BELL LABORATORIES RECORD

EARTH CURRENT MEASUREMENTS
MARY K. CORR

19A TRANSMITTER For Private Airplanes
B. S. BAIR

BEND TESTER
W. J. FARMER

DECEMBER 1935 Vol. XIV No. 4

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In this Issue

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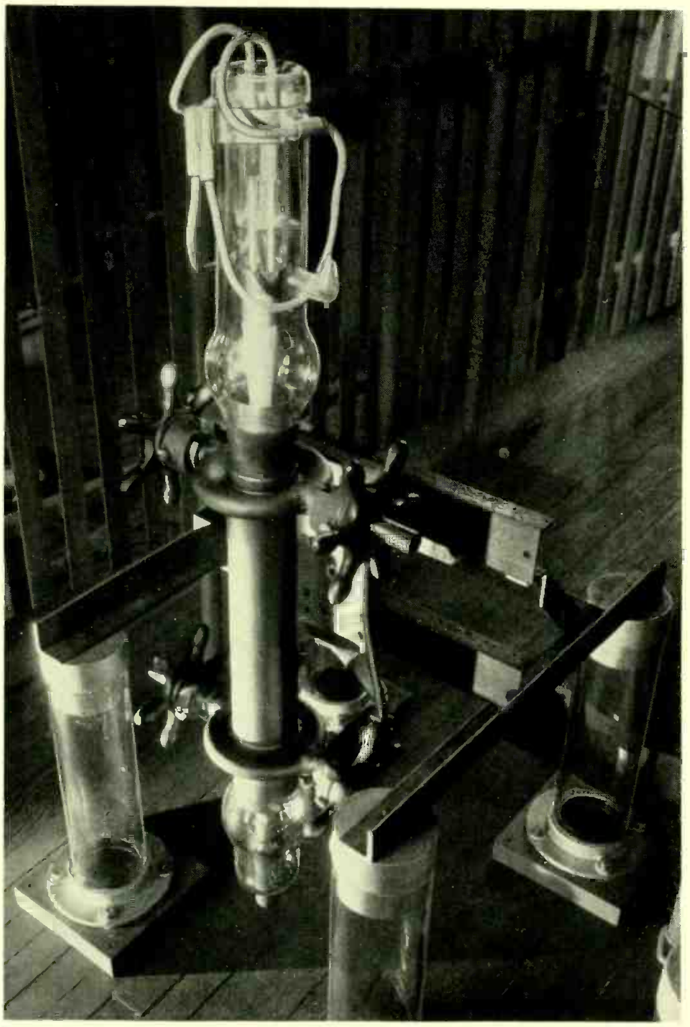

Hundred-kilowatt amplifier tube

VOLUME FOURTEEN—NUMBER FOUR

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1935

Earth Current Measurements

By MARY K. CORR
High Frequency Transmission Development

ELECTRIC currents are continually flowing in the earth's crust from natural causes, but no one was aware of their presence until the middle of the last century when they manifested themselves as a source of interference in the grounded circuits of telegraph lines. These earth currents are continually changing in magnitude and direction at a given place. Their general characteristics also change considerably with location, showing greater variation in polar regions than near the equator, and also in mountainous sections where the soil is thin than in broad alluvial valleys. They appear to be associated systematically with conditions on the sun, with the magnetic state of the earth, and also with certain phenomena involved in radio transmission. For this latter reason in particular the investigation of earth currents is of importance to the Bell System. Since the measurements involved are made by determining the voltage between two points of the earth's surface many miles apart, the telephone company with its widespread wire network is in a particularly advantageous position to undertake such earth current studies.

Conditions have recently been explored by means of instruments making continuous records at various locations along the Atlantic Coast from Maine to Florida and also in both the upper and lower Mississippi Valley. The measurements in Florida included the use of a submarine cable circuit to Cuba. With circuits approximately 100 miles long, the voltages recorded under ordinary conditions are usually less than 10 volts, but with exceptionally disturbed conditions, for example during auroral displays, transient voltages six or more times the normal have been observed. During periods when the earth currents are normal, there is found to be a progressive change in the direction of flow which results in two complete rotations every twenty-four hours. These diurnal changes vary but little from month to month, and consequently the peak values always occur at nearly the same hours of the day. The time of sunrise seems to be associated in some manner with a reversal of flow from west to east, but the correlation at sunset is less satisfactory, possibly because of insufficient data. There is a gradual decrease in the magnitude of the currents with the approach of winter and a gradual increase again to the height of the summer season. At higher latitudes this seasonal variation is more pronounced than near the equator.

Although for many years earth-potential differences were observed during electromagnetic storms on various circuits of the Bell System, systematic studies of earth current conditions as related to radio transmission and magnetic storms were first undertaken in 1928. These investigations, which were continued over a period of about four years, established a definite correlation between abnormal earth currents, magnetic storms, and variations in transoceanic radio transmission. In 1932, the scope of the work was extended to include a study of normal variations as distinct from the disturbed conditions to which the previous studies had been restricted. Locations were chosen for these further measurements at Wyanet, Illinois, which is situated in the Mississippi Valley where the soil is believed to be very deep and the geological formation homogeneous; at New York, which is located at the northern edge of a region known to have high resistivity; and at Houlton, Maine, which is much more northerly than either of the other two places and is in the region where

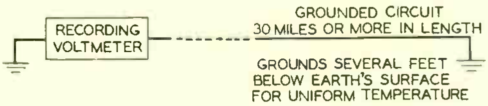


Fig. 2—Voltages developed between points in the earth 30 miles or more apart have been recorded by using wire lines to connect these points to a meter

auroras appear frequently. At these locations continuous recording was done over a period of at least one year. Measurements were also made for short periods at several other points along the Atlantic Coast. By this procedure the characteristics of the diurnal variation were established for the places which are indicated on the map, Figure 1. The two lines in each circle indicate the distance apart of points between which measurements were made, and their orientations.

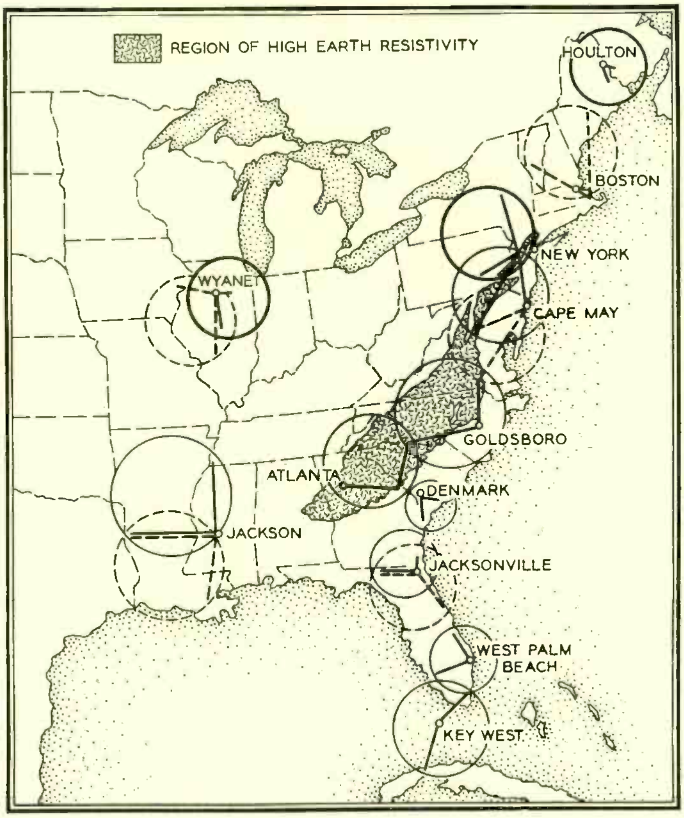


Fig. 1—Earth currents have been investigated along the Atlantic Coast and in the Mississippi Valley by using telephone lines to measure potentials between widely separated points in the earth's crust. The distances between points and their orientations are indicated by the heavy lines within the circles

The earth as a conductor is so extensive that it is not practical to measure earth currents by methods which would be used in a wire circuit. The measurements made are actually in terms of the voltage between points on the earth's surface, as indicated schematically in Figure 2; the wire line serves only as a means of connecting the two widely separated ground points to the measuring device. To determine changes in direction of current as well as magnitude, it is of course necessary to record the potential simultaneously in two lines at the same place, disposed preferably at right angles to each other. As far as the existing plant network will permit, two associated circuits are so chosen that one runs north-south and one east-west. These circuits must be many miles long in order to minimize the effects of stray electric currents of man-made origin. Figure 3 shows the two Leeds and Northrup recording potentiometers used at Wyanet, and the meters required for the frequent checking of the lines under test. Part of an earth potential record for a rather disturbed day can also be seen.

