BELL LABORATORIES RECORD

AUDIO-FREQUENCY ATMOSPHERICS
E. T. Burton

CURVED SPACE
S. A. Schelkunoff

TRANSMISSION LOSS THROUGH WALLS
K. D. Swartzel

APRIL 1934 Vol. XII No. 8

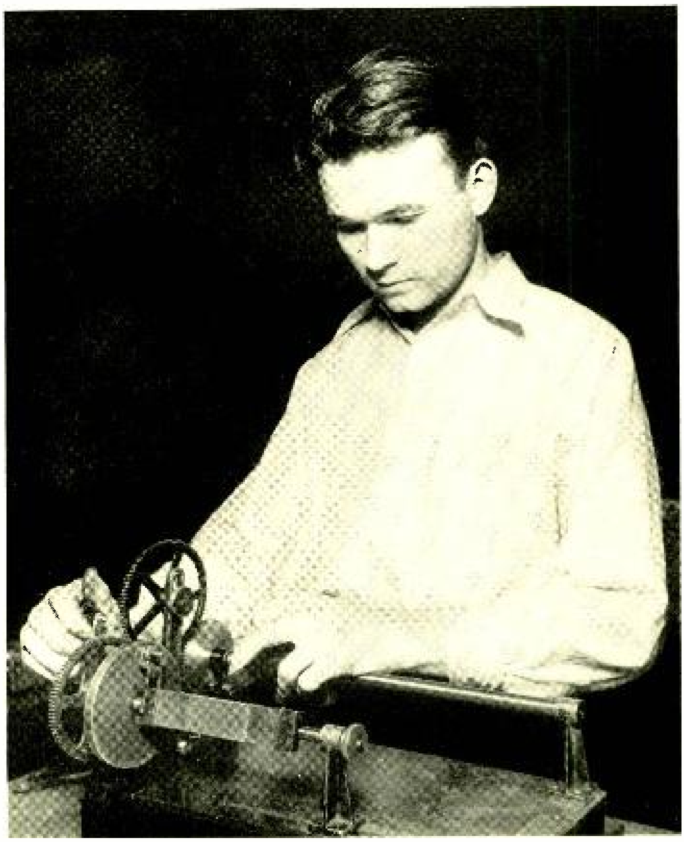
Bell Laboratories Record

Published Monthly by Bell Telephone Laboratories, Inc.

Subscriptions are accepted at $2.00 per year; foreign postage $0.60 extra per year. Subscriptions should be addressed to Bell Laboratories Record, 463 West Street, New York City

In this Issue

BELL LABORATORIES RECORD



VOLUME TWELVE—NUMBER EIGHT

for

APRIL

1934

Audio-Frequency Atmospherics

By E. T. BURTON
Transmission Research

ALTHOUGH it is well known that communication systems may be subject to interruption by intense atmospherics accompanying electrical storms or magnetic disturbances, the existence of appreciable interference from normal fields may not be realized. Systems involving extremely long lines on which signals of good quality are to be received at very low amplitudes must be carefully guarded against undue atmospheric pickup. In certain cases the design of the conductor as well as that of the amplifying apparatus depends in a large measure upon the types of interference normally encountered near the terminals. This is especially true when the transmission systems involve long submarine cables, and are used for telephone communication.

In order to obtain fairly complete data on the effect of audio-frequency atmospherics in shielded and non-shielded conductors, an extensive investigation of audio-frequency atmospherics has been made at several widely separated locations*. Trinity Harbor on the eastern coast of Newfoundland was chosen for the first observation post. Here a series of interference measurements, using an eight-mile submarine cable as the pick-up device, was conducted during the summer of 1929.

**E. M. Boardman, A. B. Newell, and E. W. Waters collaborated with the author in these investigations.*

Fig. 1—One end of Trinity, Newfoundland, where some of the earliest tests on audio-frequency atmospherics were made

An old warehouse, built on a wharf was fitted up as a testing laboratory and a series of day and night observations was established. For a period of some four months experiments were conducted, the serious experimental work being interspersed with trips by motorboat in search of sources of interference and for examination of other harbors. Although all the usual types of industrial interference were observed in small magnitude, the major part was of atmospheric origin.

The usual audio-frequency atmospherics are low in intensity during the day, appearing aurally as subdued rumbling sounds in the lower frequency range accompanied by higher frequencies of crackling or hissing character. During the evening a gradual increase of intensity is usual, accompanied by the appearance of a type of musical atmospheric to which has been applied the onomatopoetic name "tweek". This sound is a short damped oscillation, usually rapidly falling in frequency, which appears to be produced by multiple reflection of of static impulses between the earth's surface and an ionized region of the upper atmosphere. By calculations based on the lowest tones of this type of atmospheric, the effective altitude of the audio-frequency reflecting layer can be determined. At the approach of daybreak, the intensity of atmospherics ordinarily falls rapidly, the tweeks disappear, and a low intensity of other natural interference is reached shortly after sunrise.

Another distinctive type of atmospheric frequently has the character of a varying tone enduring from one to several seconds, often accompanied by a rushing sound. These tones are sometimes likened to thin whips or wires drawn rapidly through the air. The quality of these atmospherics varies from clear whistles to rushing sounds with little or no tonal quality. There is considerable evidence that these sounds, which have been termed "swishes" or "long whistlers", are in some way related to disturbances of the earth's magnetic field.

The second series of observations was made in 1930-31 on the western coast of Ireland. The experiments were conducted at Frenchport, a remote and bleak location, abounding in peat bogs, subjected to rain and fog during the summer and lashed by gales in winter. This location is over forty miles from the nearest railway and is entirely devoid of electrical power. The shore where the little test building was located is rugged, with boulder-heaped beaches, speaking eloquently of the force of storms.

The order of work here followed that in Newfoundland, but was more elaborate in that the frequency range from 40 to 30,000 cycles per second was covered. The interference encountered was similar in character to that at Trinity. The tweeks were somewhat less abundant, and occasional very long and clear whistles of the swish type were observed. Whereas in Newfoundland ascending swishes appeared to be as frequent as those of descending tone, in Ireland the latter type was predominant.

Early in 1931 a study of interference was made on the new telephone cable between Key West and Havana.* These observations, made during the winter, showed the atmospherics at Key West to be of moderate intensity, although the tweeks were more prominent than for the same season in Newfoundland and Ireland. This may be attributed partially to very shallow water in the vicinity of Key West which exposes the cables to atmospher-

*Record, *May*, 1931, *p. 412.*

Fig. 2—Testing station at Frenchport (Portnafrankagh) on the coast of Ireland

ing twilight periods. Variations in the height of the lowest ionized reflecting regions of the atmosphere, for example, may be observed by noting the changes in pitch of the tweeks.

It has long been believed that the sun radiates, in addition to light, rays of particles or corpuscles, and that both light and corpuscles contribute to ionization of the earth's atmosphere. Since the velocity of a corpuscular radiation should be very much lower than that of light, a solar eclipse would cut off the two types of radiation from the earth at different times. The moon, moving through a corpuscular radiation as the time of an eclipse approaches, would produce a trailing corpuscular shadow. The earth in overtaking the moon's visible shadow would enter the corpuscular shadow first. It has been calculated that the interval between the corpuscular and visible eclipses should exceed two hours.

ics, and probably to the proximity of the Caribbean area where electrical disturbances are frequent.

At Havana all atmospheric interference was very weak, since the ocean's depth near that port is sufficient to provide an effective shield for the cable. At both terminals of the Key West-Havana cable, interference from power and from other cables was of appreciable magnitude.

Comparison of the data on audio-frequency atmospherics thus gathered indicates that the northern locations are somewhat quieter than the southern, and that the winter intensity is much lower than that of summer. These observations apply to all atmospherics except swishes, which appear unrelated to seasonal or local meteorological conditions.

Aside from the information pertinent to wire communication systems, the observations of audio-frequency atmospherics have suggested methods by which ionization of the upper atmosphere might be studied. One scheme involves examination of the atmospherics during a solar eclipse in order to discover changes of intensity or quality such as normally occur dur-

In hope of observing the corpuscular and sunlight ionization effect separately, apparatus was set up at Conway, New Hampshire for experiments during the solar eclipse of August 31, 1932. The apparatus, consisting mainly of a large loop aerial, an audio-frequency amplifier, and dynamic-type headsets, possessed an overall characteristic which was practically uniform over the entire voice range.

Preliminary tests disclosed qualities of atmospherics which had not been noticed with the earlier apparatus utilizing the old type of headsets. Experiments several days before the eclipse showed the lower limiting frequencies of the tweeks to progress gradually during the twilight periods, falling during the evening and rising during the morning. Furthermore, during twilight periods a very obscure and nearly continuous tonal quality termed a "weak resonance" appeared in the static. This resonance took the form of a band of frequencies which shifted slowly during twilight as did the tweek tones, but usually was somewhat above the tweek frequencies. During complete darkness the resonance was not observed, possibly because of the prominence of the other forms of atmospherics.

Observations of atmospherics made on August 31 disclosed no effects which could be attributed directly to the eclipse until fifteen minutes before totality when the atmospheric intensity increased approximately five decibels. This level was retained until some twenty minutes after totality. During this period the weak resonance appeared, falling in frequency until five minutes after totality when a rapid rise in frequency began. These tones disappeared about twenty minutes after totality. The observations on resonance tones and on static intensity disclosed definite evidence of considerable sunlight effects upon the location of the audio-frequency reflecting layer, but no effects of corpuscular ionization.

