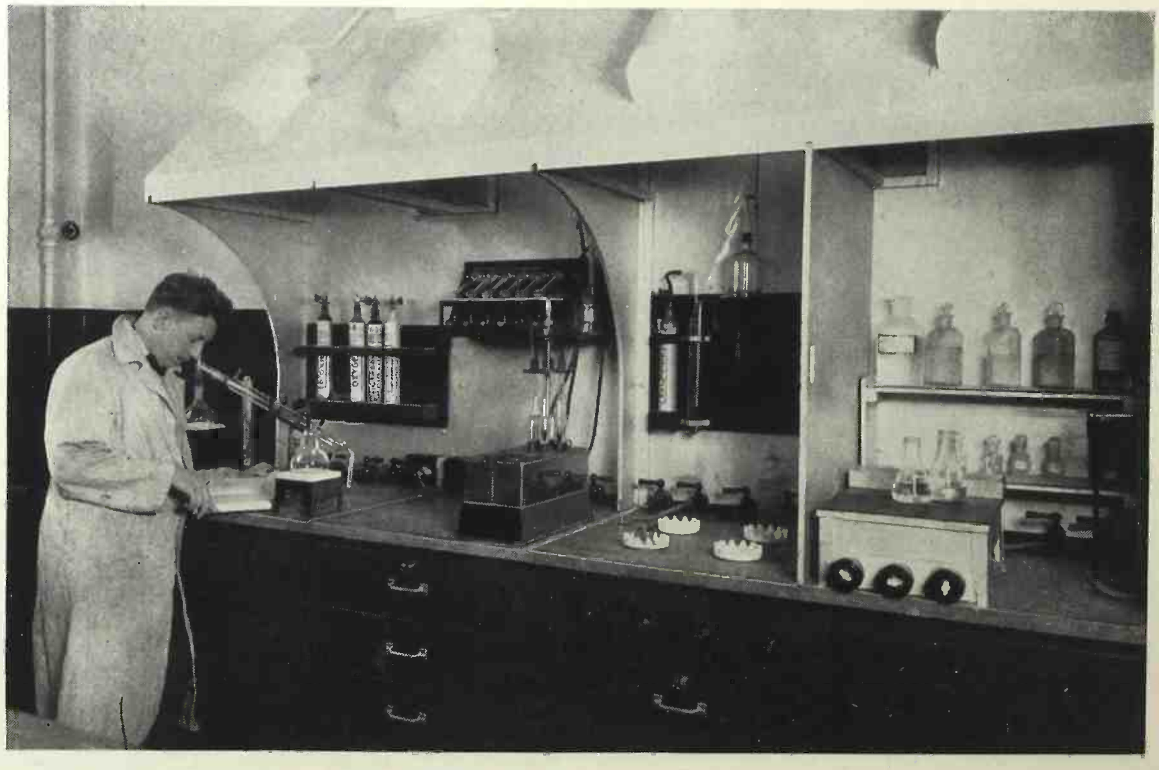
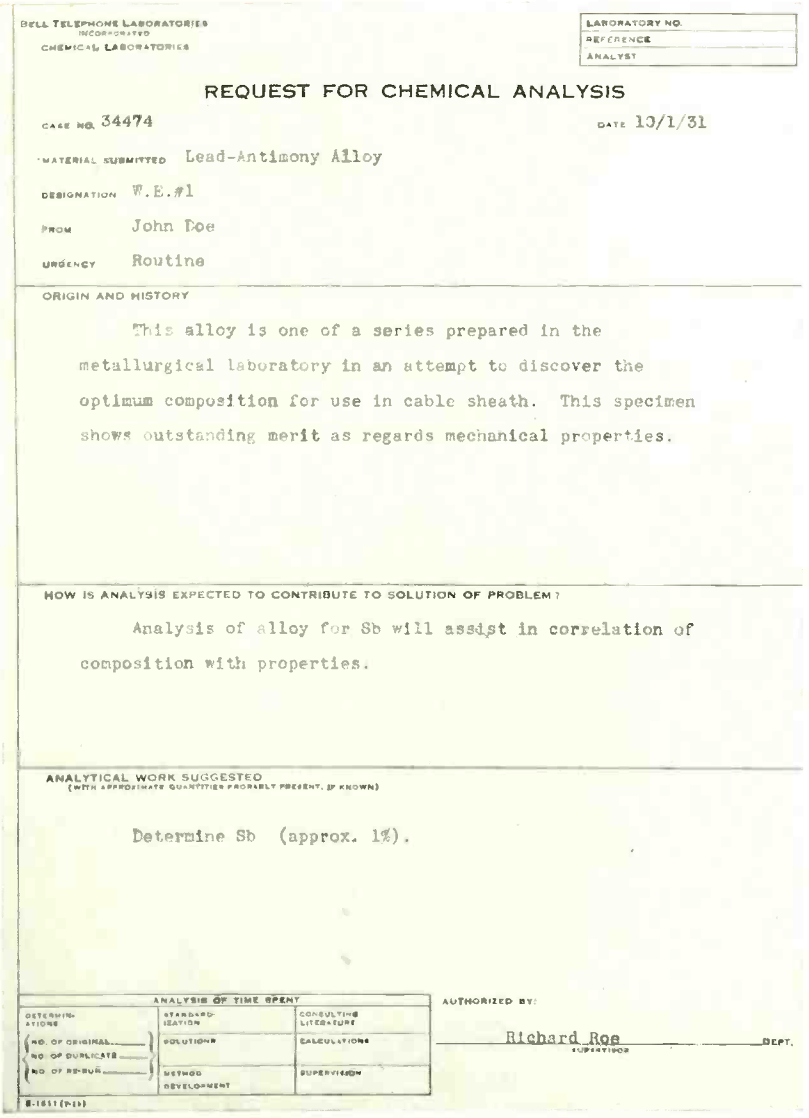