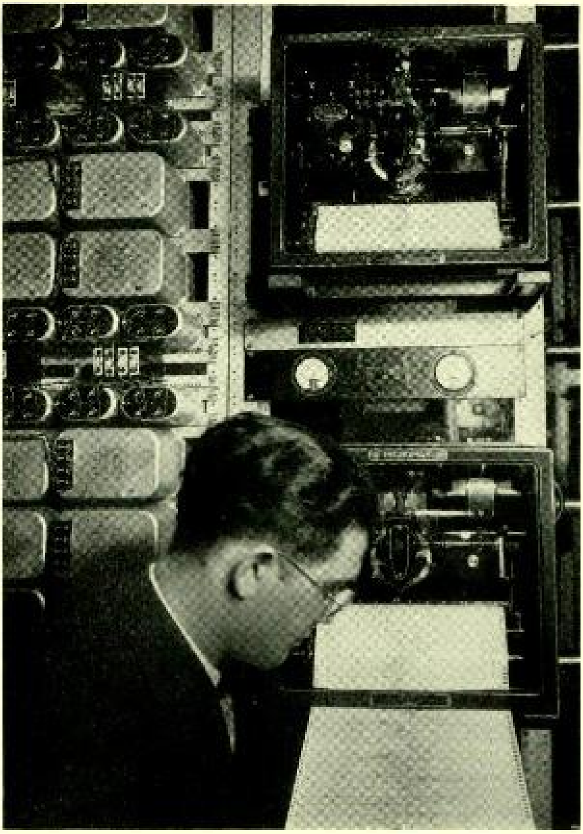


Fig. 3—A recording voltmeter is used to measure the earth potentials which fluctuate continually

The record of a typical quiet day, shown in Figure 4, was made on a cable pair extending westward about seventy-five miles from Wyanet. The potential found was small and oscillated about the zero line from midnight until 7 A.M., when the current began definitely to flow eastward. This continued until noon when the direction of flow changed to westward and remained so until about 4 P.M. The potential was relatively large from 4 P.M. until midnight but reversed direction every hour or two. Many short period oscillations were also superimposed on the longer swings. The maximum potential recorded for the day was approximately two volts, at 10 A.M. During abnormal periods, which may last from a few

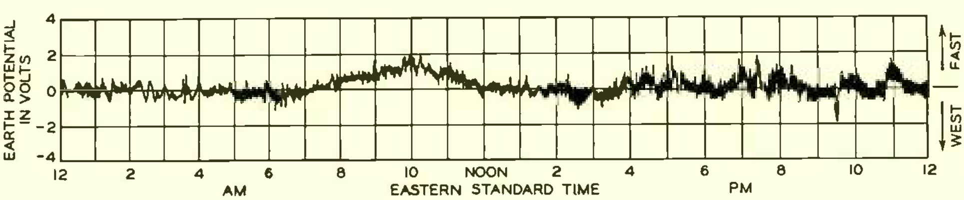


Fig. 4—The direction in which earth currents flow at a given place changes during the day. At sunrise there is a reversal in direction from west to east

minutes to several days, the behavior becomes very erratic, sometimes causing reversals of direction from +5 to −5 volts within a minute. Measurements of earth potential made by the Carnegie Institution of Washington at Watheroo in Australia indicate that in the southern hemisphere a very similar east-west diurnal characteristic exists.

A graphic summary of one year's work at Wyanet in which the potential gradients or mean diurnal variations per unit distance are given for each month in so-called fishbone diagrams is shown in Figure 5. These diagrams indicate that during each day there is a rotation of the direction of the earth potential flow through 720 degrees. As already mentioned, the daily variations are quite similar over a period of months, so that the peak values appear at about the same time each day. The seasonal changes show a gradual decrease in the magnitude of the vectors as winter approaches and then a gradual increase again to the middle of the next summer. Measurements made at Houlton yielded similar results. In this more northern location the amplitude of the diurnal variation is roughly four or five times as large as at Wyanet, and the seasonal variation is much more noticeable. Observers in the field of terrestrial magnetism have noted that the magnitude of seasonal change in magnetic variation also decreases with decreasing latitude and becomes rather insignificant at the equator.

The potential gradient as measured at New York shows a much constrained rotational pattern, the potential changing abruptly from north-west to south-east, but the total amount of rotation, 720 degrees during each twenty-four hours, is the same as at Wyanet. An area of high resistivity to the south-west of the New York circuits is believed to be

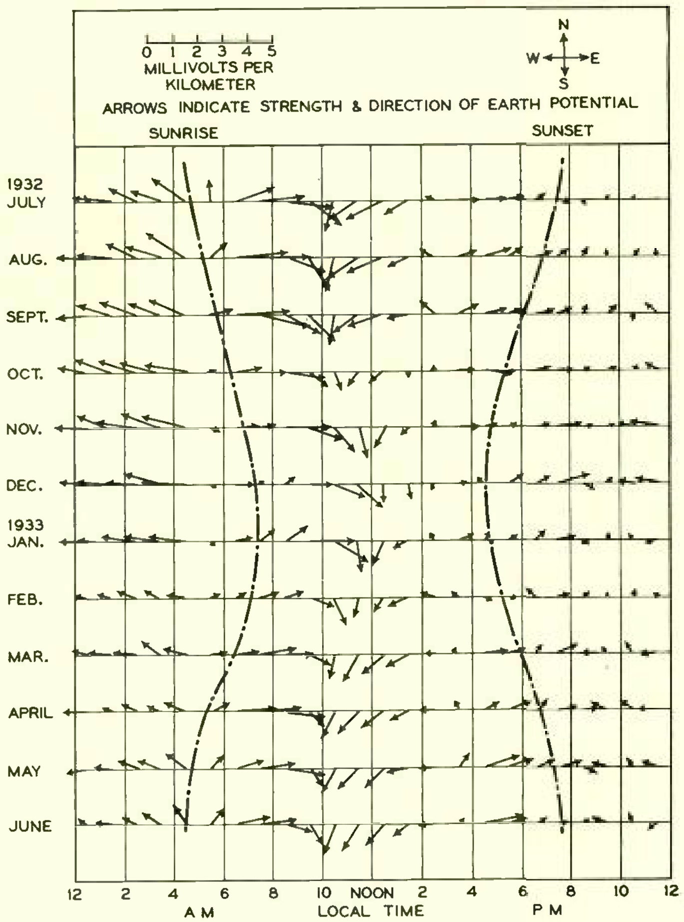


Fig. 5—The daily changes in direction of flow of earth currents vary little from month to month. The currents are greater in amount during the summer months

the underlying cause of the directivity of the flow in this locality. The annual variation in the magnitude of the potential gradient reaches a maximum in the summer and a minimum in the winter at New York, just as at Houlton and Wyanet. The maximum amplitudes of earth potential measured during one year at Wyanet, New York, and Houlton were roughly in the ratio of 2:6:10. At each of these locations the change of vector direction from west to east appears to be related to the hour of sunrise but the evening directional change is apparently displaced from time of sunset.

At the stations where recording was done for only a month or so, the diurnal variation for the particular months studied was determined. These stations included a second New York circuit, extending south of the long term New York circuit as shown by the light circle in Figure 1. At this second New York station and at two locations in northern Florida the maximum diurnal values of the potential are large and exceed those measured at Houlton, Maine. At Jackson, Mississippi, on the other hand, the values are smaller than at Wyanet, Illinois. The direction of current flow along a north-west to south-east line predominates at New York and Goldsboro, while at Denmark, Jacksonville, and Key West a generally east-west direction is maintained. At West Palm Beach, which is midway between Jacksonville and Key West, the direction of the current is rotational. It was expected that at Key West, with deep water covering almost the entire circuit to Havana, Cuba, and to Miami, Florida, the resistivity would be the same in all directions and the potential would not show directional selectivity, but such was not the case. Geological characteristics at West Palm Beach are thought to be the same as at Jacksonville, but the directional patterns differ. There are thus several inconsistencies in these characteristics that remain to be explained.

A few earth current "storms" or violent disturbances have been studied in detail. These are particularly noticeable during auroral displays, but also occur when no such manifestation is visible. Instantaneous values of from 20 to 30 volts, usually with very rapid oscillations and reversals of potential direction, have been recorded at Houlton during auroral manifestations. At Wyanet the aurora was much less frequent and the potential recorded was seldom more than three volts. The directional effects during disturbances and the relative magnitudes of the potential gradient at different sites were found to be the same as those for the normal diurnal variation.

The underlying causes of earth currents are not completely understood, but it has been definitely established that they have diurnal and annual cycles which vary with geographical location. When solar disturbances occur, and during auroral displays, large transient earth currents flow and there is an accompanying disturbance in short-wave radio signals. Further extension of our knowledge of these currents and more complete coördination of the data with the associated solar and magnetic phenomena and with radio transmission are needed because of their bearing on the engineering of radio circuits.

Propagation of Ultra-Short Radio Waves

By CHARLES R. BURROWS
Radio Research

ULTRA-SHORT radio waves have the distinct advantage, where portability of equipment is a factor, that the dimensions of the apparatus required are relatively small, since these depend directly on the wavelength used. Waves of such short lengths, eight meters or less, are also not ordinarily returned to the earth at long distances by reflections from the upper atmosphere and therefore do not cause interference with stations in distant cities.* For these reasons police cars, for example, can advantageously employ ultra-short wavelengths for communication with headquarters; and short over-water circuits like that across Cape Cod Bay between Provincetown and Green Harbor, Massachusetts, become practical by their use†. These and the possibility of many other applications are making it increasingly important to obtain a considerably fuller knowledge of the transmission characteristics of very short waves.

Many of the properties of ultra-short waves are analogous to those of light. The concepts of reflection, refraction, diffraction and wave interference may fruitfully be borrowed from optics and applied directly in predicting the propagation characteristics of ultra-short waves. In simple cases these predictions are closely checked by experimental observations; in more complicated cases experiment indicates that some factors may enter which are at present undetermined.

The propagation of ultra-short waves over level terrain can be explained on the basis of the phenomenon of reflection alone. The waves may be regarded as radiating from the transmitting antenna at some definite point above the ground and the field produced at the receiving antenna as the sum of two waves: one propagated directly between the two antennas, and the other by reflection at the ground as shown in Figure 1. On this basis the received field intensity can be shown to be equal to that which would result in free space multiplied by a certain factor. This factor within limits is proportional to

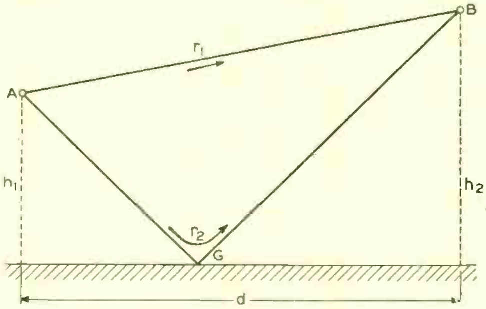


Fig. 1—In the propagation of ultra-short waves over level terrain, energy is propagated both directly as indicated by r_1 and by reflection at the ground as indicated by r_2

the product of the two antenna heights, and inversely proportional to the product of the wavelength and the distance between the antennas. These relationships have been confirmed by a series of experiments conducted in southern New Jersey with the aid of

*Record, *November*, 1933, *p.* 66.
†Record, *October*, 1934, *p.* 34.