RESEARCH IN SCIENCE CREATES EMPLOYMENT

"*Any claim that current economic distress, with its widespread unemployment, is the result of too much research in science and that there should be a holiday in such research is based on a complete misunderstanding of what fundamental and applied science has done and is doing.*

"*To whatever extent the things of science are involved as primary factors in bringing about the present temporary unemployment, it is the* use *we have made of them rather than the things themselves which are at fault. There is little doubt that our ability to develop proper social controls has lagged behind our ability to utilize things resulting from scientific research. We are now engaged in the painful process of attempting to rectify our past deficiencies. That, however, is no reason for calling a halt on a type of human progress whose history has demonstrated it to be such a powerful tool for enlarged employment and happier conditions of living for a vast population. . .*"

From an address by Dr. Jewett broadcast from the Columbia Studio on the afternoon of February 22, in a symposium on Science Makes More Jobs.

How Sharply Can A Metal Part Be Bent?

By G. R. GOHN
Telephone Apparatus Development

METAL has been termed the backbone of modern civilization. Without its use our present industrial and mechanical advancement would have been impossible. By far the greater proportion by weight of the material entering into the manufacture of the telephone plant, exclusive of buildings, is metal. This metal is used for a large variety of purposes. Most evident, of course, are the copper wires and lead-covered cable used for the transmission of messages. Equally important, however, is the metal used in frameworks which carry telephone apparatus, and in the apparatus itself. In designing such apparatus, space and weight limitations demand the use of parts which are both small in size and light in weight, but which yet possess sufficient strength to insure the proper functioning of the apparatus. In general these requirements are best met by the use of parts made from formed sheet metal, either with punches and dies, by roll forming, or on multi-slide presses. Parts made in this manner are not only lighter than castings, or machined or forged parts, but have the additional advantage of being identical and interchangeable—essential requirements if mass production is to be achieved at a reasonable cost to the ultimate consumer. Such formed parts vary in size from the small terminals, brackets, and springs shown in Figure 1, where the metal may be only five thousandths of an inch thick, to the large loading-

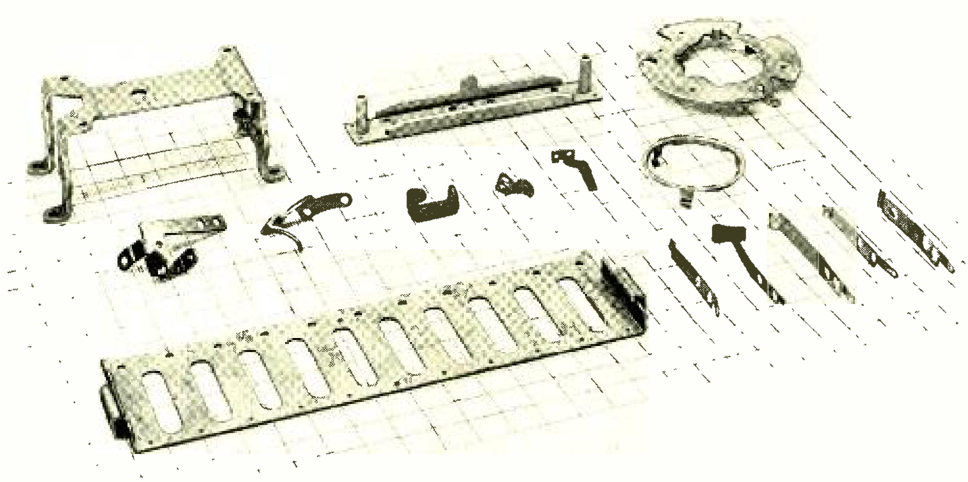


Fig. 1—Some of the smaller "formed" metal parts manufactured by the Western Electric Company, shown on a background of half-inch squares

coil cases of three-eighths inch stock shown in Figure 2. All such formed parts should show smooth unbroken surfaces, free from any marked "orange peel" effect which is so evident in parts which have been bent over too sharp radii.

A variety of ferrous and non-ferrous sheet metals are used; brass, phosphor bronze, and nickel silver being the most widely employed. Usual thicknesses run from five thousandths to one eighth of an inch, although heavier material is used occasionally as with the loading-coil cases already referred to. For any one material different degrees of hardness also are employed, varying from the soft or annealed grades to the extra hard or spring tempers. Since maximum strength is usually required for these parts, the harder tempers are generally employed, and to meet the limitations of space and weight, it is desirable to use as small a radius of bend as can be satisfactorily made with the material employed.

When hard materials are bent around too small a radius, however, they crack, and a weakened part results. Before undertaking the design of formed metal parts, therefore, it is important to know the minimum allowable radii for bends. Unfortunately, little information has been available on this subject, and until recently it was customary to rely on previous experience in specifying the radius to be used. A few years ago, a paper* was presented before the American Institute of Mining and Metallurgical Engineers in which were described tests for determining the minimum satisfactory forming radii for sheet metals of various kinds and thicknesses. These tests had the advantage of being made under conditions similar to those applying to the manufacture of telephone parts.

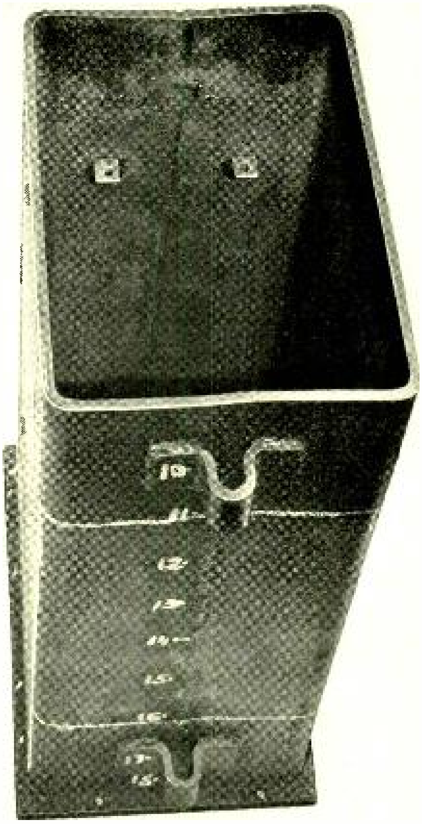


Fig. 2—The "forming" method of construction is employed at times even for metal as thick as three-eighths inch

In forming a right-angle bend in sheet metal, the inner surface is under compression while the outer surface is under tension. As a result there is a tendency for the outer surface to break or crack open if the radius of bend is too sharp. As the radius is made larger, this cracking becomes less pronounced until the outer surface presents an open "orange peel" effect rather than a crack. When the radius is made still larger, the "orange peel"

**Forming Properties of Thin Sheets of Some Non-Ferrous Metals by W. A. Straw, M. D. Helfrick and C. R. Fischrupp, Transactions of the A. I. M. E., Inst. of Metals Division for* 1931, *pp.* 317-328.

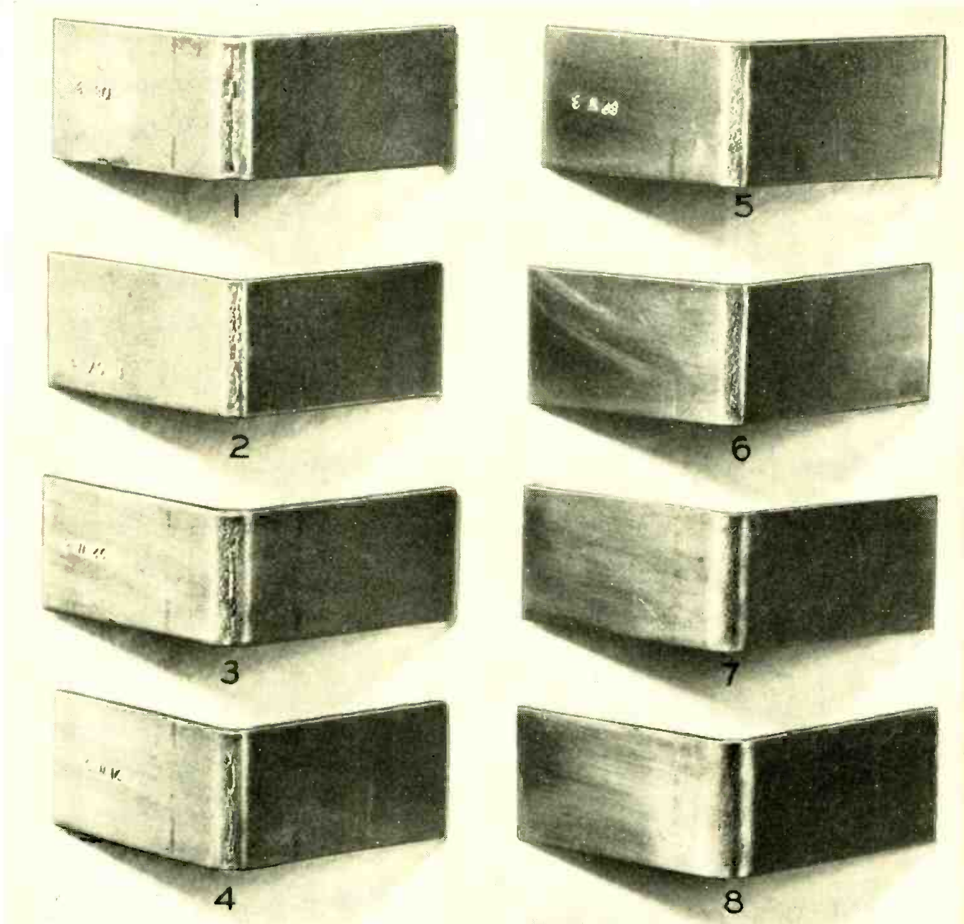


Fig. 3—Effects of bends of various radii on brass sheet

effect becomes finer grained and less open, until with large enough radii no effect is noticeable. A series of bends showing the effects of different radii is given in Figure 3. Here the sample marked 7 is considered satisfactory. Although there is still a slight "orange peel" effect, it is close grained and shows no cracks under microscopic examination.