Fig. 4—A corner of the microanalytic laboratory

sary analyses are performed when an analytical division conceives itself as merely an uncritical service unit. Our Analytical Division, therefore, welcomes opportunities for consultation with engineers who wish analytical work performed but are not certain exactly what should be done. In reporting the results of analytical work, it also attempts to assist the engineer in the interpretation of these data in the light of his peculiar problem.

The work in fundamental research which our Analytical Division carries out is justified for two reasons. It is frequently necessary in order to perform a requested analysis to develop a suitable method. Usually a comparatively slight modification of an existing method is all that is required, but occasionally months of research are called for. Furthermore it sometimes comes about that, when a method has been worked out for a specific purpose, it is possible by relatively slight extension of effort to collect data of more general significance. To neglect these opportunities would constitute failure to acknowledge the general responsibility for the advancement of fundamental scientific knowledge.


BELL TELEPHONE LABORATORIES
INCORPORATED
CHEMICAL LABORATORIES

LABORATORY NO.
REFERENCE
ANALYST

REQUEST FOR CHEMICAL ANALYSIS

CASE NO. 34474 DATE 10/1/31

MATERIAL SUBMITTED Lead-Antimony Alloy

DESIGNATION W.E.#1

FROM John Doe

URGENCY Routine

ORIGIN AND HISTORY

This alloy is one of a series prepared in the metallurgical laboratory in an attempt to discover the optimum composition for use in cable sheath. This specimen shows outstanding merit as regards mechanical properties.

HOW IS ANALYSIS EXPECTED TO CONTRIBUTE TO SOLUTION OF PROBLEM?

Analysis of alloy for Sb will assist in correlation of composition with properties.

ANALYTICAL WORK SUGGESTED
(WITH APPROXIMATE QUANTITIES PROBABLY PRESENT, IF KNOWN)

Determine Sb (approx. 1%).

ANALYSIS OF TIME SPENT

DETERMINATIONS	STANDARDIZATION	CONSULTING LITERATURE
NO. OF ORIGINAL; NO. OF DUPLICATE; NO. OF RE-RUN	SOLUTIONS	CALCULATIONS
	METHOD DEVELOPMENT	SUPERVISION

AUTHORIZED BY:

Richard Roe
SUPERVISOR
DEPT.

E-1611 (P-13)

Fig. 5—The Request for Chemical Analysis is the formal basis on which analytical work is undertaken

The organization of the Analytical Division is outlined in Figure 1. The central unit is obviously the General Laboratory, wherein are carried out the majority of requested analyses. The main function of the Methods Development and Research group is to supply the General Laboratory with suitable methods for the work they are called upon to perform. The Microchemical group handles problems in which the sample available is too small for macrochemical attack. This work is highly specialized in both technique and apparatus. It has been our experience that many of the special laboratory techniques devel-

Fig. 6—Electrometric methods of analysis are coming into increasing use

oped for microanalysis can be advantageously applied to macroanalysis. It happens sometimes also that, even where a large sample is available, the microchemical approach is more efficient. This group is therefore charged with the additional duty of surveying the methods used in the general laboratory with a view towards incorporating into them any microchemical principles that will increase their speed or permit a closer approach to the desired precision.

It is hoped in the early future to organize a fourth group with the title "Photometric Analysis." Under this head can logically be included all methods for determining composition—except direct visual observation—that utilize radiation as a tool. Further classification might be made on the basis of the particular portion of the radiation spectrum employed. Practically, however, ordinary and X-ray spectrometry comprise the full application that has been made of radiation to analytical chemistry.

It will be instructive to follow through an analytical examination from the origin of the request to the final report. An engineer interested in cable sheath finds that a new alloy has unusual mechanical properties. Hoping that a knowledge of composition will aid him in explaining this observation, he prepares a "Request for Chemical Analysis." This is a blank form which when properly filled out will not only give sufficient information to enable the analyst to make the actual analysis intelligently but will also give him some knowledge of the general research problem in which his work plays a part. This latter is necessary if the analyst is to be expected to regard his work as anything more than routine. The Request, together with the sample, is sent to the supervisor of the Analytical Division who decides whether the determination can be immediately performed by the General Laboratory or the Microchemical group, or whether development of methods is first required. When the sample and Request reach the analyst who is to do the work, he is given a copy of the proper method, which he adapts to the problem in hand. At the conclusion of the work he writes out his report from which is prepared the formal "Report of Analytical Laboratory" for the engineer making the Request.