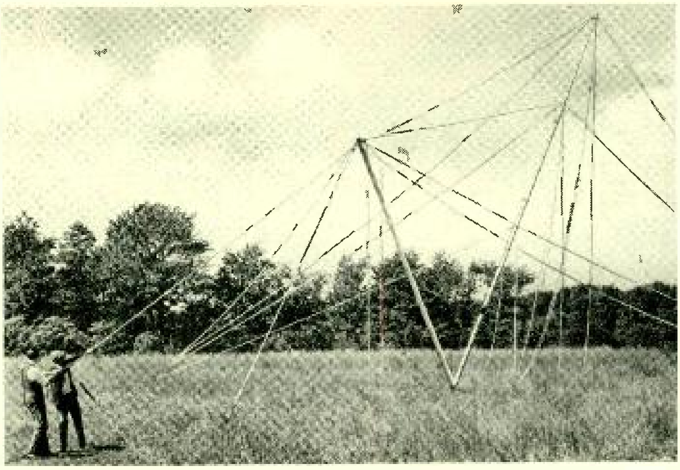


Fig. 2—This portable antenna mast is in three sections so that it can be carried on the side of a truck. Two men can assemble and erect the eighty-four-foot structure in an hour

the equipment shown in the accompanying illustrations.

The results are directly applicable to practical cases of ultra-short-wave transmission over level land, between two points close enough to permit neglecting the curvature of the earth. They show that the transmission with antennas which have the same configuration and dimensions, measured in wavelengths, is independent of the wavelength used. This means that small antennas can be used, for example, in mobile equipment, without decreasing the efficiency by transmitting on very short wavelengths, since the actual size of the antennas for a given output decreases with the wavelength. On the other hand, the efficiency of transmission of antennas of a given size can be increased by decreasing the wavelength used.

The propagation of ultra-short waves within a city, as in police communication, is complicated by the effects of buildings, trolley wires and elevated structures. As an automobile with a receiver is driven along a city street, the received field is found to vary from point to point in a very irregular way, as shown in Figure 3. When the records of many such trips in a particular city are averaged, however, the data show greater regularity and point to some interesting relationships.

The mass plot of these data (Figure 4) shows the same inverse-square-of-distance trend which is characteristic of transmission over level terrain. Besides causing the individual points to deviate from the mean curve, the city structures moved the mean curve to lower values. This indicates that the average effect of the city structures was to introduce an additional attenuation which is independent of distance. Moreover, the mean field turned out to be approximately the same as that which would have been produced if all the city structures had been removed and the antenna brought to the same height above the earth as it had

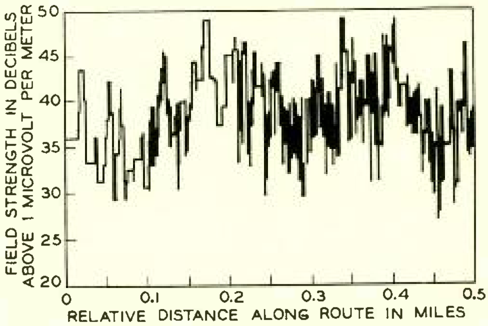


Fig. 3—These typical large field-strength variations were recorded while driving through the business district of Boston at about a mile and a half from the transmitter

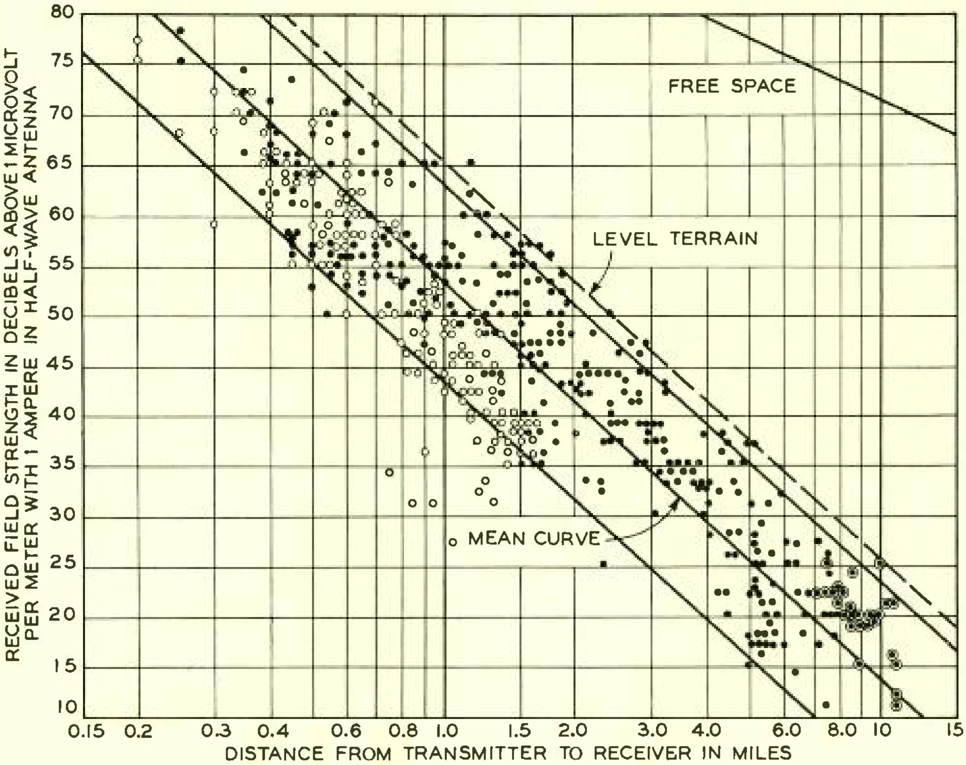


Fig. 4—Averages of field strengths observed at various distances from the transmitter in Boston are shown by open circles (business areas) and solid circles (residential areas). The upper two straight lines show the field strengths which would be observed in free space, and over level terrain with no buildings. The fact that the line representing the mean of the observations is parallel to the level terrain curve indicates that the buildings introduce an attenuation which on the average is independent of distance

been above the average roof height.

The field strength contours in Figure 5 reveal some other characteristics of ultra-short-wave transmission. The field is consistently higher when there is salt water immediately in front of the receiver, in the direction of the transmitter. The fact that the higher field does not persist at greater distances, when the receiver is separated from the water by more land, indicates that the influence of the water is strictly local. The phenomenon can be explained by observing that the higher conductivity of the water makes the directive receiving characteristic more favorable to low angle reception. Figure 5 also shows, by the crowding of the contours in the northeast corner, the relatively higher attenuation in the high building area.

In all these cases it has been possible to explain the results entirely in terms of reflection, and the interference between reflected and directly propagated waves. When ultra-short waves are transmitted over the path whose profile is shown in Figure 6, however, the concepts of diffraction and refraction must be taken into consideration to explain the observed fields, on account of the presence of an intervening hill. The variations of field strength with frequency

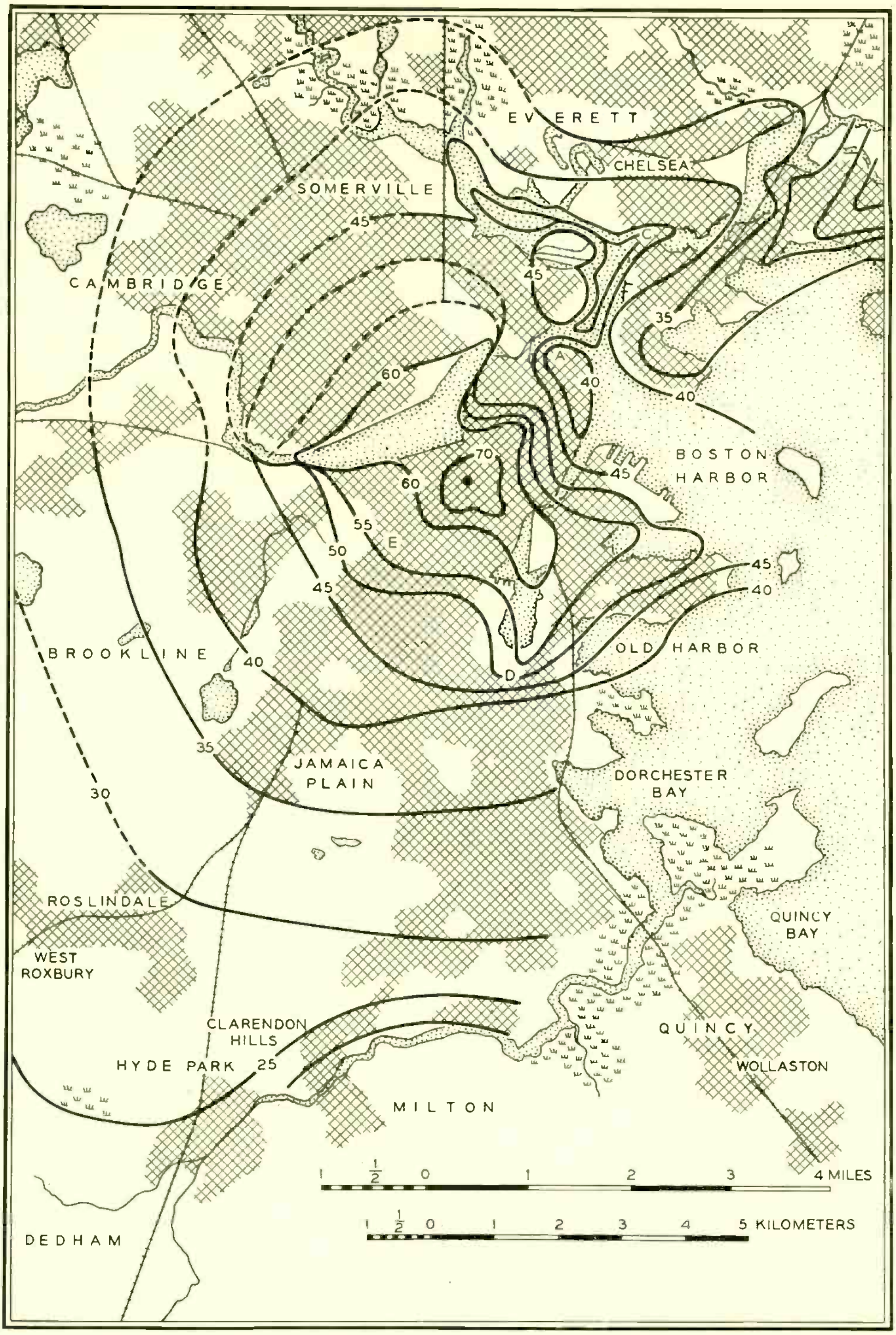


Fig. 5—A field strength map for ultra-short-wave transmission in Boston. The contours give the field strength in decibels above one microvolt per meter with one ampere in a half-wave antenna. Dotted lines represent plausible values in unexplored regions