The method previously referred to for determining the minimum satisfactory radii has since been slightly modified and considerably extended by the Laboratories, and used for determining radii for all design work involving sheet metal. This method was selected after a consideration of other commercial tests because it represented a dynamic forming test which was quite similar to the operations encountered in various manufacturing processes. In this method, the satisfactory radius is determined by inspection of the outer surface of the bend. Samples of sheet metal, about three inches long by three-quarters inch wide, are formed in a punch press (Figure 4) over accurately ground 90° V-shaped forming-punches. Eleven punches are employed: one ground sharp and the others with radii ranging from .0156 inch to .250 inch. The die has a sharp 90° groove as shown in the illustration.

A variety of factors affect the forming properties of metals. The sheet material as supplied by the manufacturer may be either cold rolled or annealed, and the effects of bending differ accordingly. With annealed material, the crystals or grains of metal are equi-axial, and hence the material has no directional properties. With cold rolled material, on the other hand, the crystals are broken up and elongated. As a result the metal has marked directional properties, and the best forming is secured where the bend is perpendicular to the direction of rolling. Because of this, samples for testing are sheared in three different directions: with the long axis parallel, perpendicular, and 45° to the direction of rolling. Other factors such as variations in grain size, composition, and the presence of impurities, affect the bending properties to some extent, but for these tests only thickness, temper, and direction of rolling are considered.

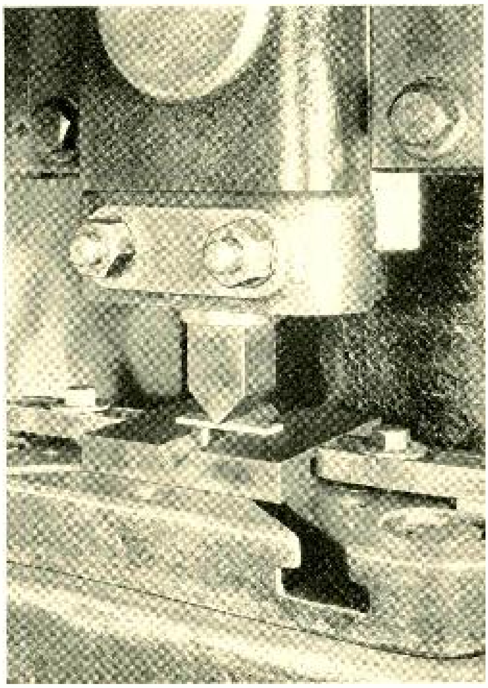


Fig. 4—Samples of metal are formed on a punch press into 90° angles of various radii, and the smallest radius giving a satisfactory bend is determined by inspection

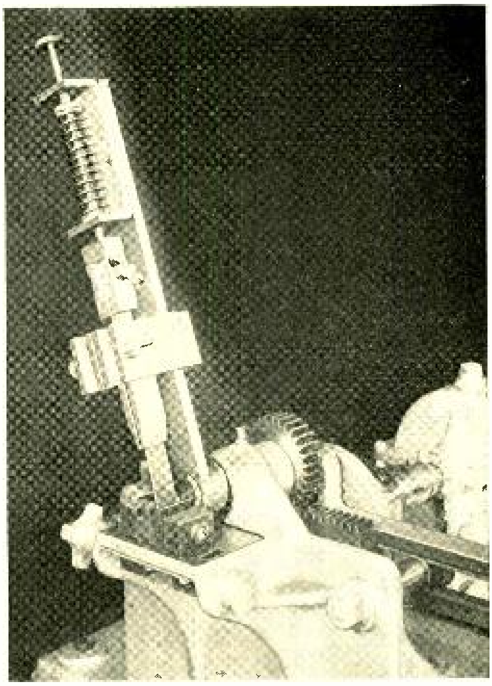


Fig. 5—The Amsler testing machine repeatedly bends a sample at right angles until it breaks

Although this method is very satisfactory in that it gives directly the information desired, it has the disadvantage of introducing a personal element. The minimum satisfactory radius is determined by inspection of a surface, and different people, or the same person at different times, may not always judge alike. Another method of evaluating the forming properties of sheet materials, the Amsler bend-test machine, does not involve a personal element, but on the other

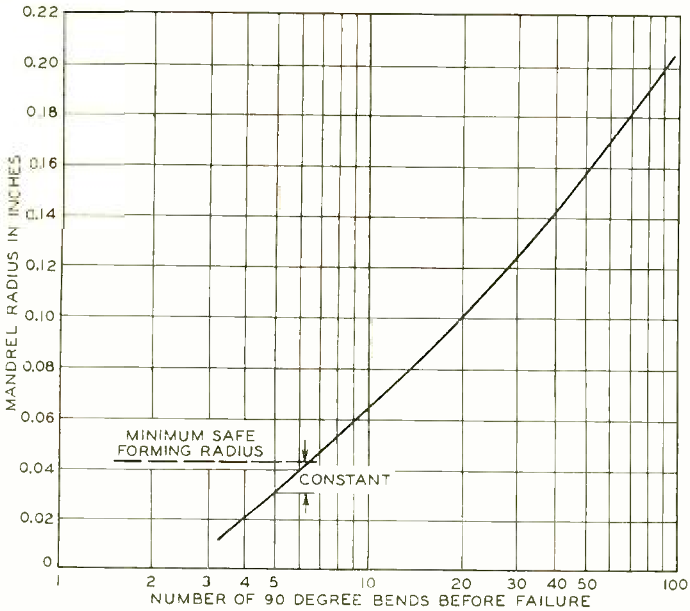


Fig. 6—Plot of radius of bend against number of bends before failure from results obtained with Amsler testing machine (24 B. & S. gauge material)

hand it does not give directly the minimum satisfactory radius of bend. By correlating the results obtained from the two types of tests, however, it has been possible to employ the Amsler test to determine minimum radii directly.

In the Amsler testing machine, shown in Figure 5, specimens are repeatedly bent through an arc of approximately 90° until failure occurs. The bending is done over mandrels of accurately ground radii. By bending several specimens of the same material over mandrels of three different radii, and recording the number of bends before failure of each, a plot may be made (Figure 6) between radius of bend and number of bends before failure. Although such plots have not been made for all thicknesses, for 24 B&S gauge material it has been found that the radius of bend corresponding to five bends before failure on the Amsler machine plus a small constant, gave a satisfactory radius as determined by the forming test. When this relationship is established for all thicknesses, it will be possible to use the Amsler testing machine, which involves no personal element, to determine the minimum satisfactory forming radii for all materials. Thus from the preceding discussion it can be seen that two tests are available for determining the forming properties of sheet metals. The basic test is, of course, the one which employs the 90° V-shaped mandrels since the arbitrary constants necessary for use in applying the Amsler reversed-bend test are determined from the former test. Once these constants are determined, however, any new material may be tested by means of the Amsler test, which is the preferable one since it is free from any personal or observational error.

From the results of such tests, therefore, the minimum safe forming radius may be found for all the commonly used materials and for the various thicknesses and tempers. With this information available it is possible for the designer to specify the proper radii to be used in forming sheet metal parts with assurance that such parts may be satisfactorily fabricated.

Regulation of Central-Office and Tie-Trunk Service in Private Branch Exchanges

By R. W. HARPER
Local Systems Development

IN the larger manual private branch exchanges, it is frequently the practice to identify by colored lamp-caps the lines of those members of the organization whose duties do not regularly require them to use outside telephone service. Internal calls are completed without question, but should an outside telephone number be requested, the PBX attendant will make the connection only in accordance with the rules of the organization. This supervision is even more simply carried out with a small manual PBX, since there the operator knows all the employees and their duties.

In PBX's of the dial type, stations can usually call the central office or the tie trunks directly since an attendant is not needed to establish the connection. For dial PBX's, therefore, some mechanical means have to be provided to prevent the establishment of a direct connection should a restricted station call the central office or a distant PBX. An arrangement must also be made so that an attempt to establish an outside call by a restricted line will not prevent any of the trunks from being selected by stations entitled to outside service. This is accomplished by arranging dial PBX's so that when a restricted station dials, in an attempt to call outside, a busy signal will be returned as a request for disconnection.

Although the method of obtaining this varies for the different types of private branch exchanges, a common principle underlies them all. Trunks to central offices and tie trunks are connected to the bank terminals of one or more levels of the first selectors. The eleventh step of each level is used to return a busy signal to the calling station if all trunks in that level are busy. Arrangements are made, when a restricted line is calling, to move the selector around to the eleventh step, whether or not the trunks are busy. How this is accomplished is shown in Figure 1. When a restricted line calls, a ground is placed on the lead RS. If the selector moves up to the outside trunk level, the contact N is closed and the ground operates the E relay. This relay controls the rotary magnet which steps the brush around to the eleventh position. When this position is reached, contact M is opened. This stops the rotation, and a busy signal is returned to the subscriber.

Initially, line switches were used in

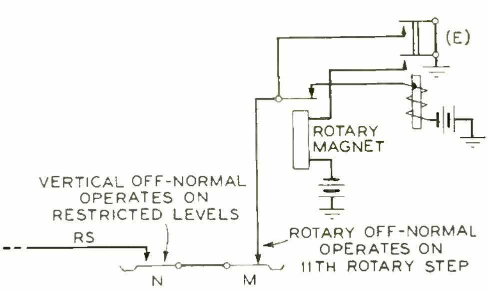


Fig. 1—Restricted service of selectors is obtained by the action of relay E when a ground appears on the RS lead

dial PBX's to establish the connection between the station line and the selector. This mechanism connects four wires: two for talking, one for the sleeve or holding lead, and a fourth or RS lead used for obtaining restricted service. When the receiver at a restricted station is removed from the hook, the line switch plunges in and relays A and B, shown in Figure 2, are operated. Through relay B a ground is placed on the RS lead and provides restricted service at the selector in the manner already described.