TENTATIVE
ANALYTICAL PROCEDURE
BELL TELEPHONE LABORATORIES
INCORPORATED

SUBJECT Analysis of Sb-Pb Cable Sheath (The Determination of Antimony)

PROCEDURE NO. 200139
ISSUE NO. 1
DATE April 9, 1931

APPLICABILITY OF METHOD
Routine Procedure for the Rapid Determination of Antimony in Lead Antimony Alloys, Containing approx., 1% Antimony.
Precision, ± 0.02% Sb.

PROPOSED BY L.A.W.
EXPERIMENTAL WORK BY E.G.M.
WRITTEN BY E.G.M.
APPROVED BY B.L.C.

REFERENCES
Shaw, Whittemore and Westby - Anal. Ed. - Ind. & Eng. Chem. - Vol. 1, 402 (1930)
T.M. 200140
Memorandum: Case 34474 - 323-E.G.M. 4/15/31

Under a hood, heat 30 cc. of concentrated sulphuric acid and 4.0 grams of fused potassium bisulphate in a 500 cc. Erlenmeyer flask until a temperature of 320°C. (approximately) is reached. Continue heating at this temperature for five minutes. Without removing the, etc., etc., ----

Fig. 7—A complete description of the method to be pursued is furnished the analyst for each analysis he undertakes

This Report gives a sufficiently detailed summary of the analytical data together with a statement of the precisions of these data. The Report also has a space headed "Conclusions and Recommendations" in which is given any supplementary information believed to be helpful to the engineer.

Copies of the Tentative and Standard Analytical Procedures are available to any interested engineer. The preparation of these methods is the special duty of the Methods Development and Research group. Every effort is made to make them complete, concise and unambiguous. Full statements are given of any limitations in the applicability of each method and of the precisions attainable. These precisions are arrived at by the Research group, who make a sufficiently large number of determinations on identical samples to permit the application of statistical analysis to the data. If, for example, the determination of antimony in standard cable sheath is stated to have a precision of ±0.02%, this statement means that on the average an antimony determination will have this degree of certainty.

It means this, however, only provided the analyst always carries out the manipulations with care and skill. Since carrying out the frequently intricate operations of chemical analysis with consistent care and skill requires ability of a high order, the staff of the General Analytical Laboratory must clearly be as alert and proficient as in the more definitely research divisions of the Chemical Department. Theirs is a considerable responsibility; for there are few places where mistakes can be more costly than in an analytical laboratory.

A Portable Sound Meter

By T. G. CASTNER
Transmission Research

ALTHOUGH the seriousness of room noise in its effect on telephone service has long been recognized, it is only in the last few years that there has been a strong public interest in the reduction of noise in general. In studies both of the methods of noise reduction, and of the effects of noise on people—such as interference with hearing, annoyance, and influence on working efficiency and health—measurements of the amount of noise are highly important. Apparatus for such measurements was accordingly developed by the Laboratories. Employing an indicating meter to obtain the advantage of a visual reading, it measures noise and sound in general, and has thus been called a sound meter. The appearance of the sound meter, which is arranged in two boxes, is shown by the photograph at the head of this article, and a simplified schematic showing the relation of the principal elements, is given in Figure 1.

Measurements of sound are made difficult by the complex relationship existing between the sensation known as sound and its physical cause—pressure variations in the air. The sound meter is designed to receive these pressure variations or waves, amplify them electrically, and evaluate the characteristics of the corresponding electrical wave, including its frequency composition, intensity, and duration, so as to produce a measure of the sound.

An electrodynamic transmitter, used as the sound pick-up, converts the sound into electrical energy of the same frequency composition. A five-stage amplifier with a calibrated gain control is employed to raise the energy level received from the sound pick-up sufficiently to give a meter reading at the lowest sound level for which the meter is designed. Between the third and fourth stages of the amplifier is inserted the network used for weighting energies at different frequencies approximately according to their relative contribution to loudness, so that the indication of the meter will correspond, in general, to what is heard by the average ear, and not merely to the physical energy content in the sound. A rectifier converts the amplified and weighted energy into direct current for operating the indicating meter.