as observed experimentally under these conditions are shown in Figure 6, Curve I. The shadow effect alone is not sufficient to explain the attenuation-frequency characteristics of the path, as can be seen from Curve II. Taking reflection also into account, and assuming that the ground is a perfect reflector, gives Curve III. Curve IV includes a correction for refraction in addition to those for diffraction and perfect reflection. Finally when the effect of imperfect reflection is considered the curve is raised at the lower frequencies as shown in Curve V. Evidently the latter curve satisfactorily reproduces the general trend of the observations shown in Curve I. The fact that maxima and minima occur in Curve I at lower frequencies than those predicted by Curve V indicates that the approximate theory of ultra-short-wave transmission upon which this curve is based neglects factors which become important above 100 megacycles. Further studies are in progress to determine more completely the physical characteristics of ultra-short waves and indicate more definitely their field of usefulness as carriers of the spoken word.

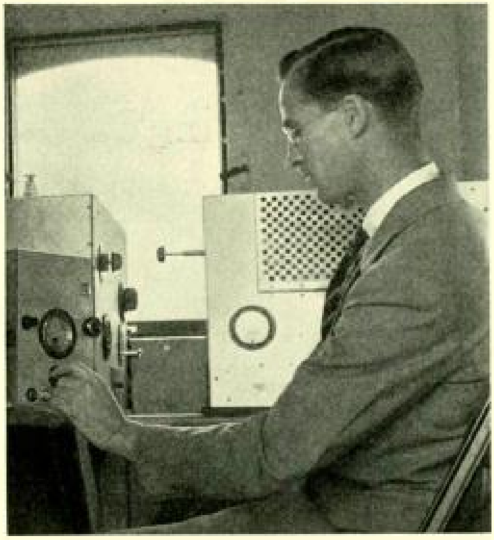


Fig. 7—Loyd E. Hunt, who is shown with the ultra-high frequency transmitter used in these measurements, and Alfred Decino have taken important parts in these experiments on ultra-short-wave transmission

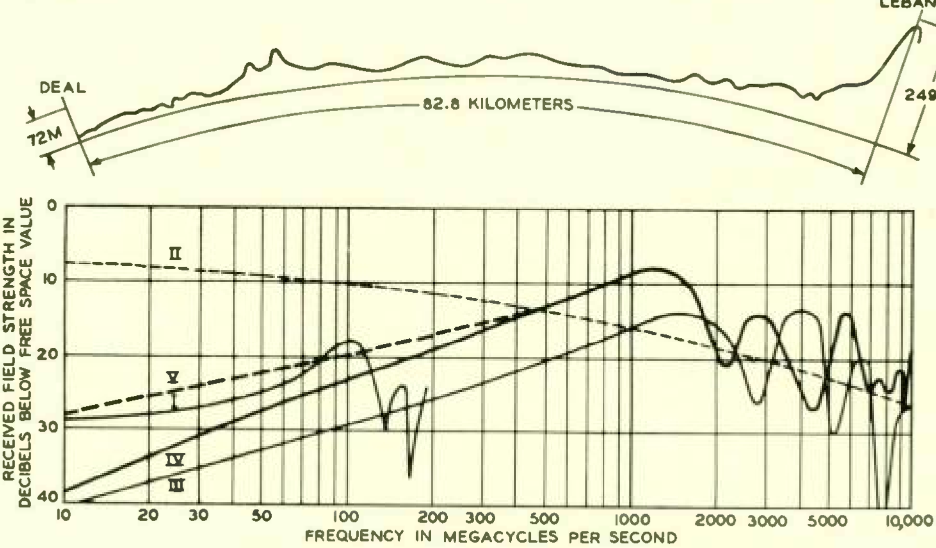


Fig. 6—Profile (above) of the "non-optical" transmission path between Deal and Lebanon, New Jersey, and (below) the frequency characteristics for the path as observed (Curve I) and as calculated assuming diffraction only (Curve II); perfect reflection and diffraction (Curve III); refraction, diffraction and perfect reflection (Curve IV); imperfect reflection, diffraction and refraction (Curve V)

Preparing Metals for Microscopy

By F. F. LUCAS

THAT metals constitute one of the most important groups of materials used in the telephone plant is obvious. But it is not so widely known that the service rendered by metals and alloys has been greatly improved in recent years through metallurgical and metallographic studies. Many new fields of usefulness have thereby been opened. Since the structure of metals and their physical characteristics go hand in hand, the metallographer has played an important part in these new developments. In this connection the careful preparation of metal specimens for microscopic examination has been found to be an indispensable step in the work.

The object in preparing a metallographic specimen is to produce a highly polished plane surface free from alterations so that the details of the structure which are subsequently brought out by etching will be typical of the metal under examination. With the development of high-power microscopes it became necessary to improve the technique of preparing specimens for examination to take advantage of the possibilities of the new equipment, for improvement in resolution attributable to superior lens systems can only be realized in practice by correspondingly more careful preparation of the surfaces to be examined. This is obvious when it is realized that we can now obtain real images of details which measure but a few hundred atoms in diameter; also that clearly defined details of structure can be observed which by actual measurement are only a fraction of the wave length of the light used to illuminate the specimen. In principle the preparation of specimens, which is merely a graded series of polishing operations, is relatively simple but in actual practice the fulfillment of all the requirements with the requisite precision is a difficult task.

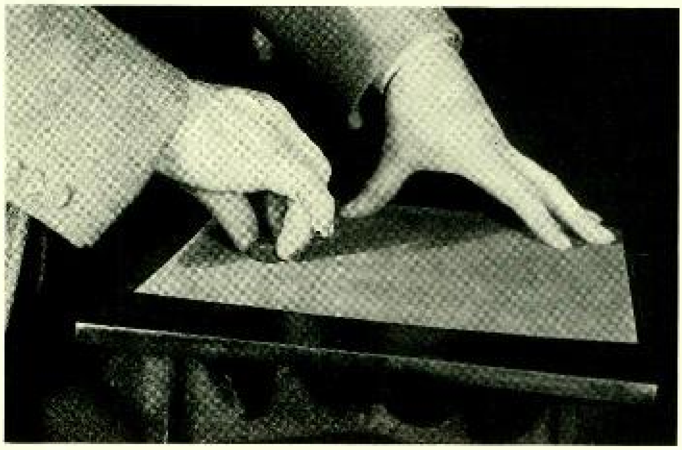


Fig. 1—One of the most important steps in preparing specimens is a series of polishing operations on a bench plate with aloxite papers of progressively increasing fineness

A metallographic specimen should preferably be round because it is easier to hold in the fingers and less likely to be caught in the polishing lap. It should be about one inch in diameter and one-half inch high. Small or irregular specimens may be mounted to advantage in bakelite rather than in fusible metal as was formerly customary. The first step in the preparation of the surface is to grind one face of the specimen flat. This is done on a bench grinder with a six-inch aloxite wheel. The specimen is held with the fingers flat against the surface of the wheel, which is cooled by a stream of cold water directed just above the position of contact with the specimen. The edges of the specimen should be beveled to prevent tearing the lap in subsequent work. Then follow a series of grinding operations with aloxite papers laid on a bench plate for rigidity and flatness. These papers are of increasing fineness for each succeeding operation and vary in grade from number 240 to 400. The specimen is pushed back and forth slowly by the fingers under light pressure; the direction of grinding in each succeeding case is across the scratches of the previous paper, since the object to be attained is the complete removal by a finer cut surface of the scratches of the preceding coarser paper. About fifteen minutes in all is required for the paper work which is one of the most important operations of the entire process since it is here that the foundation is laid for the final polishing operations. These latter are carried out on horizontal laps which consist of metal discs about six inches in diameter covered with fine woolen broadcloth for the preliminary lap and with the finest "Kitten's ear" broadcloth for the final lap. The cloth is held in place by a metal ring or hoop which fits over the rim of the lap wheel. The broadcloth covering is soaked in water before it is applied to the wheel so that it can be stretched tightly across the surface by the ring. A separate polishing head or machine should be used for the final polishing operation to prevent contaminating the fine abrasive of the final operation with the coarser abrasive from the preliminary polishing. Alundum powder mixed with water to form a thin

Fig. 2—The final polishing operation is carried out on horizontal laps covered with broadcloth which is stretched tight and wet with a thin paste of alundum powder and water. R. M. Sample is demonstrating the method