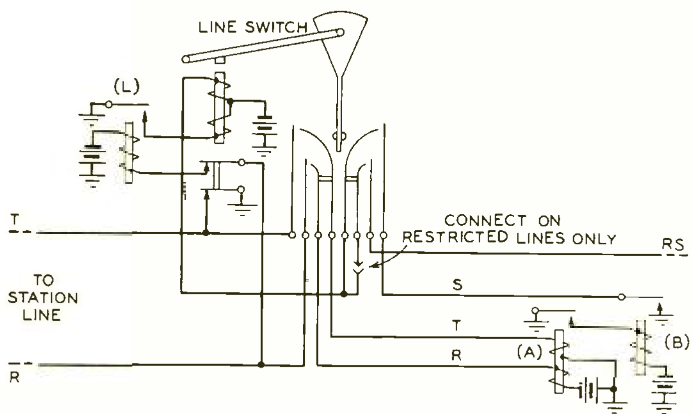


Fig. 2—With private branch exchanges using the line switch a fourth wire is available to serve as the RS lead

In the more modern private branch exchanges of the dial type, line finders are used in place of line switches. These, in the smaller PBX's, are of the 50- or 100-point type which, like the line switches, make connections to four leads. Restricted service is obtained, therefore, as shown in Figure 2 except that the ground connection is made through a line finder instead of a line switch.

Larger PBX's of the new type use 200-point line finders, however, which make connection to only three leads. An arrangement must be provided, therefore, to transmit the restricted service ground to the selector. To accomplish this, one of the talking leads is made to serve a double duty: first to indicate whether or not the line is a restricted one, and —having accomplished this—to act as one of the talking conductors.

In Figure 3 is shown the scheme used. When the receiver is lifted from the hook, the line finder locates the calling line and makes connection to it. If it is a restricted line, a ground is placed on the "tip" lead by the line

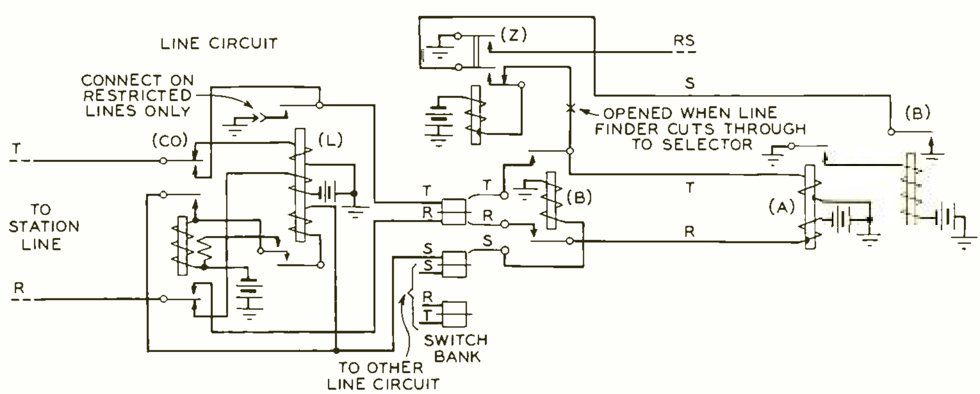


Fig. 3—For larger PBX's using the 200-point line finder, a special arrangement using relay Z is required to obtain restricted service

relay. This ground operates the relay Z which is held operated, and which places a ground on the RS lead to the selector. When the line finder cuts through to the selector, the connection is opened between the Z relay and the "tip" lead which is then free for talking. Ground on the RS lead acts to restrict the service at the selector as with the other systems. In all cases when the line calling is not restricted from outside calls, no ground is placed on the RS lead, and outgoing trunks are selected in the usual way.

By these comparatively simple means the trunks from a PBX to a central office or distant PBX are made directly available only to those who are entitled to use them. Others receive a busy signal if they attempt to call outside, and central-office trunks are kept available for important calls. Provision is made, however, for restricted stations to obtain outside connections for those calls which they should be allowed to make. Instead of dialing, however, they call the operator who in turn completes the connection for them.

DR. K. K. DARROW'S NEW EDITORSHIP

DR. KARL K. DARROW, *Research Physicist, has recently accepted an invitation from the French publishing firm of Hermann et Cie to edit a series of books on a branch of modern physics. He has chosen the field of thermionics and photoelectricity. The firm is already publishing a series for quantum mechanics and modern theoretical physics in general, under the direction of Louis de Broglie; one for radioactivity, transmutation, and nuclear physics under that of Madame Curie; and one for relativity under that of Paul Langevin. The invitation to become "directeur" of such a series is only the most recent of many testimonies to the general recognition of Dr. Darrow's unusual ability in organizing and expounding the theoretical and experimental results achieved by modern physicists. His own writings, especially the books* Contemporary Physics *and* Electrical Phenomena in Gases, *have contributed widely to the general understanding of these results. His most recent published writings are* Electricity Released from Matter, *printed by the Massachusetts Institute of Technology in the book of proceedings of the Elihu Thomson Eightieth Birthday Celebration, held last spring; and* Ions in Dense Gases, *in the March issue of* Electrical Engineering, *which is one of a series of articles appearing there for the benefit of unemployed engineers.*

sizes of drawings used at the Laboratories, much of the work falls within the 18″ x 22″ size, which is the capacity of the photo-copy machine.

The improvement in this method as applied to pencil drawings is clearly shown in Figure 2. At the upper left is an enlarged photograph of an original pencil drawing, and at the upper right and lower left are photographs of tracing reproductions made from the original pencil drawing by the two processes previously referred to, while at the lower right is a photograph of a tracing using a negative made on the new sensitized paper by the photo-copy process, which used reflected light. The great improvement is clearly evident.

Thus it will be seen that it is now possible to dispense with hand-inked work entirely for the usual type of drawing, and to obtain, solely by mechanical means, reproduced tracings from pencil-on-paper drawings which compare favorably with inked tracings which heretofore had to be made completely by hand. Although it is recognized that the resulting tracings are not as good as hand-inked tracings, they are found to be satisfactory for most purposes.

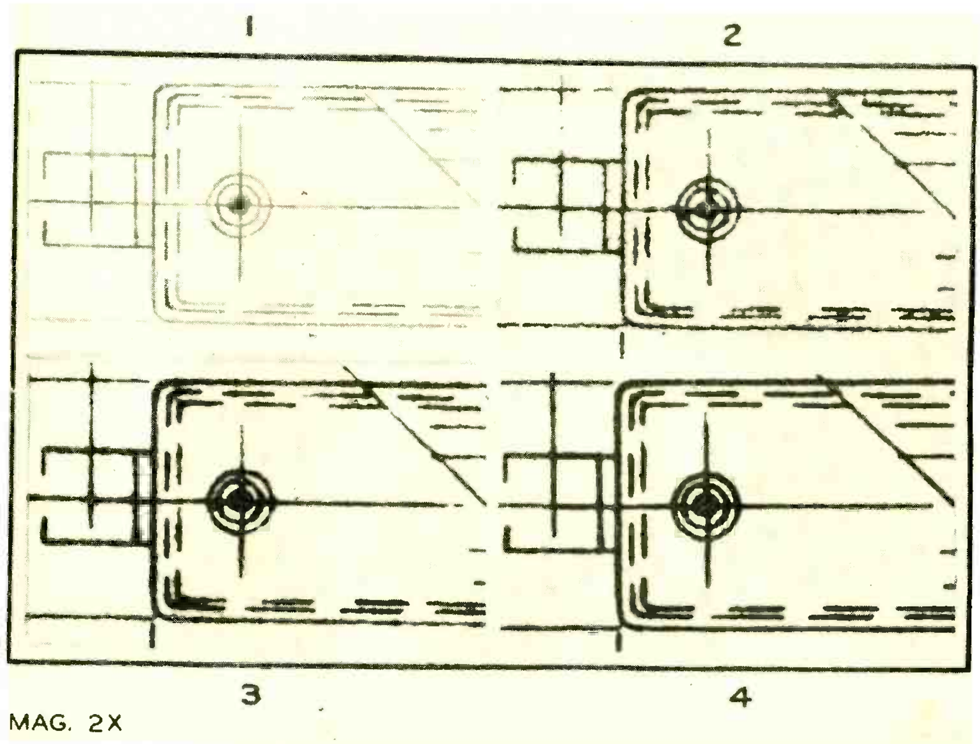


Fig. 2—Comparison of appearance of pencil drawing, upper left, and various types of reproduction

Surveying in Curved Spaces

By S. A. SCHELKUNOFF
Transmission Research

THE concept of a curved space may seem absurd. Curvature appears to be a property of lines and surfaces and, as such, is amply illustrated in our daily experience. Lines may be curved in a plane and surfaces may be curved in space. But to say that space in turn is curved is to imply a four-dimensional something-or-other, relative to which the space is curved. However, since we cannot get out of our three-dimensional space, we can have no sensible idea of the four-dimensional "space". So, for all practical purposes, there is only one physical space and this space is three-dimensional*. How can we, then, ask whether this space is flat or curved?