Present data indicates that the ear is most sensitive to sound at a frequency in the neighborhood of 2,000 cycles; at either higher or lower frequencies greater intensities are required to produce the same loudness. Due in some measure to the way we hear, this increase in intensity is different for each loudness level, and experimental curves, showing the relative increase in intensity for frequencies below 2,000 cycles at four different loudness levels, are given in Figure 2. Zero loudness level for the purpose of this work is taken as the

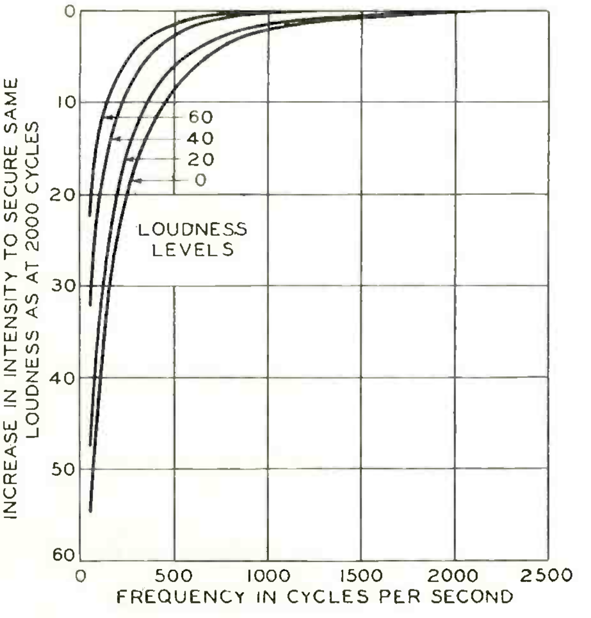


Fig. 2—To produce the same loudness, sound must be increased in pressure intensity as the frequency falls below 2,000 cycles. The relationship at four loudness levels is shown above. Levels are expressed in db

threshold of audibility at 1,000 cycles, and other levels are given in decibels above this level—the level in db being ten times the common logarithm of the ratio of the intensity at the level taken to that at zero level.

An inspection of the curves of Figure 2 shows that only at the lower frequencies are there large differences between the various curves. It seemed preferable, therefore, rather than to com-

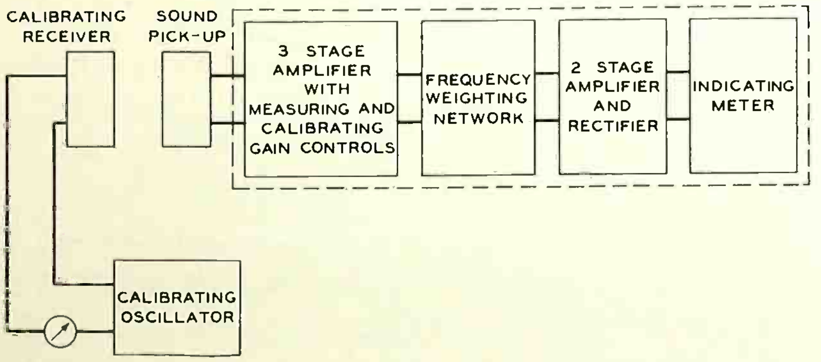


Fig. 1—An oscillator and receiver, used for calibration, form part of the equipment of the sound meter

plicate the design and use of the meter by employing a network adjustable for loudness, to select some one of the curves of Figure 2 as a basis for the design of the weighting network. That for 40 db loudness seemed to be the one that would be

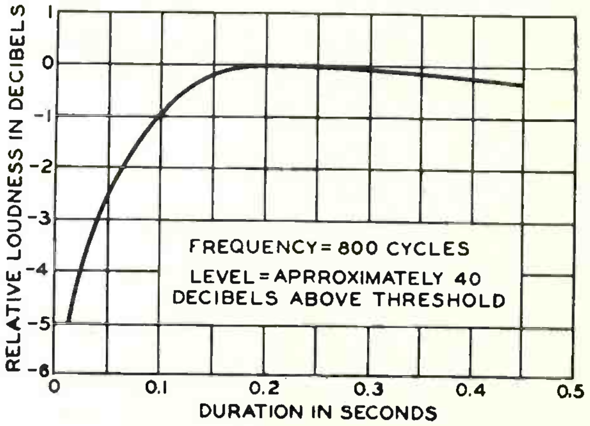


Fig. 3—Response of the ear to sounds of short duration

most useful for general sound measuring work. The network was designed, therefore, to attenuate the received frequencies in a manner complementary to the 40 db curve of Figure 2. Loudness data is not at present available for frequencies above 4,000 cycles so that for this range the threshold of audibility for the average ear was used as a basis for the weighting curve.

After the complex wave has been weighted by the network, it is rectified so that the combined effect of the various component frequencies is indicated by the meter. Each component frequency, of course, has its own loudness level but the ear does not recognize these various separate levels but rather a single level in which the various components are combined in a complex manner. The full-wave rectifier employed, of the copper oxide type, is a square-law rectifier which provides the best approximation to the performance of the ear in combining different frequency components that can be obtained in a simple and portable device. The best available information on the response of the ear to sounds of short duration indicates that the ear fully appreciates the loudness of a tone lasting two-tenths of a second or more. Loudness of tones of shorter duration is a function of the time during which the tone persists as shown in Figure 3. The indicating meter selected, therefore, is one that gives a full deflection for sounds lasting longer than about two-tenths of a second. It has a long, easily readable scale calibrated over a range of twelve db. The total noise level is the