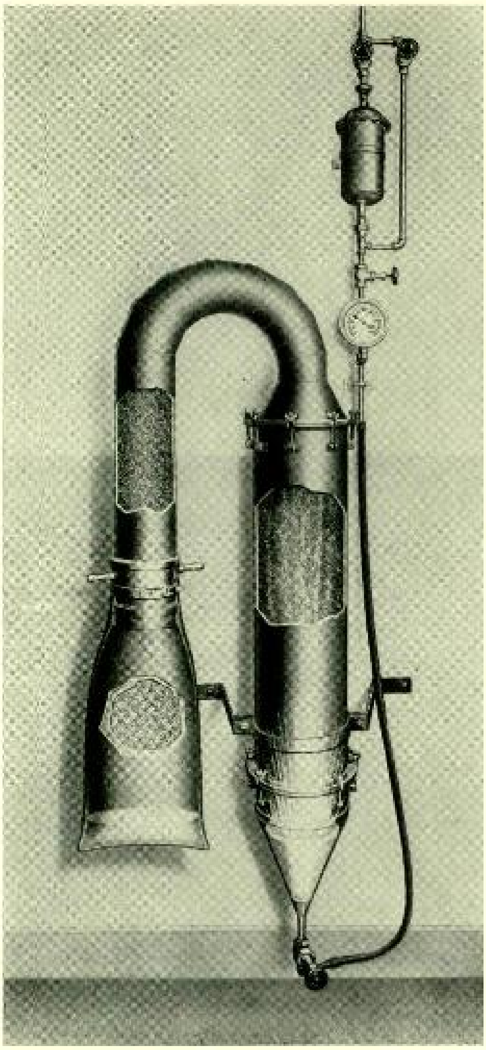


Fig. 3—An air flotation separator was devised to refine polishing materials. Commercial magnesium oxide was placed in the cone-shaped hopper, and all but the coarse particles blown over into the collecting bag by a current of air

paste is spread on the wet broadcloth for this operation. This is replenished from time to time as needed from a bottle containing alundum powder and water. The specimen is moved back and forth from center to periphery under light pressure and is oriented so that the lap scratches cut the scratches of the last and finest aloxite paper at right angles. From five to ten minutes of this procedure should suffice. To inspect the specimen it is rinsed with tap water and examined with a 6X hand magnifier.

The specimen has now reached the finishing stage on the alundum lap, and should present a uniform surface. If it is a hard steel it will give a fairly good mirror image although under the magnifying glass very fine scratches will be seen. The next operation is to improve the mirror surface and define the inclusions sharply. This is done by rotating the specimen slowly about the lap in the opposite direction to that in which the wheel rotates so that the polishing will take place from all directions. The progress of the work, which takes about five minutes, should be checked frequently with a metallurgical microscope—magnification 100 diameters. The specimen is then thoroughly washed and dried on bibulous paper or a linen towel.

The final polishing operation is done with magnesium oxide. For this the polishing cloth of "Kitten's ear" is prepared by soaking it over night in a two per cent to four per cent solution of hydrochloric acid in water to soften it, after which it is thoroughly washed in water and stretched tightly on the polishing lap. Magnesium oxide powder, specially prepared by the process to be described later, is mixed with water to form a thick cream and spread over the central part of the lap. The specimen is then polished by the rotation method described for the semi-final polish on the alundum lap. This requires about fifteen minutes; at the end of this time a brilliant mirror-like surface, with inclusions standing out sharply defined and no pitting of consequence, should result.

During the last few moments liquid soap is applied to the lap to loosen the fine particles of abrasive which adhere to the surface of the specimen. After washing thoroughly with soap and water and then drying, the specimen is ready for etching.

The etching is done by holding the specimen with non-corrosive forceps and carefully submerging it in the etching solution which may consist of reagents such as nitric acid, picric acid or hydrochloric acid in absolute alcohol. The etching process is watched under a strong light and a stop watch is frequently used to time the process. The specimen is then washed in three successive alcohol washes and dried in a warm air stream. It is then ready for the microscope and should be kept in a desiccator when not in use.

The quality of metallographic specimens depends to a large extent upon the fineness and uniformity of the final polishing material—magnesium oxide. There are two grades of commercial magnesium oxide, one of which is prepared by grinding and the other by precipitation. Either is satisfactory provided it is free from hard, gritty particles. Since it is impossible to obtain a satisfactory commercial product it was necessary to devise a quick and convenient means for refining the magnesium oxide. This was done by constructing the air flotation separator shown in the illustration. The cone-shaped hopper at the bottom of the separator encloses an air nozzle having a large number of small apertures. This hopper is connected by means of an airtight rubber gasket to the vertical pipe above it, the upper end of which is similarly attached to the curved pipe leading downward and to the left. The lower straight portion of this curved pipe has a screw fitting to which is fastened a porous paper bag, about the size of an ordinary flour sack. This is secured to the collar of the fitting by

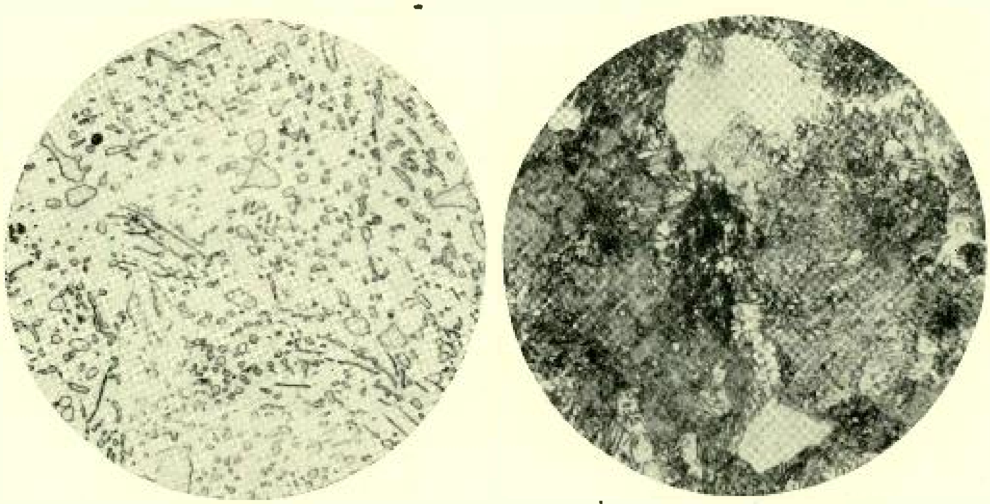
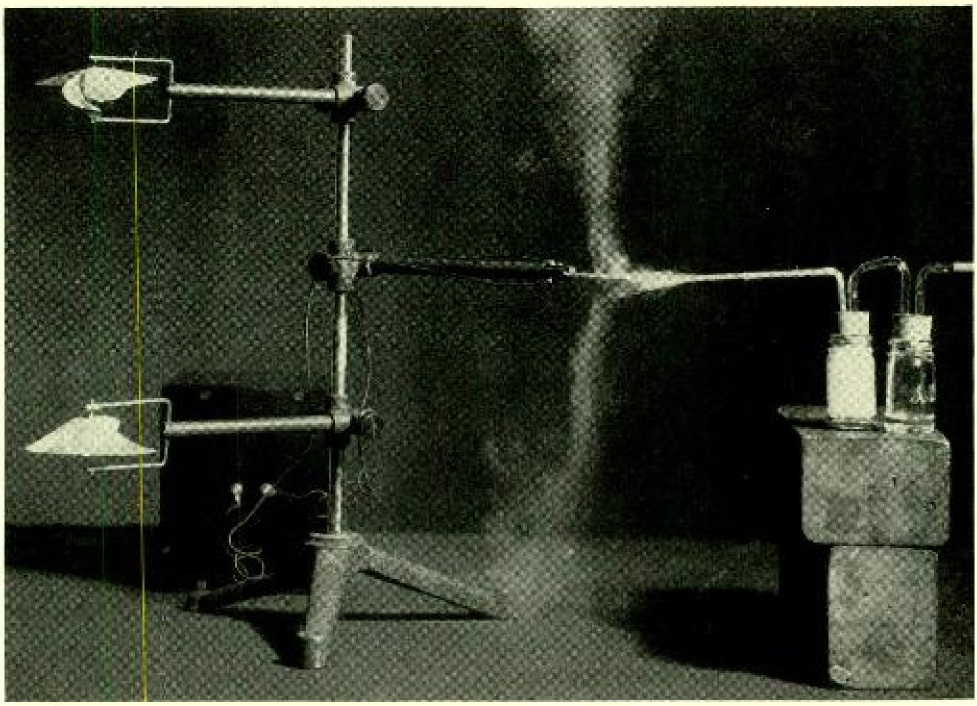


Fig. 4—The microstructure of steel changes radically with heat treatment. At the left is a fully annealed specimen. The carbide, which is the hardening element, is shown dispersed throughout the mass as minute globules. At the right is the same specimen after heating to 1500 degrees C. for 40 minutes. The small globules have been dissolved in the iron and precipitated again on cooling. The micrographs represent a circular area on the specimen 0.002 inch in diameter

means of adhesive tape. Over the paper bag is secured by a convenient lever fastener a porous cloth bag of the general type used on vacuum cleaners. This bag is used as a safeguard in case the air pressure should cause the paper bag to burst. Now and then a defect or weakness occurs in paper bags and unless some provision is made, such as the cloth bag, the fine powder will be blown far and wide.

When ready for use about five pounds of commercial heavy magnesium oxide powder are placed in the cone-shaped hopper at the bottom of the separator and the nozzle is connected to a filtered air supply under a pressure of about thirty pounds per square inch. The air is gradually turned on until the bag is fully distended and under considerable pressure which blows the powder upward and carries the finer particles over the "goose-neck" into the paper bag where they are collected. The coarser and heavier particles drop back. The operation is a continuous one requiring little attention except to tap the hopper occasionally in order to prevent the powder from collecting about the walls. The yield is large and one day's operation will provide a month's supply of fine magnesium oxide. By varying the height of the vertical pipe some control can be exercised over the fineness of the resulting powder. Two interchangeable sections are employed, one of which is thirty-five inches and the other seventy-eight inches long. Both are nine inches in diameter. If the former is used, a coarser, quick-cutting powder results which will be found satisfactory for most work providing too high an air pressure is not used. The longer pipe produces a finer powder and a lessened yield. For finishing work on critical specimens this abrasive leaves little to be desired.