What we have just said applies, however, only to the idea of "relative" curvature, to the curvature of an ellipse with respect to a "straight" line, to the curvature of a sphere with respect to a "plane". But let us suppose that we are on the surface of a big ball, many times larger than the earth; and, while we are at it, let us imagine that the atmosphere around this ball absorbs light to a much greater extent than our atmosphere so that the usual experiences, cited to prove that the earth's surface is similar to the surface of a small ball, can no longer be relied upon. In other words, let us suppose that our experience is limited to measurements of distances on the surface of our world. Does it mean, in that case, that we could never find out whether this surface were plane, or spherical, or some other kind of surface? Obviously not, for, given time, at least we can go around the world and that would prove to us that the world is different from a plane. The geometries of different surfaces as revealed by actual surveying may differ a great deal and in this difference lies the key to the idea of "intrinsic" curvature of a surface, the curvature revealed by measurements of distances made on the surface itself without getting outside. If so, there may be something, after all, to the idea of "intrinsic curvature" of our physical space as revealed by astronomical surveying in it.

Lest a misunderstanding may arise, let us recall that there exists a fundamental difference between mathematics and physics. Physics is concerned with actual phenomena and relations between objects. Mathematics, on the other hand, is concerned with possible phenomena and possible relations. The conclusions of physics are settled by experiment while the deductions of mathematics must merely be logically consistent with the premises. Physics takes facts as they are; mathematics considers them as they might be and, in special instances, as they are. The material bodies in our universe attract one another according to the inverse square law, and there is only one celestial mechanics for a physicist; they might be attract-

**The space-time continuum of relativity has four dimensions, of course, but space in the usual sense of the word is the "proper space" for any particular observer, representing for him the "cross-section" of the space-time continuum at any instant.*

ing each other according to any other law, and there is an infinite number of systems of celestial mechanics for a mathematician.

At times, several physical theories may be devised to account for the same set of physical facts. This is possible because the failure of one group of hypotheses to explain all the available facts may be compensated by some additional hypotheses. Thus, Ptolemy placed the earth in the center of the universe and made the planets move around the earth in circles. That did not agree with actual observations. He decided then that the planets move in circles ("epicycles") whose centers move in circles around the earth. By the time a sufficient agreement with observation was reached, the number of epicycles was found to be quite formidable. All the compensatory hypotheses become unnecessary as soon as we adopt the Copernican point of view. Perhaps we can state, without courting objections, that there is only one physical theory of the real world, based upon the least number of assumptions. Yet, logically speaking, the real world might have been one of a literally infinite number that mathematicians can imagine.

While Euclid has developed one possible geometry, Lobachevsky another, and Riemann still another, only one of them will fit best the real facts; and the question, as to which one it is, has to be decided on the basis of actual measurements and not by philosophic speculations or because one of these geometries happens to be taught in high schools. It is to be remembered that in a limited part of space all geometries are approximately alike, just as all surfaces are approximately plane if small enough parts are taken. The fact that Euclidean geometry fits well our daily experience is not startling at all; we might have expected it.

Let us now return to our measurements on some particular sur-

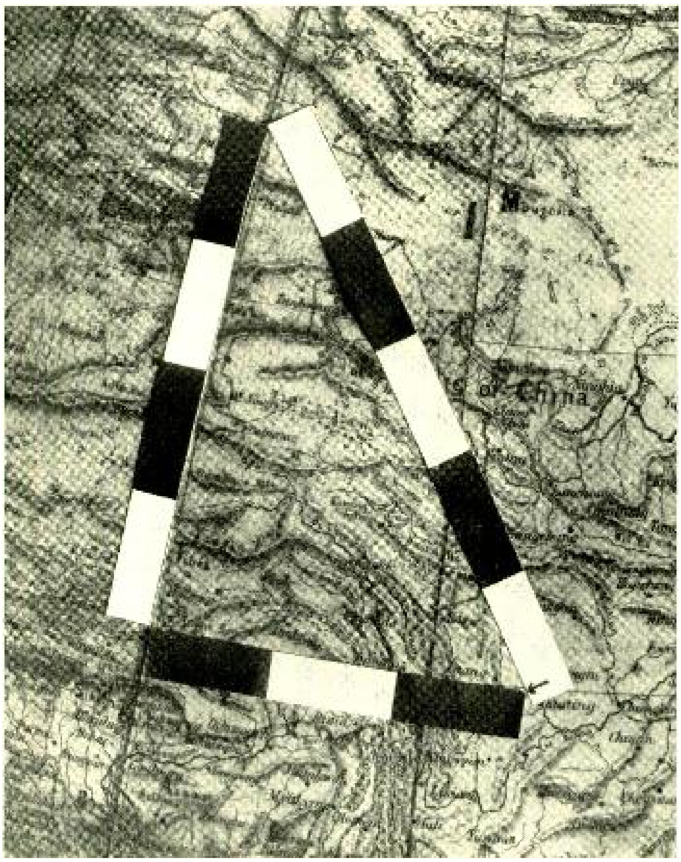


Fig. 1—The square on the hypotenuse of a right triangle does not equal the sum of the squares of the other two sides if the triangle is drawn on a sphere, as can be seen from this attempt to draw a 3-4-5 right triangle on a globe of the World

face. Different paths can be drawn between any two points on it. One of these paths is the shortest*, is called the "geodesic", and it is the "straight" path so far as our surveying measurements are concerned. It is the geodesic that interests the practical navigator who, being confined to the water's surface, ignores the three-dimensional aspect of the world.

Taking three points, we can join them by geodesics and form a triangle. Among various triangles some are "right-angled", that is have two of their sides perpendicular to each other. The side opposite the right angle is called the hypotenuse. If the surface is a plane the right triangles in it possess a remarkable property which is known as the theorem of Pythagoras: the square of the hypotenuse equals the sum of the squares of the other two sides. But, when we come to consider surfaces that are *not* plane, we have to distinguish those which are merely "bent" like a piece of twisted paper, from others which are "fully curved" like a rubber sheet deformed not only by bending but also by stretching.

A bent surface, technically known as a developable surface, is one which in material form can be flattened out into a plane without stretching. A cylinder is a familiar example. The intrinsic geometry of such a surface, consisting of those properties of geometric figures which can be ascertained without getting outside the surface, is obviously the same as the ordinary plane geometry, and the Pythagorean theorem still holds. This general statement is true, however, only if we confine our attention to sufficiently limited areas—to geometry "in the small", so to speak. There are some properties "in the large" that are unlike the properties of geometric figures drawn in a plane. For instance any

Fig. 2—Any two meridian lines seem everywhere equidistant to the Equadorean who confines his attention to the neighborhood of his native country

On a sphere there are some pairs of points diametrically opposite between which an infinity of equal paths exists. Such situations will not occur, however, if we concern ourselves only with sufficiently limited areas of the surface.

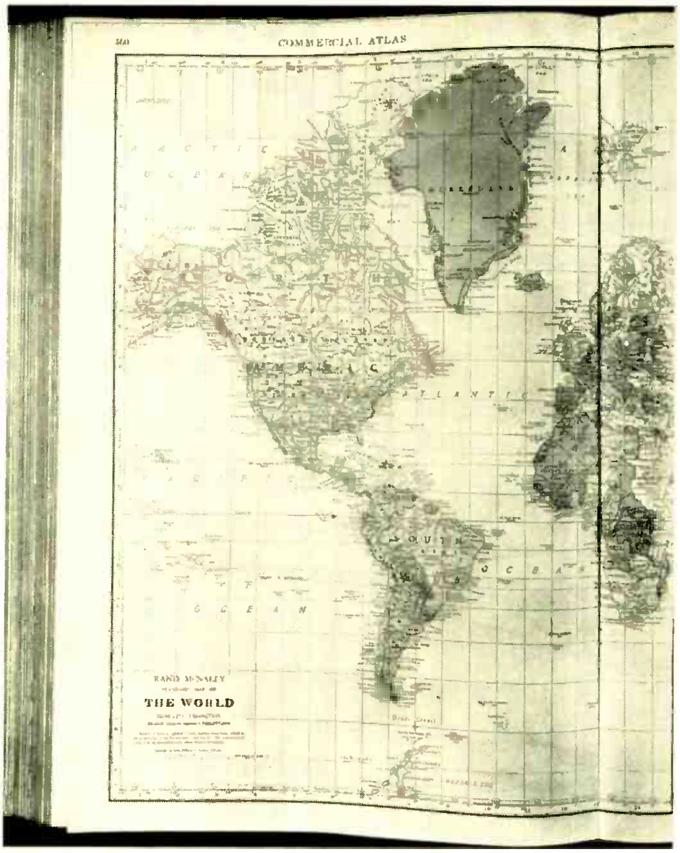


Fig. 3—If the Equadorean assumes that meridian lines are everywhere equidistant, he obtains a false idea of the size of Greenland

plane circle if conceived as a perfect rubber thread can shrink to a point without leaving the plane. This is true of some, but not of all circles on a cylinder. The circles that go around the cylinder cannot shrink without leaving the cylindrical surface.

On a sphere, on the other hand, even small geometric figures have properties quite different in many respects from the properties of plane figures. No portion of the sphere can be made to fit a plane without stretching its parts. The square of the hypotenuse is no longer equal to the sum of the squares of the other two sides.

Just as much can be said of other non-developable surfaces. For the present purposes, we shall not distinguish between real planes and developable surfaces but shall consider them equally "flat", reserving the word "curved" to non-developable surfaces. The term "curvature" will be used, therefore, in a much stronger sense than ordinarily. In this sense, Pythagoras' theorem is true on flat and only on flat surfaces, so that if the square of the hypotenuse of a right triangle drawn upon a surface does not equal the sum of the squares of the other two sides, then the surface is curved. This test is "intrinsic", and surveying measurements on the surface itself are sufficient for finding out what kind of a surface it is.