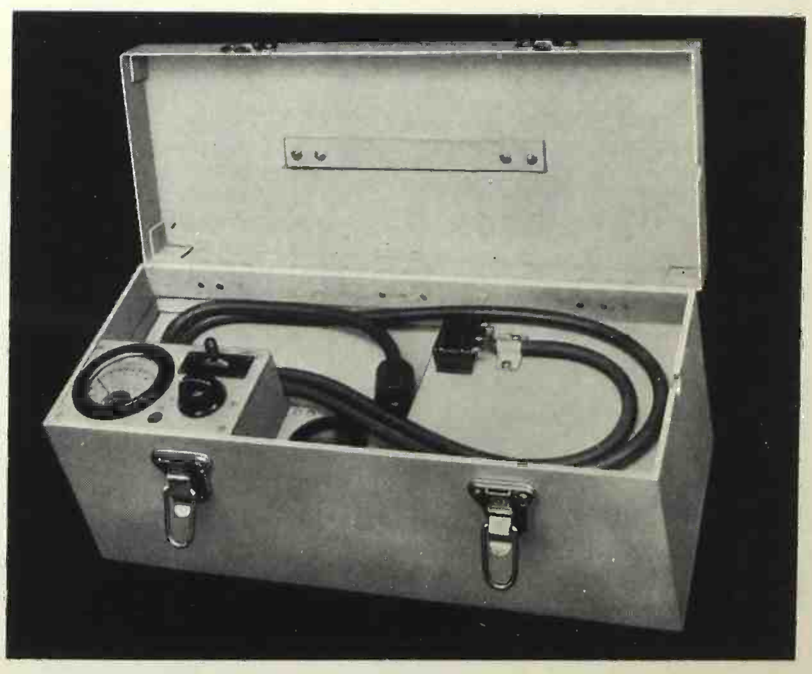


Fig. 4—The battery box includes the calibrating equipment, and has room for carrying the sound pick-up

reading on the gain-control dial of the amplifier plus the indication of the meter. The gain-control dial is calibrated in 5 db steps and in use is adjusted so that the variations in sound may be read on the meter.

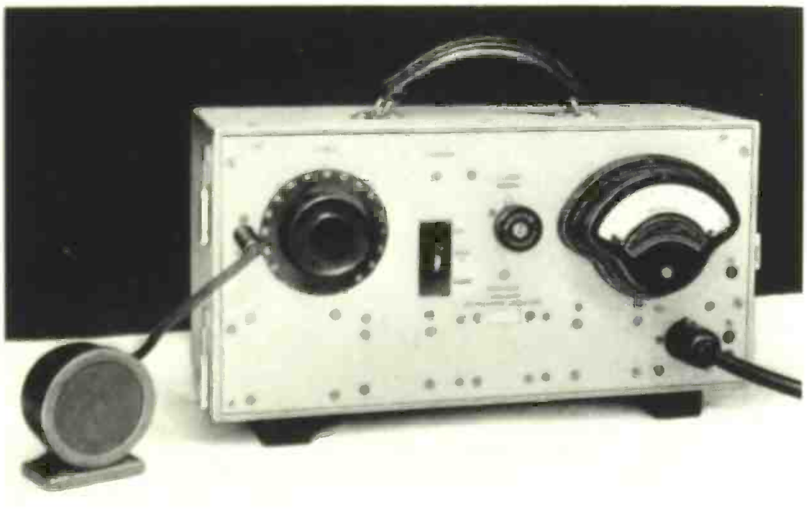


Fig. 5—An experimental model of the new sound meter. Each of the two units weighs about 35 lbs. so that the complete unit is readily portable

The sound meter is calibrated to read in db above a reference level which is defined as a pressure of .001 dyne per square centimeter of a free progressive wave at 1,000 cycles. Chosen because it is definite and easily reproducible by purely physical measurements, this reference level is approximately 10 db above the threshold of audibility for the average observer. This primary calibration is made by placing the sound pick-up in a free progressive wave of 1,000 cycles at a point at which the pressure has been determined from measurements with a search tube condenser transmitter previously calibrated by comparison with a Rayleigh disk. By a calibrating control on the amplifier, adjustable with a screwdriver so as not to be disturbed in use, the gain is set so as to make the meter read the level of the 1,000 cycle wave in db above the reference level.

The range of the meter is from about 10 to 100 db above reference sound level. Sound levels less than 10 db are rarely found except in very quiet residences or in sound-proof rooms, and levels greater than 100 db are almost painful. This 90 db range, however, requires a high gain amplifier. This high gain together with the use of low-power tubes—necessary because they must operate on dry cells—has required a number of precautions in the design of the amplifier. To make the sound meter read differences in level correctly, overloading of the vacuum tubes, and feed-back between parts of the circuit had to be made negligible. Sufficient shielding had to be used to make the effects of commonly encountered electro-magnetic and electrostatic fields of no importance. Cushion mountings were used for both the vacuum tube sockets and for the amplifier as a whole to eliminate microphonic pick-up.