The separated powder is placed in pint fruit jars and the uncovered jars are placed in a drying oven at a temperature of 100 degrees Centigrade for about twelve hours. While still hot the jars are sealed tightly with covers and rubber rings, and allowed to cool. In this condition the powder will keep almost indefinitely. Using the shorter pipe, a typical particle size determination of the finished powder by ultra-microscope methods showed the average diameter of the particles to be 0.176 micron. The uniformity of the product is shown by the fact that nearly half of the particles were of the average size and that only six per cent were as much as 0.33 micron in diameter. They are difficult to measure since they are transparent to the light of the ultra-violet microscope and are therefore invisible in the usual mounting media. This limitation was overcome by using an ultra microscope with intense annular illumination. Magnesium oxide prepared as here described provides the most effective abrasive thus far available for the final polishing operations in the preparation of metallic specimens for microscopic investigations.



Wind From Quartz Crystals

By S. C. HIGHT
Radio Research

IN recent years quartz crystal plates have come into wide use as frequency stabilizers for high-frequency radio systems. Such plates exhibit the piezo-electric effect in having an interlinked electric and mechanical vibration: if an alternating electric potential is applied across opposite faces, the crystal will vibrate mechanically, and conversely a mechanical vibration produces an alternating electric potential on opposite faces. The frequency at which the plate vibrates depends primarily on its dimensions, although ambient conditions have some influence. The action of these quartz plates has been studied intensively in these Laboratories, and during the course of some of these studies experiments were made with the currents of air created by a crystal while vibrating. Currents are produced flowing away from each of the two opposite broad faces of a crystal. The effect is shown in the photograph at the head of this article, where smoke is employed to indicate the path of the air stream.

With one type of plate that is used for frequency control, the quartz crystal is cut so that the electric axis is perpendicular to the large area of the plate, as shown in Figure 1. Resonance occurs at a frequency equal to 2.86×10^6 divided by the thickness of the plate in millimeters. When an alternating potential of this frequency is applied to the opposite faces of the plate, the surfaces move alternately apart and together. The motion of each surface is thus analogous to that of a piston with large area and very small stroke—the number of strokes per second being very large.

Consider for example a plate five centimeters square and 2.86 millimeters thick. The natural frequency of such a plate is a million cycles per second, and experimental measurements show that the surface moves about 8×10^{-5} centimeters. From the area of the plate and the amplitude of the motion, it may readily be calculated that each stroke of the surface, considered as a piston, displaces approximately two cubic millimeters of air. Since the surface is making a million strokes per second, the total displacement, if accumulative, would be 2000 cubic centimeters per second. A vibrating plate yielding such a displacement would constitute a fair size pump if there were some valve arrangement to prevent the air from flowing back as the surface receded.

As already stated such a surface does pump a current of air, and experi-

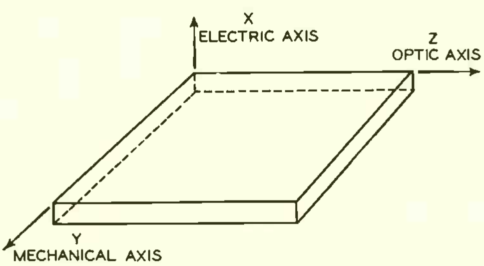


Fig. 1—An X-cut quartz plate has its electrical axis perpendicular to the face

ment shows that the quantity is just about that given by the above calculations. There must, therefore, be a valve action of some sort. While a completely satisfactory explanation has not yet been found, an analysis of the conditions at the surface indicates a likely cause of the action.

The molecules comprising the air have a mean free path, and thus an approximate spacing, of about 1000 Angstrom units. Since the movement of the surface is approximately 8000 Angstrom units, it moves through about eight layers of atoms. From the amplitude and frequency of the crystal vibrations it may be inferred that

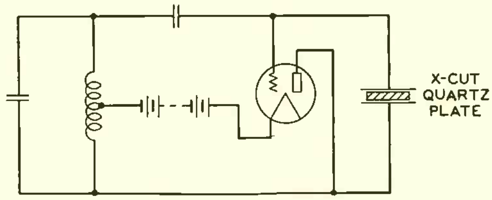


Fig. 2—Schematic of circuit used for producing crystal wind

the surface of the plate reaches a maximum velocity of 500 centimeters per second, and to reach this high velocity in so short a time—a quarter of a millionth of a second—the acceleration must be some 20,000 miles per second per second. This is a tremendous acceleration. If it were continued for ten seconds the surface of the crystal would be a million miles away and moving with a velocity greater than that of light.

Under normal conditions the air molecules are moving in random directions with velocities slightly under 500 meters per second. As the crystal surface moves out, it gives to those molecules not already moving away from the face an outward acceleration of large value. As the surface of the crystal recedes, the kinetic energy imparted to the molecules forces them to continue in their outward directions, but molecules around the edges of the plate, which still have random motion, rush into the space made vacant. As the surface moves out on the next stroke, these molecules are in turn forced out, and the result is an essentially continuous stream of air flowing away from the faces of the crystal. This valve action is nearly independent of the frequency of vibration of the plate. Winds have been observed for vibrations as low as 50 and as high as 4000 kilocycles.

To study these winds it is best to apply the electric field to the crystal by means of thin metallic films on the crystal surface. A coating of silver may be applied by the process used in making mirrors, or thin films of platinum or other metals may be applied by sputtering, or evaporation in a vacuum. These films are very light and flexible, and—adhering to the crystal—move with the surface of the crystal in vibrating. Contact is made at one corner of the slab by a spring clamp, which also serves as a support for the crystal. The circuit used, shown in Figure 2, is similar to the usual oscillator circuits that are employed for controlling the frequency of radio transmitters.

With a one-megacycle crystal of the dimensions considered above, the wind generated is sufficient to operate four-inch paper windmills placed on both sides of the crystal at a distance of a foot. The shape of the air stream can be studied by watching the action of the smoke. Turbulence is observed several feet from the crystal. The air stream has about the same cross-sectional area as the crystal for a distance of about a foot and then gradually becomes wider.

Dr. Davisson Honored by the Royal Society

The Hughes Medal has been awarded by the Royal Society (London) to C. J. Davisson for his discovery, jointly with L. H. Gormer, of electron diffraction. The award, established in 1900, has been conferred on such distinguished scientists as Dr. Owen Williams Richardson, Dr. Niels Bohr, Dr. Francis William Aston, Duc Maurice de Broglie, Sir Venkata Raman and Dr. William Lawrence Bragg.

Electron diffraction is what takes place when a stream of electrons is shot into a suitable crystal. The atoms, arranged in a regular pattern in the crystal, cause the electrons to emerge in a few sharply defined beams. Occurrence and disposition of the beams can only be explained by the hypothesis that electron streams behave in some respects like trains of wave such as those of light and x-rays. Since it was well known that electrons are just as discrete particles as the pellets of lead from a shotgun, the idea that a stream of them could also be treated as a beam of light was a forward step which opened up wide vistas to the atomic physicist.

Dr. Davisson has been engaged in fundamental investigations in thermionics and electronic physics ever since he became associated with the Laboratories in 1917. In 1928 he was awarded the Comstock prize by the National Academy of Sciences and in 1931 the Elliott Cresson Medal by the Franklin Institute.

DR. GEORGE A. CAMPBELL

Thirty-eight years of unusually productive service in the Bell System were concluded when Dr. Campbell retired from the Laboratories on the first of December. As a mathematical physicist and inventor his achievements entitle him to rank first among theoretical workers in electrical communication. The diversity of his contributions illustrates the unusual versatility of his genius.

In the early 1900's he formulated rules for loading coils and their spacing. Appreciating the function of capacity in cross-talk between adjacent communication circuits he designed the "shielded" balance and the capacity unbalance test set which have been used on thousands of miles of toll cable. He was the first to apply the "articulation" method of testing telephone equipment; he made a comprehensive study of substation networks from which he derived the anti-side tone set; and he invented the electric-wave filter. His basic analysis of repeater circuits, showing the advantage in the two-way, two-element circuit, aided transcontinental telephony in 1914; and his four-wire circuit is used in most of the long-distance toll cables in service today.