These ideas can be extended to space. Starting from some particular point, let us go along some geodesic to another point, from there we proceed on another geodesic perpendicular to the first, and reach a third point from which we depart for the fourth point, following a third geodesic at right angles to the geodesic surface* containing the first two. We can also reach the fourth point directly along a sort of diagonal geodesic. The square of this diagonal distance may or may not be equal to the sum of the squares of the other three segments. *If it is*, we say that the space

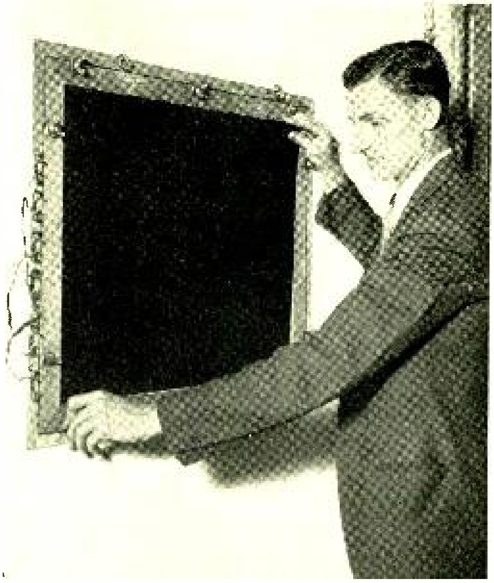
**A geodesic surface is analogous to a plane, in the same way that a geodesic is analogous to a straight line.*

is flat; otherwise the space is curved.

Everyone is familiar with flat maps of the world. On them some countries, such as Greenland, look big, out of all proportion. If these maps were drawn from the point of view of Greenlanders, the equatorial regions would look huge. This always happens if, in drawing a map of a sphere, we identify it with a plane. An equatorial dweller would draw his meridians of longitude as perpendiculars to the equator and carry them toward the pole as parallel lines. He would infer from this picture that these lines are as far apart as ever even when they reach Greenland, so that his ideas about the speed of dog teams traveling East and West would be radically different from the actual experience of an Eskimo. Eventually an agreement between the disputants would be reached by recognizing that "parallel meridians" intersect at the poles. This solution of the dilemma upsets some "axioms" of plane geometry on which Pythagoras' proposition rests, and the Greek geometer's theorem must go by the board.

The Eskimo and the Ecuadorean would also find an alternative solution of their difficulties by considering the world's surface imbedded in space, so they could join points on the surface by the shortest distances *outside* the surface itself. This would mean an admission on their part that the world's surface is one whose points are approximately 3900 miles away from a fixed center. They might name this surface a "sphere" unless it were already named. No one could seriously object to this view because the picture of the world as the surface of a large ball would seem a possible physical picture. The practical navigator, however, being compelled to sail on the surface, would prefer the first solution. Whatever the individual preferences may be, both points of view are physically acceptable since we recognize the existence of a physical three-dimensional space in which the earth's surface is contained.

If now we come to consider our three-dimensional universe, and some "astronomical surveyor" were to observe facts that did not square with the theorem of Pythagoras, we would have the choice of two general lines of belief. On the one hand, we might regard the points of space as points of a four-dimensional something-or-other, and so restore the theorem to its simpler form. We should however consider such a reduction as artificial and without physical significance. On the other hand, the acceptance per se of the more complicated theorem of Pythagoras, that is, the admission that space has intrinsic curvature, offers no difficulties since there is no reason why the rule for computing the length of an hypotenuse should be as simple as the one given originally by Pythagoras on the basis of measurements made in a very limited area. If someone were to point out that the theorem of Pythagoras has been logically proved, we should have to reply that it has been proved to depend upon other postulates, the applicability of which to the physical world had not been tested except in limited areas, and in sufficiently small regions the curvature would have no great effect on the measurements.



Measurement of Transmission Loss Through Partition Walls

By K. D. SWARTZEL, Jr.
Acoustical Research

THE question of the transmission of sound through partitions is almost as old as the first race of men who built dwellings of mud or stones. Their buildings were primarily for protection from the elements and their enemies, but the quiet afforded by four walls was no doubt a factor influencing them to build shelters for luxury and comfort. More recently, with the increasing concentration of people in large towns necessitating housing many families of diverse interests and habits in a small area, and many workers within the limits of a small business district, the sound-insulation value of partitions used in the walls of buildings has become of considerable importance. Many theatres, radio and recording studios, factories, stores, churches, offices, apartments, and homes require insulation from stray sounds of external origin.

Sound insulation is largely a matter of the specification of wall structures with sufficient transmission loss. The transmittivity of a partition is the ratio of that part of the sound energy passing through the partition and radiated into the air, to the total sound energy striking the partition. The reciprocal of the transmittivity expressed in decibels is called the transmission loss.

Probably the easiest way to measure the transmittivity of a partition is to place it in an opening between two rooms which are otherwise well insulated from each other so that no sound can pass from one to the other by any path except through the partition. If a tone is generated in one room, the transmittivity of the partition can then be calculated from the difference in intensity levels in the two rooms, the size of the partition, and the reverberation time of the quieter room.

The plan of the laboratory used for these measurements is shown in Figure 1. In the larger room, the source room, are placed loud speakers as a source of sound. These are driven by a 13A oscillator and a power amplifier. The partition to be tested is built into the six-foot-square opening into the test room. In each room are located several moving coil microphones to detect the sound. The output of the microphones is measured with an automatic level recorder, shown in Figure 2, a device capable of automatically drawing a graph of intensity on a moving paper record. The frequency dial of the heterodyne oscillator is rotated by a small synchronous motor at a speed which covers a frequency range from 60 cycles to 4000 cycles in about four minutes. Corresponding frequencies are automatically marked on the recorder record as the dial turns.

Fig. 2—The author reading the automatic level recorder used in the measurement of the transmittivity of walls

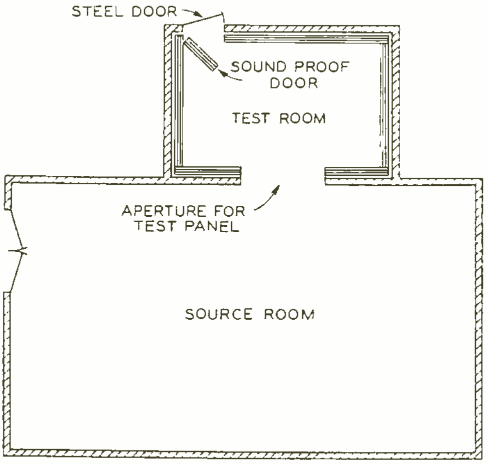


Fig. 1—Diagram of room layout for measuring the transmittivity of partitions

With a partition in place, the procedure of the measurements is as follows. Intensity records throughout a continuous frequency range are recorded in the source room at several different microphone and loud-speaker positions, and averaged so that no special room-condition can influence the results. A similar number of intensity measurements are made and averaged in the test room. From the difference in the average levels of the two rooms, data may be obtained on the continuous transmission-frequency characteristic of the partition.

Because of the shifting of the interference pattern in the room, the curves drawn by the level recorder are not smooth. The irregularities, which envelop an average level, may be reduced by using a slow response speed on the recorder. A warble tone from the oscillator instead of a steady tone helps in the same manner. To average the levels at several points in the room simultaneously a number of microphones may be connected in succession to the recorder for a small fraction of a second by a motor-driven rotating switch.

Results of transmission-loss measurements on some partitions are given in Figure 3. Curve 1 shows the transmission loss as a function of frequency for a 6-foot-square metal-frame door having four 28-inch-square panels of quarter-inch plate glass. This door was loosely clamped at the edges against a felt strip about a half inch in thickness, so that some of the transmitted sound may have been due to the rather imperfect seal. Curve 2 shows the transmission loss for a standard unplastered three-inch wall of hollow gypsum tile, and curve 3 is for the same wall with two coats of gypsum plaster on each side.

No attempt is made to express the insulation value of a wall with a single figure, as no generally acceptable method of weighting the various frequencies or frequency intervals is available.

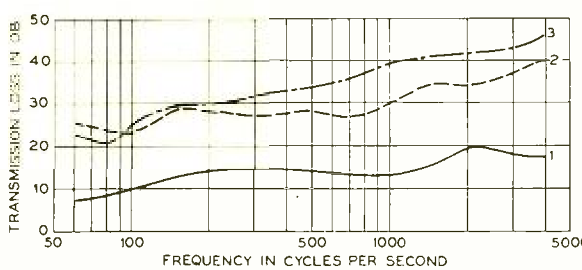
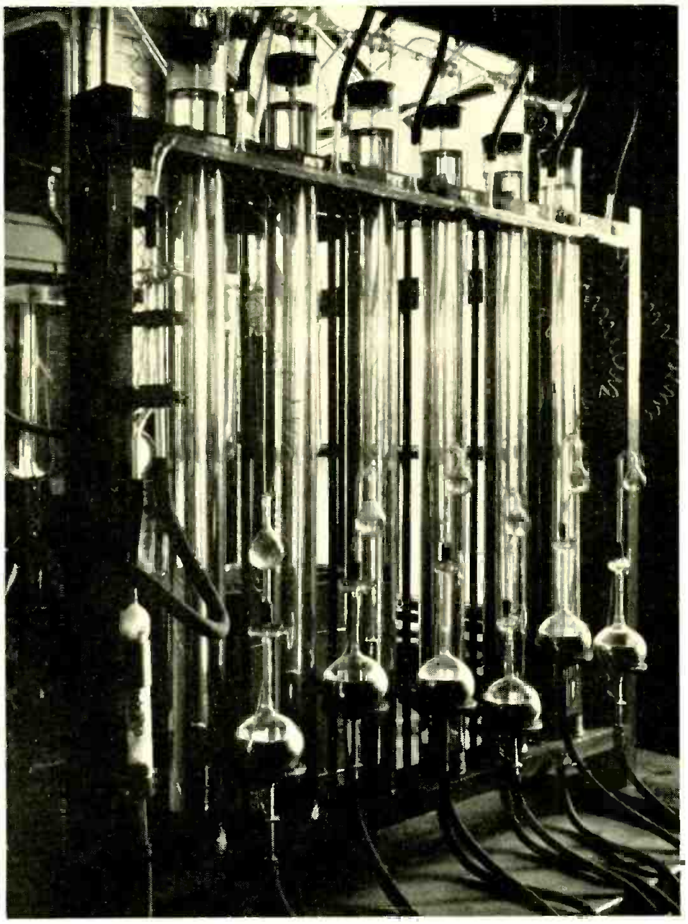


Fig. 3—Typical transmission-loss curves for various types of walls



The Oxidation of Organic Substances

By L. EGERTON
Chemical Laboratories

EVERYONE knows how vital the oxygen of the air is to his very existence, but few fully realize to what extent this same element plays an opposite and sinister role. Each year, by aging materials, it takes its toll from industry and necessitates many costly replacements. Iron falls into rust. Rubber loses its "life", hardens, and cracks. Oils become gummy and cease to lubricate. Paint films lose toughness and adherence. Paper becomes yellow and brittle, falling at length into chips.