Although the sound meter amplifier is very stable electrically, it was thought desirable to include as part of the associated equipment, a means of making an overall acoustic calibration in the field so that there will be no doubt that the meter is operating properly. The apparatus for this secondary calibration consists of a stable type of telephone receiver, a small 1,000 cycle oscillator for energizing the receiver with a known current, and a means of coupling the receiver to the sound pick-up in order to produce a definite acoustic pressure on the pick-up. A small milliammeter mounted in the battery box is used for measuring the current applied to the receiver, and by means of a key may also be used to check the "B" battery voltage. The arrangement of the battery box is shown in Figure 4.

Before calibration, the filament current of the amplifier must be adjusted to the normal value. A filament rheostat is provided on the front of the sound meter panel, evident in Figure 5, and the output meter may be used to measure the filament current by the operation of a key. The shunt associated with this meter is designed so that with normal filament current a mid-scale reading is obtained. When the battery voltages are within their normal limits calibration once a day is sufficient for most work.

Experimental models of the sound meter have been available for only about a year but already a number of important uses for the meter have been found. In the Laboratories, measurements of room noise in offices and shops, noise produced by the operation of machine switching dials and by ventilating fans for telephone booths have been made. The meter has been a valuable aid in setting up artificial room noises to simulate room noise encountered in typical telephone locations, and has been used for measurements on telephone bells and other signalling devices.

Outside the Laboratories the sound meter has been extensively used in measurements of street noise, room noise in telephone operating rooms, and noise due to various types of machinery. It has also been of service in determining the suitability of different types of warning signals in the presence of various amounts of background noise. The sound meter has also been employed extensively by the Acoustic Consulting Department of Electrical Research Products, Inc. for determining the distribution of sound energy throughout large rooms such as theatres and lecture halls; in setting up optimum sound levels in recording and broadcasting work; in determining the value of sound insulating and sound absorbing materials for reducing noise; and in the control of uniformity of manufactured products for which quietness is important.

Contributors to This Issue

J. R. Townsend joined the Engineering Department of the Western Electric Company in 1919. He was first concerned with the testing of telephone apparatus, but later he specialized in the development of testing methods and requirements for the materials which composed the apparatus. To further this work, he and the organization of which he is in charge have built up a remarkably complete laboratory and technique for the testing of materials. Last year the American Society for Testing Materials awarded the Dudley Medal to him, jointly with W. A. Straw of Western Electric and C. H. Davis of the American Brass Company, for their article, "Physical Properties and Methods of Test for Some Sheet Non-ferrous Metals," published in the proceedings of the A.S.T.M.

J. R. Townsend

After receiving the degree of B.S. in Chemistry from George Washington University in 1921, B. L. Clarke spent a year of graduate study at the Nobel Institute in Stockholm, Sweden. In 1923 he received the M.A. degree from Columbia University, and the following year the Ph.D. degree, instructing meanwhile in chemistry at the College of the City of New York. After a year as a Research Fellow at the Carnegie Institute of Washington, and a like period as a National Research Fellow in Chemistry at Stanford University, he joined the Chemical Research Department of these Laboratories in 1927. During his first two years here he worked on the nature and prevention of the corrosion of lead cable sheath by the fumes from wooden cable duct. Since 1929 he has had charge of the analytical and lubrication groups.

B. Leuvelink became a member of the Engineering Department of the Western Electric Company in 1918. After three years in the Drafting Division he was assigned to the specifications

B. L. Clarke

B. Leuvelink

H. C. Montgomery

plicate the design and use of the meter by employing a network adjustable for loudness, to select some one of the curves of Figure 2 as a basis for the design of the weighting network. That for 40 db loudness seemed to be the one that would be

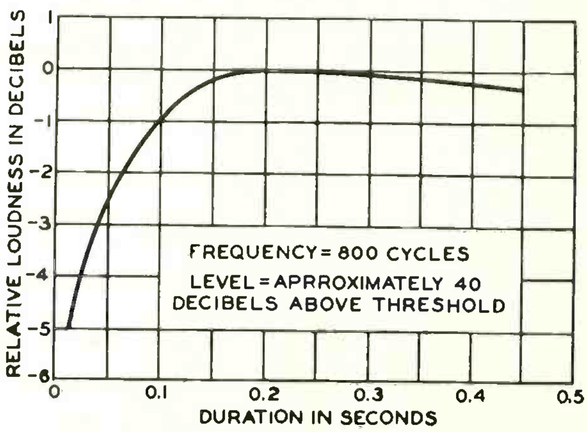


Fig. 3—Response of the ear to sounds of short duration

most useful for general sound measuring work. The network was designed, therefore, to attenuate the received frequencies in a manner complementary to the 40 db curve of Figure 2. Loudness data is not at present available for frequencies above 4,000 cycles so that for this range the threshold of audibility for the average ear was used as a basis for the weighting curve.