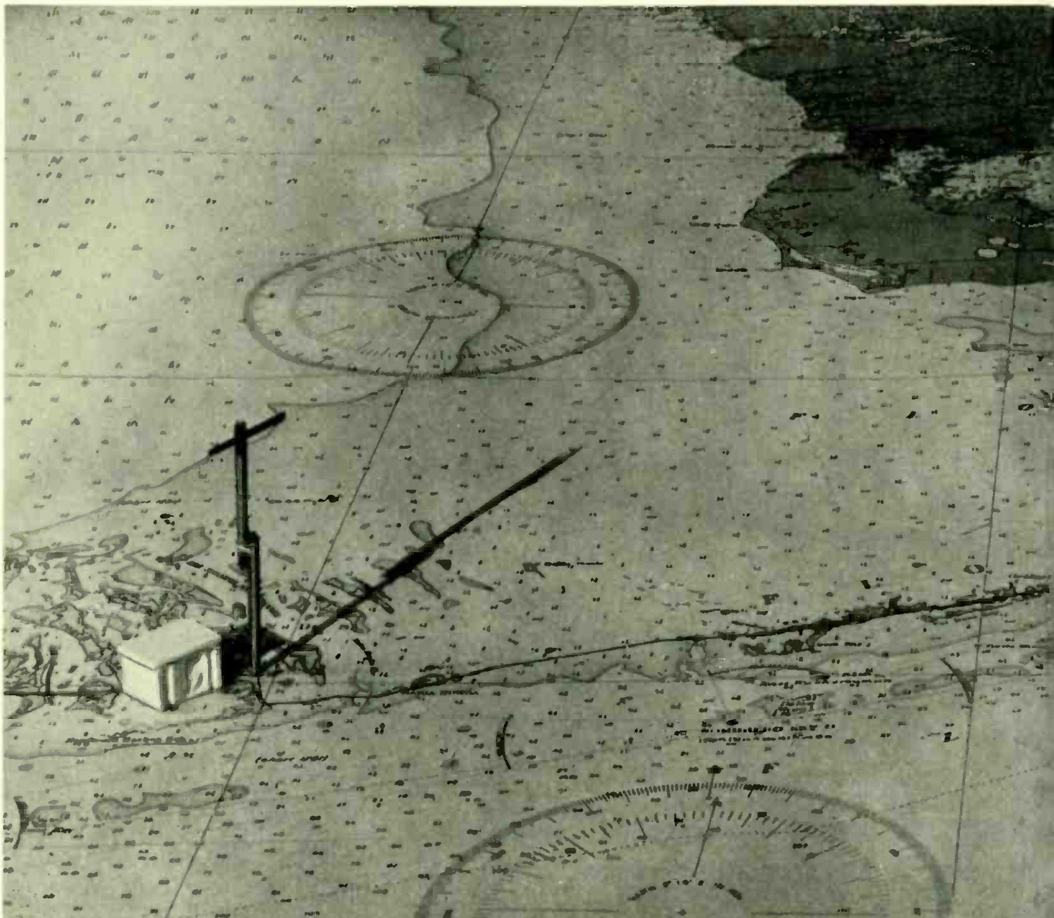
Radio Bridges Hurricane Break

By F. B. WOODWORTH
Radio Development Department

On September second, a tropical hurricane swept across the Florida Keys, completely demolishing large sections of the Florida East Coast Railway along a forty-mile stretch from Tavernier to Vaca Key. The telephone pole line runs along the railroad right-of-way between Miami and Key West, where it connects to the Havana cables, thus forming part of the route between the United States and Cuba. In some places the railroad fills were washed away, allowing the poles to topple over. In other places, high water lifted the rails and ties from the roadbed, and the wind blew them against the poles, knocking them down. Where the poles were on the windward side of the railroad, they remained standing. The damage to all communication and transportation services in the vicinity was so severe that it was several days before the true extent of the devastation could be determined. It then became apparent that it would be advantageous to postpone plans for the restoration of the telephone lines until more information could be obtained regarding the plans for restoring the railroad and highway, and until different methods of taking care of the telephone service could be studied. It was, therefore, decided to bridge the gap temporarily by radio, and applications for station licenses were rushed to Washington.

Within eighteen hours after this decision had been reached all equipment for two radio circuits in each direction was on board a train bound for Florida, and B. L. Dayton of the Long Lines Department and the author were on their way to supervise the installation of the two terminals, assisted by J. F. Andrews of the Long Lines Department who was already in Florida. One of the terminals was to be located near Tavernier and the other at Big Pine Key, thirty-five miles east of Key West. Two line gangs were sent from Alabama and Louisiana by boat to Key West and thence by automobile to Big Pine Key. Here they immediately set to work clearing away the underbrush, dynamiting in masts for the antennas, and erecting two shacks, each about eight by twelve feet, for the radio transmitters and receivers. The second day after work started in the field, radio contact was established on a temporary basis. In the meantime the linemen were bringing in connections from the open-wire circuit to Key West, and on September 21 the first circuit was formally turned over for service.

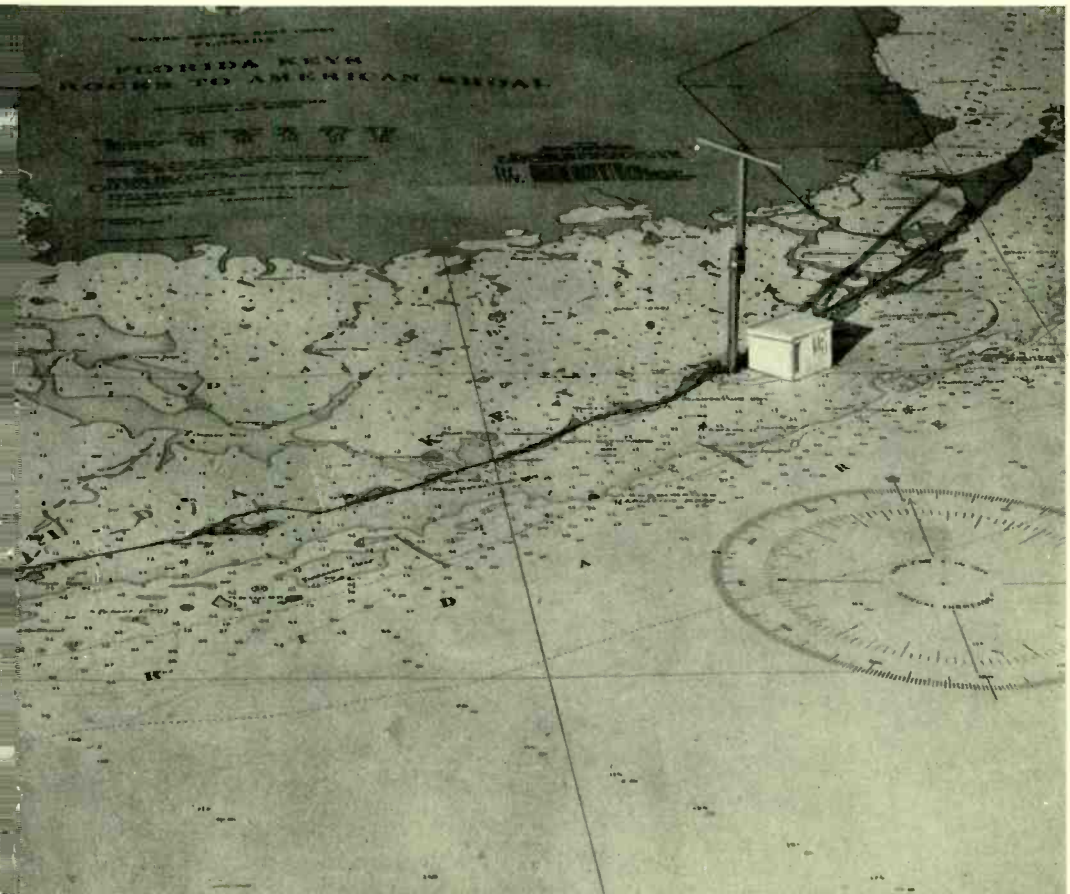
In the preliminary conferences, held to decide the type of apparatus to be employed, it was recognized that a considerable amount of electric power would be required for the operation of the radio apparatus. Since no commercial power was available anywhere near the sites of the radio terminals, it was desirable to use the most efficient and the lowest-power radio equipment available. This led to the decision to use some of the low-power equip-

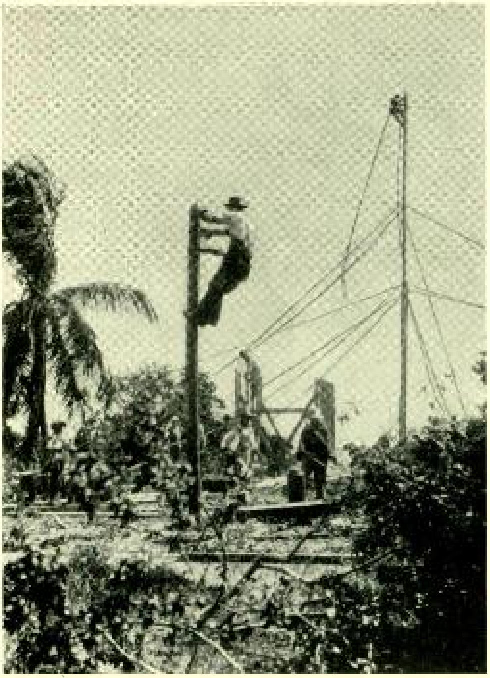


ment developed for airplane and ship-to-shore communication. To meet these requirements the five-watt 19A transmitter* and a 12-type receiver† were finally selected. Both of these units have very moderate power requirements, and 12-volt storage batteries could be used as a primary source of power. Complete radio equipment for four channels, two in each direction, including batteries and dynamotors, was shipped from New York to Miami, where it was taken by truck to the site of the eastern terminal just outside of Tavernier. Here half of it was unloaded and the rest put on a fishing boat for the fifty-five-mile water trip to Big Pine Key.

*Record, *this issue*, *p.* 136.
†Record, *May*, 1933, *p.* 273.

The equipment and arrangement at the two terminals are practically identical. The two radio shacks and antenna poles at Big Pine Key are shown in the photograph at the head of this article. The shacks are about 300 feet apart and each has its antenna poles located adjacent to it and as near the water as practicable. The transmitter antennas are single-wire verticals approximately a quarter-wavelength long. One antenna is fed by a concentric transmission line and the other runs directly to the radio transmitter. Vertical wires were also used for the receiving antennas.





Space had to be cleared in the mangrove jungle before construction could start

all speech wires near the radio receivers, and the composite coils in the connecting telephone lines, were carefully shielded and grounded. The use of underground lead cable to connect the two shacks was another precaution against such interference. With these precautions, and the inherently high quality of the radio apparatus employed, transmission is exceptionally good considering the small amount of power used. During the day a user talking from New York to Havana would not be aware that a radio link was included in the circuit. Sometimes bad static conditions are encountered at night. More than 80 per cent of the calls normally originate during the daytime, however, and the circuit, during the first few weeks, was kept in operation only during daylight hours. Indications are, however, that as cooler weather arrives the circuit can be used up to midnight.