Most organic materials of a highly complex chemical structure, such as rubber, bitumens, and petroleum products, are readily attacked by oxygen, and the resulting deterioration eventually destroys their usefulness. That the natural aging of these materials is mainly due to oxidation is inferred from the many similar effects of aging and artificial oxidation, in the rates at which they occur and in the chemical and physical changes they produce.

Because of the importance of many of these materials, especially rubber, in the telephone plant, it is essential to understand the mechanism of such oxidation processes and the accompanying changes in chemical and physical properties. Only from the basis of such understanding is it possible to foretell with some degree of accuracy the natural life of individual materials, and to develop materials having superior aging qualities.

The methods generally employed for the study of oxidation fall under three classes. Most prevalent are measurements of a practical sort on the changes which exposure to oxygen produces in tensile strength, brittleness, viscosity, and the like. In the second method the amount of oxygen absorbed per unit of time is measured quantitatively. The third method measures the rate at which the principal products of the reaction are formed, or conversely the rate of disappearance of the substance undergoing oxidation.

The apparatus shown in the headpiece is in many cases used in these Laboratories to measure the oxygen absorbed under conditions of constant temperature and pressure. The quantity of oxygen producing any given effect can thus be quite definitely determined. In each separate unit (Figure 1) of the apparatus a sample of the material is kept physically saturated with pure oxygen in a bulb A, whose temperature is controlled by placing it in a thermostat. Pressure is held constant by the electrolytic generation of gas in the bulb B, under control of the mercury manometer C which makes and breaks circuit for the electrolyzing current.* The amount of oxygen absorbed is measured on the gas burette D.

Methods analogous to these have long been used to determine the rates at which reactions in general proceed. Hence it has been discovered that most chemical reactions proceed at a rate which diminishes as the reaction progresses, so long as the temperature does not change. This is no more

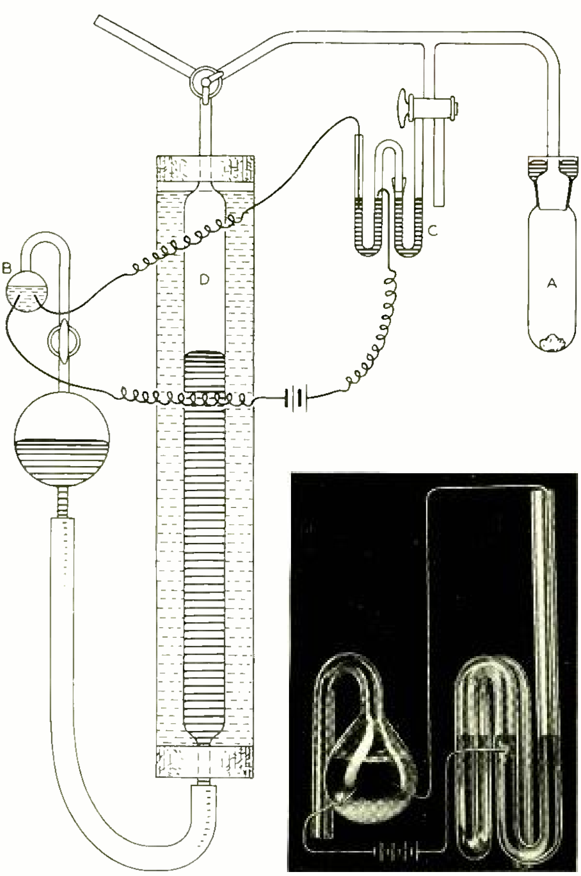


Fig. 1—The amount of oxygen absorbed by the sample in A is measured on the gas burette D. Pressure is held constant by electrolytic generation of gas from an oxalic acid solution in B, controlled by the manometer C, as shown at the lower right

**This unusual pressure-regulating device was developed by G. T. Kohman.*

than might be expected, for as time goes on, more and more of the reacting compounds are used up and there are fewer of their molecules left to promote the reaction. Some reactions can have their entire progress hastened or slowed down by "catalysts": substances whose mere presence, perhaps in only minute quantities, greatly changes the rate of a reaction and yet which remain at the end of the reaction chemically unchanged.

In contrast to the picture of diminishing reaction rate, many oxidation reactions exhibit the property of "self-acceleration". These "autocatalytic" reactions proceed at first with very slow rates, at times immeasurable, which gradually increase until a maximum is attained and then diminish. The initial period of negligible reaction is termed the "induction period".

In these reactions it is the induction period that is shortened by positive catalysts or accelerators, and lengthened by negative catalysts or decelerators. Some hold the view that the induction period is not an inherent property of the oxidizable molecule but depends upon traces of negative or positive catalysts naturally present as impurities in the material. In the field of organic oxidation, negative catalysis has recently received considerable attention, mainly because of its practical significance in the application of anti-oxidants for stabilizing materials which normally age rapidly.

The application of antioxidants to rubber is perhaps the outstanding example of their use. The similarity of the oxidation curves for rubber with those showing the gain in weight during natural aging indicate the similarity of the reactions in natural and in artificially accelerated aging. It is known that enormous changes in the

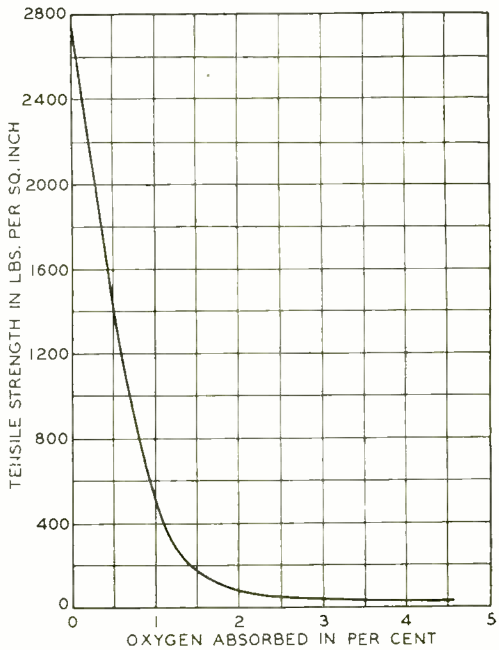


Fig. 2—The tensile strength of rubber (expressed above in pounds per square inch) decreases rapidly with increase in the amount of oxygen it absorbs (in percent of the weight of the sample)

tensile strength of rubber occur after the absorption of small amounts of oxygen (Figure 2); 0.5% of oxygen decreases the tensile strength by nearly 50%. Antioxidants are accordingly effective in prolonging the life of rubber by increasing the induction period and consequently decreasing the amount of oxygen absorbed in any given time (Figure 3).

So far as the rate of reaction is concerned, the effect of adding these "inhibitors" is not permanent. The induction period is extended by their presence, but later the rate of reaction increases until a maximum is reached and then diminishes just as in the case of the uncatalyzed reaction. Such catalysts seem to work selectively: a given substance may inhibit the oxidation of a specific compound but when tried on a different compound it may

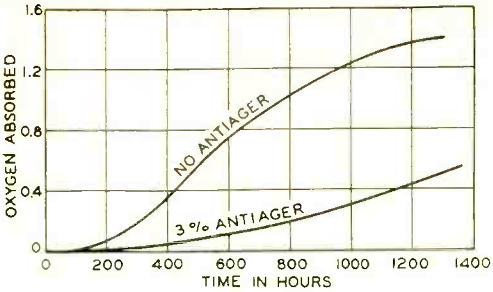


Fig. 3—A small amount of antiager will greatly decrease the amount of oxygen absorbed by rubber in a given time. The absorbed oxygen is expressed above in moles per gram-molecule of $C_{10}H_{16}$. The temperature of the reaction was 80° C

show the reverse effect and act as a positive catalyst.

While negative catalysts assist in prolonging the usefulness of many materials, positive catalysts and accelerators, in most cases, have the opposite effect. A factor very detrimental to stability is light radiation of short wavelengths. Where possible its action is often prevented by incorporating substances in the material which cut down the amount of ultraviolet radiation absorbed and thereby effectively diminish its accelerating effect upon the oxidation reaction.

Metals and metal salts promote the oxidation of hydrocarbon oils (Figure 4), accelerating the deposition of a sludge of oxidation products, and the formation of acids, both of which seriously impair the usefulness of the oil. Other materials which act as positive catalysts toward many oxidation reactions are metal complexes and organic peroxides.

In the paint and varnish industry use is made of positive catalysts as "driers": metal salts which hasten the oxidation of the "drying oils" and thus thicken and harden the oil into a film. This thickening is more than a mere oxidation. In the course of it, several molecules of the oil unite to yield a much heavier molecule having entirely different properties.