After the complex wave has been weighted by the network, it is rectified so that the combined effect of the various component frequencies is indicated by the meter. Each component frequency, of course, has its own loudness level but the ear does not recognize these various separate levels but rather a single level in which the various components are combined in a complex manner. The full-wave rectifier employed, of the copper oxide type, is a square-law rectifier which provides the best approximation to the performance of the ear in combining different frequency components that can be obtained in a simple and portable device. The best available information on the response of the ear to sounds of short duration indicates that the ear fully appreciates the loudness of a tone lasting two-tenths of a second or more. Loudness of tones of shorter duration is a function of the time during which the tone persists as shown in Figure 3. The indicating meter selected, therefore, is one that gives a full deflection for sounds lasting longer than about two-tenths of a second. It has a long, easily readable scale calibrated over a range of twelve db. The total noise level is the

Fig. 4—The battery box includes the calibrating equipment, and has room for carrying the sound pick-up

reading on the gain-control dial of the amplifier plus the indication of the meter. The gain-control dial is calibrated in 5 db steps and in use is adjusted so that the variations in sound may be read on the meter.

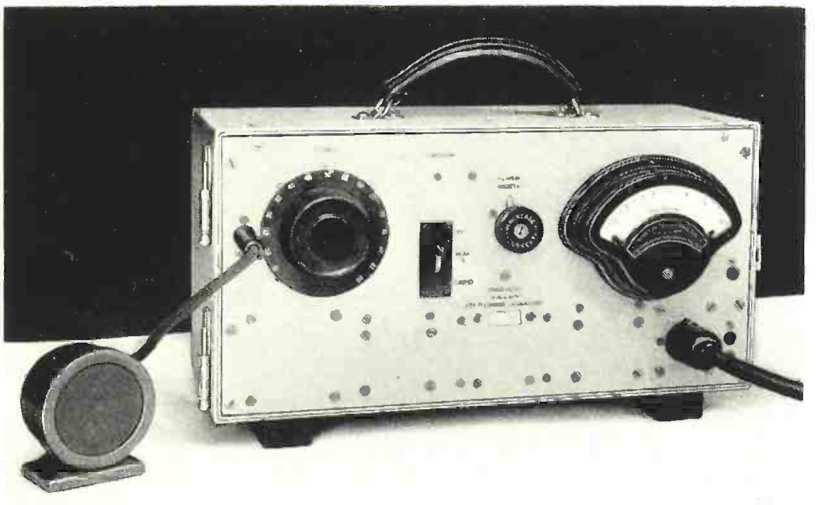


Fig. 5—An experimental model of the new sound meter. Each of the two units weighs about 35 lbs. so that the complete unit is readily portable

The sound meter is calibrated to read in db above a reference level which is defined as a pressure of .001 dyne per square centimeter of a free progressive wave at 1,000 cycles. Chosen because it is definite and easily reproducible by purely physical measurements, this reference level is approximately 10 db above the threshold of audibility for the average observer. This primary calibration is made by placing the sound pick-up in a free progressive wave of 1,000 cycles at a point at which the pressure has been determined from measurements with a search tube condenser transmitter previously calibrated by comparison with a Rayleigh disk. By a calibrating control on the amplifier, adjustable with a screwdriver so as not to be disturbed in use, the gain is set so as to make the meter read the level of the 1,000 cycle wave in db above the reference level.

The range of the meter is from about 10 to 100 db above reference sound level. Sound levels less than 10 db are rarely found except in very quiet residences or in sound-proof rooms, and levels greater than 100 db are almost painful. This 90 db range, however, requires a high gain amplifier. This high gain together with the use of low-power tubes—necessary because they must operate on dry cells—has required a number of precautions in the design of the amplifier. To make the sound meter read differences in level correctly, overloading of the vacuum tubes, and feed-back between parts of the circuit had to be made negligible. Sufficient shielding had to be used to make the effects of commonly encountered electro-magnetic and electrostatic fields of no importance. Cushion mountings were used for both the vacuum tube sockets and for the amplifier as a whole to eliminate microphonic pick-up.

Although the sound meter amplifier is very stable electrically, it was thought desirable to include as part of the associated equipment, a means of making an overall acoustic calibration in the field so that there will be no doubt that the meter is operating properly. The apparatus for this secondary calibration consists of a stable type of telephone receiver, a small 2,000 cycle oscillator for energizing the receiver with a known current, and a means of coupling the receiver to the sound pick-up in order to produce a definite acoustic pressure on the pick-up. A small milliammeter mounted in the battery box is used for measuring the current applied to the receiver, and by means of a key may also be used to check the "B" battery voltage. The arrangement of the battery box is shown in Figure 4.

Before calibration, the filament current of the amplifier must be adjusted to the normal value. A filament rheostat is provided on the front of the sound meter panel, evident in Figure 5, and the output meter may be used to measure the filament current by the operation of a key. The shunt associated with this meter is designed so that with normal filament current a mid-scale reading is obtained. When the battery voltages are within their normal limits calibration once a day is sufficient for most work.

Experimental models of the sound meter have been available for only about a year but already a number of important uses for the meter have been found. In the Laboratories, measurements of room noise in offices and shops, noise produced by the operation of machine switching dials and by ventilating fans for telephone booths have been made. The meter has been a valuable aid in setting up artificial room noises to simulate room noise encountered in typical telephone locations, and has been used for measurements on telephone bells and other signalling devices.

Outside the Laboratories the sound meter has been extensively used in measurements of street noise, room noise in telephone operating rooms, and noise due to various types of machinery. It has also been of service in determining the suitability of different types of warning signals in the presence of various amounts of background noise. The sound meter has also been employed extensively by the Acoustic Consulting Department of Electrical Research Products, Inc. for determining the distribution of sound energy throughout large rooms such as theatres and lecture halls; in setting up optimum sound levels in recording and broadcasting work; in determining the value of sound insulating and sound absorbing materials for reducing noise; and in the control of uniformity of manufactured products for which quietness is important.

Contributors to This Issue

J. R. TOWNSEND joined the Engineering Department of the Western Electric Company in 1919. He was first concerned with the testing of telephone apparatus, but later he specialized in the development of testing methods and requirements for the materials which composed the apparatus. To further this work, he and the organization of which he is in charge have built up a remarkably complete laboratory and technique for the testing of materials. Last year the American Society for Testing Materials awarded the Dudley Medal to him, jointly with W. A. Straw of Western Electric and C. H. Davis of the American Brass Company, for their article, "Physical Properties and Methods of Test for Some Sheet Non-ferrous Metals," published in the proceedings of the A.S.T.M.

J. R. Townsend

After receiving the degree of B.S. in Chemistry from George Washington University in 1921, B. L. CLARKE spent a year of graduate study at the Nobel Institute in Stockholm, Sweden. In 1923 he received the M.A. degree from Columbia University, and the following year the Ph.D. degree, instructing meanwhile in chemistry at the College of the City of New York. After a year as a Research Fellow at the Carnegie Institute of Washington, and a like period as a National Research Fellow in Chemistry at Stanford University, he joined the Chemical Research Department of these Laboratories in 1927. During his first two years here he worked on the nature and prevention of the corrosion of lead cable sheath by the fumes from wooden cable duct. Since 1929 he has had charge of the analytical and lubrication groups.

B. LEUVELINK became a member of the Engineering Department of the Western Electric Company in 1918. After three years in the Drafting Division he was assigned to the specifications

B. L. Clarke

B. Leuvelink

H. C. Montgomery

A. L. Thuras

L. W. Giles

T. G. Castner

group in preparing manufacturing information in specification form. In 1928 he was transferred to the Mechanical Design Division of the Special Products Department, specializing in the design of sound recording, reproducing and public address system equipment.

H. C. MONTGOMERY received the A.B. degree in physics from the University of Southern California in 1929, and joined the Acoustical Research group of these Laboratories shortly afterward. Since then he has been engaged in the development of methods for measuring certain aspects of hearing ability, and in the study of the data which are obtained by these methods.

A. L. THURAS received a B.S. and an E.E. degree in Electrical Engineering from the University of Minnesota in 1912 and 1913 and then joined the staff of the Bureau of Standards in Washington. He served as Scientific Observer on an expedition to Newfoundland and from 1916 to 1920 was Oceanographer for the Coast Guard. This work consisted in the development and use of continuous recording instruments for measuring the temperature, salinity, and density of sea water. Records were made chiefly in the vicinity of the Great Bank of Newfoundland, and were used to locate and study the water movement of the Labrador Current and the Gulf Stream. In 1920 he joined the technical staff of the Laboratories where he has been engaged in the study and development of electro-acoustical instruments.

Before taking the work of his senior year at Worcester Polytechnic Institute, L. W. GILES spent a year at the Laboratories associated with the development of receivers for station use. He then returned to the Institute and after receiving a B.S. degree in Electrical Engineering, in 1925, returned to the Laboratories. Here he engaged in the development of small receivers and earpiece attachments for the audiphone, and of loud speakers for sound-picture systems. In 1928 he was placed in charge of a group responsible for the development of transmission instruments involving a magnetic circuit, and has been concerned with the development of receivers and of microphones for high-quality sound reproduction.

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

AT THE TOP OF THE HILL

A LONE figure in overalls surveys the fields of his labor. Freshly planted rows point their even lines around a gently rising hill. Seemingly the world and its people are far away. But this man is not alone!

His home is at the top of the distant hill. And in his home is a telephone. Eighty-five million miles of wire lead to it. His call is a command to one or more of several hundred thousand employees. Day or night he may call, through the Bell System, any one of nearly twenty million other telephones in this country and an additional twelve million abroad.

And yet, like you, he pays but a small sum for a service that is frequently priceless in value. The presence of the telephone, ready for instant use, costs only a few cents a day. With your telephone, you are never alone. It is an investment in companionship, convenience, and security. Through it you can project your personality to the faraway places of the earth, or bring familiar voices to the friendliness of your fireside.

Undoubtedly a great factor in the continued progress and improvement of telephone service is the intangible but real spirit of service that has become a tradition in the telephone business. This spirit expresses itself daily and in any emergency. And behind the army engaged in giving service is the pioneering help of a regiment of five thousand scientists and technical men, engaged in the sole task of working for improvement. This group devotes itself exclusively to seeking ways and means of making your telephone service constantly better and better.

AMERICAN TELEPHONE AND TELEGRAPH COMPANY