Some hold the view that this "polymerization" of drying oils is purely a uniting of the molecules of oxides and peroxides formed in the oxidation reaction. In the case of some other substances, however, the presence of oxygen or peroxides is not essential to polymerization. Some molecules are capable of uniting to form a heavier molecule under the influence of ultraviolet light. The presence of oxygen in excess may serve as an inhibitor or decelerator for this photo-polymerization. In such cases, there is active competition between the oxidation and polymerization reactions, the active

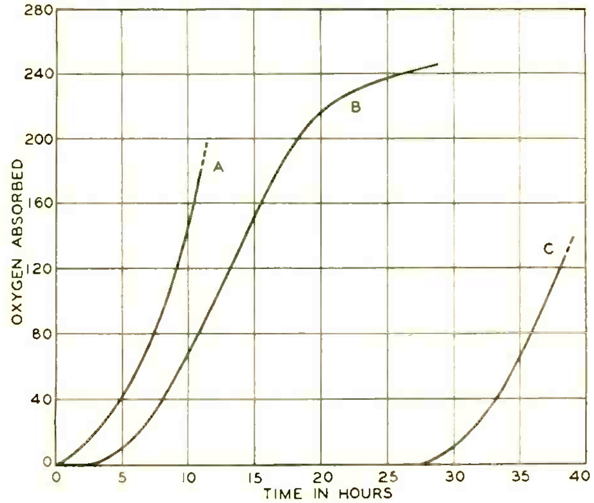


Fig. 4—These curves show that the oxidation of hydrocarbon oil at 120° C occurs sooner in the presence of the positive catalyst, copper (A), than alone (B), and can be greatly delayed by as little as .01% of a negative catalyst or antioxidant (C). The absorbed oxygen is expressed in cubic centimeters per gram of oil

molecules showing more of a preference for oxygen than for one another. Here it is possible to inhibit selectively one or the other of the two competing reactions.

In contrast to the auto-catalytic type of oxidation reaction, and more like the large majority of chemical reactions, there are those organic oxidations which show slowly diminishing rate of reaction. Bituminous materials, for example, appear to oxidize in this way (Figure 5). Accompanying the absorption of oxygen are distinct changes in the physical and chemical properties of the bitumens which seem to be in agreement with their natural aging characteristics. Other materials of interest coming under this classification are cellulose and certain insulating waxes. Here accelerated oxidation indicates that the oxidizability is quite important in determining the adaptability of the materials to specific uses. It is still questionable, however, how closely accelerated oxidation duplicates natural aging in these cases.

In passing from these matters of observation to the explanation of why they take place, one passes into a battleground of conflicting theory. So far no one theory has been evolved which adequately explains all the phenomena associated with oxidation reactions. The simplest view of the mechanism of air oxidation regards it as starting with a reaction in which molecular oxygen becomes attached to the substance undergoing oxidation, forming a highly reactive compound known as a peroxide. The final products of oxidation result from changes occurring in these intermediate peroxide bodies.

The chain of procedures which take place can be set forth more precisely in the light of the classical theory of chemical reactions, assuming a reacting system composed of molecules of A and molecules of oxygen, O_2. It is supposed that chemical combination takes place only between those particular molecules whose relative kinetic energy exceeds a limiting value known

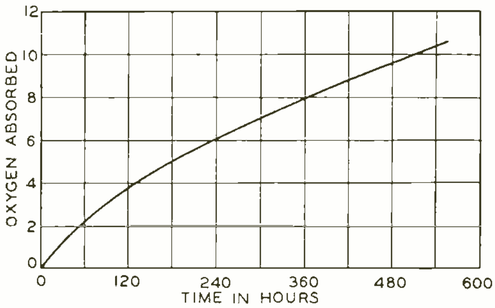


Fig. 5—The amount of oxygen absorbed by mid-continental asphalt at 80° C (expressed in cubic centimeters of oxygen per gram of asphalt) can be seen to increase with time, but at a decreasing rate

as the energy of activation. The number of suitable molecules is quite small in comparison with the total number of molecules present. Since the new molecules formed by the combination of A and O_2 possess at least as much kinetic energy as was required for their formation, they are said to be "activated". These activated molecules may give up their energy to other oxygen molecules, thus becoming "deactivated" themselves and activating the oxygen molecules. The latter may then enter in turn into combination with other molecules of A. These reactions can be compendiously indicated by such a scheme as that in Table I, where the activated molecule is placed in parentheses.

Such a reaction gives an absorption curve similar to that shown in Figure 5, in which the rate of absorption decreases with time if the temperature is constant. In order to account for the increasing velocity of absorption in auto-catalytic reactions (Figure 4), it is necessary to make some assumption which will provide for more centers, to initiate new reaction chains. To accord with observation, the reacting molecules must become more and more numerous until the reaction proceeds with explosive violence, unless the reaction chains are broken.

It is sufficient to assume that in addition to the reactions shown in Table I, the reactions shown in Table II can take place. Here it is supposed that the peroxide first formed may also react with a molecule of A to form two molecules of an oxide, one of which may possess enough energy to impart peroxidic characteristics to the oxide molecule. The active molecules of oxide constitute centers which initiate a new series of reaction chains, and thus increase the rate of reaction.

Negative catalysts may function in such reactions by combining with the activated peroxide and returning all the components to the system in a stable condition (Table III, 1). Another possible mechanism is a reaction of the catalyst with oxygen to form an activated peroxide like that of A, followed by a mutually destructive reaction between the two activated peroxides (Table III, 2). Many valid criticisms may be brought against these proposed mechanisms, but they have nevertheless presented a helpful picture of auto-oxidation and the action of catalysts in it.

TABLE I

$$A + O_2 + \text{energy} \rightarrow A(O_2)$$
$$A(O_2) + O_2 \rightarrow AO_2 + (O_2)$$
$$(O_2) + A \rightarrow A(O_2)$$

TABLE II

$$AO_2 + A \rightarrow AO + A(O)$$
$$A(O) + O_2 \rightarrow AO + (O_2)$$

TABLE III

$$(1): A(O_2) + B \rightarrow A(O) + B(O) \rightarrow A + B + O_2$$
$$(2): B + O_2 \rightarrow B(O_2)$$
$$A(O_2) + B(O_2) \rightarrow A + B + 2O_2$$

Contributors to This Issue

Sergei A. Schelkunoff received the B.A. and M.A. degrees in mathematics from the State College of Washington in 1923, and in the fall of that year joined the Carrier Research group of these Laboratories. Three years later he returned to Washington State as an instructor in mathematics and later became an associate professor. In 1928 he received the Ph. D. degree from Columbia University. The following year he rejoined the Laboratories, entering the Mathematical Research group where he has since been pursuing electromagnetic studies in their relation to communication problems.

G. R. Gohn, after receiving an A. B. degree from Otterbein College in 1926, took graduate work at Ohio State University for a short period and then entered the school of mines at Columbia. Here he received a B. S. in Engineering in February 1929, and the degree of Metallurgical Engineer the following June. He then joined the Technical Staff of the Laboratories where, with the Materials Group, he engaged in studies of non-ferrous sheet metals, die-casting alloys, and spring design. In 1932 he spent, for training purposes, five months in the Engineer of Manufacture department of the Western Electric Company. On returning to the Laboratories he again joined the Materials Group where he is occupied with studies of metallic materials at the present time.

S. A. Schelkunoff

K. D. Swartzel received an A. B. degree in mathematics from the University of Pittsburg in 1929. By special arrangement, however, he was not in residence at the University during his last term. This enabled him to spend the early spring of that year doing recording work at the Paramount

G. R. Gohn

K. D. Swartzel

E. T. Burton

T. C. M. Woodbury

R. W. Harper

L. Egerton

West Coast Studios, and to join the Technical Staff of the Laboratories in April. Here, with the Research Department, he has been engaged in acoustical studies and in the design of apparatus for acoustical measurements.

E. T. Burton's studies at the University of Indiana were interrupted by the War, in which he served as Lieutenant in the U. S. Engineers' Corps. In 1920 he received the A. B. degree, and joined the Research Department of these Laboratories, where he engaged in investigations connected with various low-frequency and carrier-frequency signaling systems, especially long submarine telephone cables. In 1924 he received the M. A. degree from his Alma Mater. He has of late been particularly interested in the nature and origin of audio-frequency atmospherics, and in other phenomena whose study is on the border line between electrical engineering and meteorology.

T. C. M. Woodbury studied electrical engineering at Wentworth Institute, Boston and graduated in 1916. After several years on design work with the B. F. Sturtevant Company and the Holtzer-Cabot Electric Company, he joined the Apparatus Drafting Department of the Laboratories in 1924. Since 1931 he has been engaged in standardization work. During the last six or seven years Mr. Woodbury has been studying law out of hours. In 1931 he received the L. L. B. degree from St. John's College, and a year ago his L. L. M. from St. Lawrence University.

R. W. Harper's telephone career began as soon as he came to America from Scotland. After three years with the Plant Department of the Cincinnati and Suburban Telephone Company, and seven years of wide field experience with the Installation Department of the Western Electric Company, he entered the Engineering Department of the Michigan Bell Telephone Company in 1917. During the World War he served in the Signal Corps, and at its conclusion he joined these Laboratories. His work here has been in circuit design, especially, for the past six years, that of private branch exchanges, on which he now supervises the work.

L. Egerton received the B. S. degree in Chemical Engineering from the University of Colorado in 1928. After a year with the American Smelting and Refining Company in Denver he came east to join the Chemical Laboratories at West Street. Here he has been principally concerned with investigations of the oxidation and deterioration of organic insulating materials, such as rubber, asphalts, hydrocarbon oils, and paper. Last fall he digressed briefly into a study of the preparation of copper oxide under controlled and reproducible conditions.