Not only was the installation completed in a remarkably short time, but it was carried out under adverse conditions. The sites were covered with a dense mangrove jungle, with mosquitoes and sand flies in droves. Some conception of the appearance of the country may be obtained from the illustration which shows one of the sites during an early stage in the construction. Smudges were kept going continuously in a more or less vain effort to beat back the mosquitoes. Although the shacks were screened, so that the installation inside the shack could proceed without too much annoyance from mosquitoes, the screening proved of little value in barring the sand flies, which readily passed through its meshes. In addition, there were the transportation difficulties caused by the remoteness of the radio terminal sites and the disruption of normal transportation services. In spite of all obstacles, however, the work proceeded rapidly, and the second channel was turned over on September 28. For the first time a radio link had been used in this way as an emergency means of restoring service in an important telephone line.

Measuring Inductance of Coils With Superimposed Direct Current

By H. T. WILHELM
Telephone Apparatus Development

THE general use of alternating current as the primary source of power for radio transmitters has focussed more attention on the design of filters to suppress hum in the rectified supplies. These filters are composed of condensers and coils. Only the alternating component of the current passes through the condenser, but the direct as well as the alternating component of the current passes through the coils. These coils usually have iron cores and the values of their inductance, on which their effectiveness depends, vary with both the direct and alternating currents passing through them. For accuracy in design, therefore, the inductance of the coil must be known under operating conditions. In the past it has been customary to measure the inductance of these coils with the required direct current values but at low alternating voltages because of limitations of the existing equipment. The greater attention now being paid to design details, however, and the more careful consideration of cost, have led to the need for apparatus which will measure the inductance of coils under exact service conditions.

To make such measurements possible, the Laboratories have developed a circuit employing a Maxwell type bridge that will measure the inductance of coils with as much as one thousand volts across them, and with superimposed direct current as high as twelve amperes. The circuit has several unusual features which are indicated in the schematic diagram of Figure 2. It consists of three principal parts: an a-c

Fig. 1—Making a measurement of inductance with the new measuring circuit

power supply, a d-c power supply, and the bridge itself.

The a-c supply equipment consists of a half-kva transformer with a ten-to-one voltage ratio, a blocking condenser, C_1, to keep the direct current from passing through the transformer winding, and an a-c voltmeter, also equipped with a blocking condenser. An external regulator of any convenient type is employed to adjust the applied voltage up to the maximum of 120 volts.

The d-c supply equipment consists primarily of a retardation coil to keep the alternating current out of the direct-current supply, and a protecting condenser. A battery or any other convenient source of direct current may be employed. A direct-current ammeter for measuring the superimposed direct current and a rheostat for controlling the value of the current are required but are not mounted with the rest of the equipment.

The retardation coil has four equal windings, and is designed to withstand high alternating potentials. By suitable switches, the four windings may be connected all in series, all in parallel, or in a series-parallel combination, thereby making it possible to use a single retardation coil for the entire range of the bridge. With a d-c supply circuit consisting only of the battery and retardation coil in series, an open in the battery connections would result in the production of high potentials on the low-voltage apparatus. To avoid this the large capacitance condenser, C_2, is shunted across the terminals of the d-c supply. This condenser, by providing a low impedance path to ground for alternating potentials, prevents any possibility of high voltages building up across the battery leads.

Both the a-c and d-c supplies are connected across terminals BD of the Maxwell bridge. This bridge is of the product-arm type. The fixed arms are opposite each other rather than adjacent, so that the bridge constant depends on their product rather than their ratio. The coil to be measured is connected across the terminals B and C, and the resistance and capacitance standards, used to measure the effective resistance and inductance of the coil, are in the arm AD. The balance equations for the bridge are: $L_X = (R_{AB}\ \ R_{CD}) \times C_{AD}$, and $R_X = (R_{AB}\ \ R_{CD})/R_{AD}$. The fixed arms, R_{AB} and R_{CD}, are selected so that their product, which appears in the equations for both L_X and R_X, is 10^6 ohms; and as a result $L_X = 10^6 C_{AD}$, and $R_X = 10^6/R_{AD}$. Thus the inductance of the coil in henrys is equal to the capacitance of the standard in microfarads and the effective resistance of the coil is a million times the reciprocal of the resistance of the standard. For very precise work it would be necessary to add to this

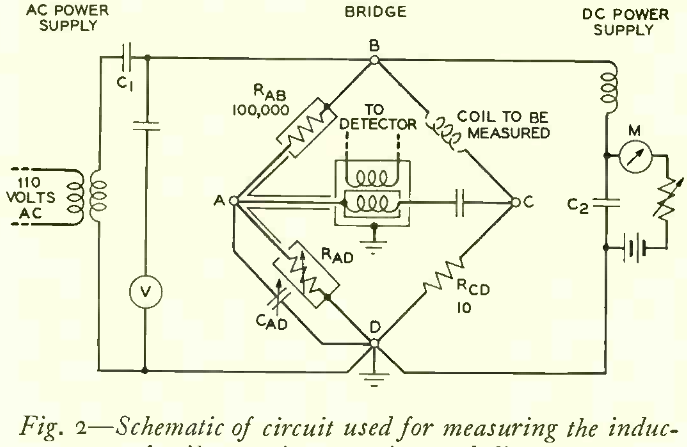


Fig. 2—Schematic of circuit used for measuring the inductance of coils carrying superimposed direct current

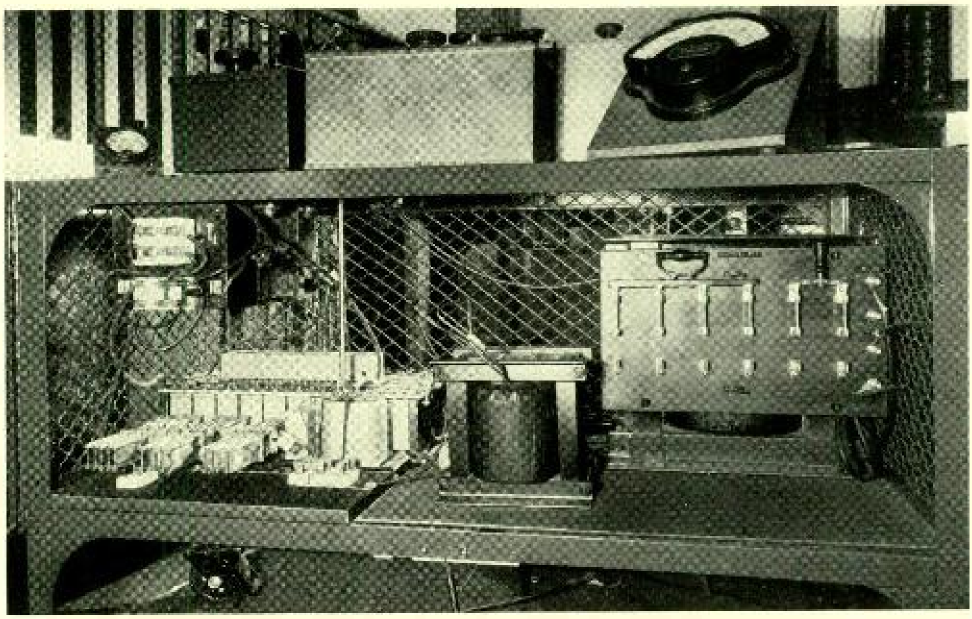


Fig. 3—Inductance measuring table showing meters and standards on top and all apparatus at high potential mounted in the lower section

the conductance of the capacitance standard, but this conductance is so small that it is negligible under the conditions for which the bridge is designed.

A ratio constant of 10^6 could be obtained by using for the arms AB and CD any two resistances whose product is one million. If each resistance were 1000 ohms, for example, the same balance equations would still apply, but the distribution of current and voltage in the bridge would be radically different. By using 100,000 ohms in AB and 10 ohms in CD, as indicated in the schematic, the voltage and current distribution is particularly suited to the problem in hand. The low resistance of the path B–C–D insures that practically all of the direct current passes through the unknown reactance, and thus permits an efficient use of the superimposed direct current. The low impedance of R_{CD}, compared to the high impedance of the unknown inductance, on the other hand, insures that practically all the voltage drop of the applied alternating potential occurs across the arm BC, which again is the objective desired. The drop across the arm CD is ordinarily less than 2 per cent of the total, and thus the reading of the a-c voltmeter may be taken, with sufficient accuracy, as the voltage across the unknown inductance. Other advantages of this arrangement are that the direct current through the standard resistance is reduced to a negligible amount, and that the a-c potential applied to the bridge need not be higher than that desired across the unknown inductance.

With the ten-ohm resistance in arm CD, the range of the bridge is from 2 to 40 henrys, but provision has been made for extending this range both up and down. By changing the resistance of the arm CD from 10 to 20 ohms, which is done by throwing a small switch, a ratio of 2 is provided,

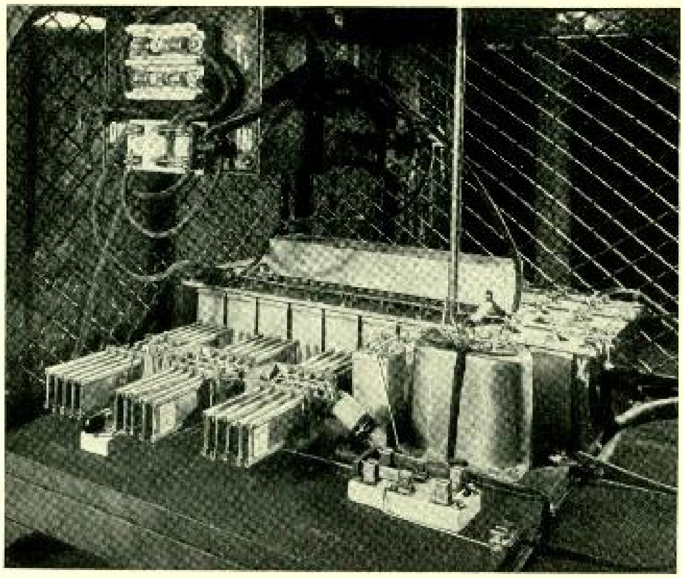


Fig. 4—Arrangement of lower section of inductance measuring unit

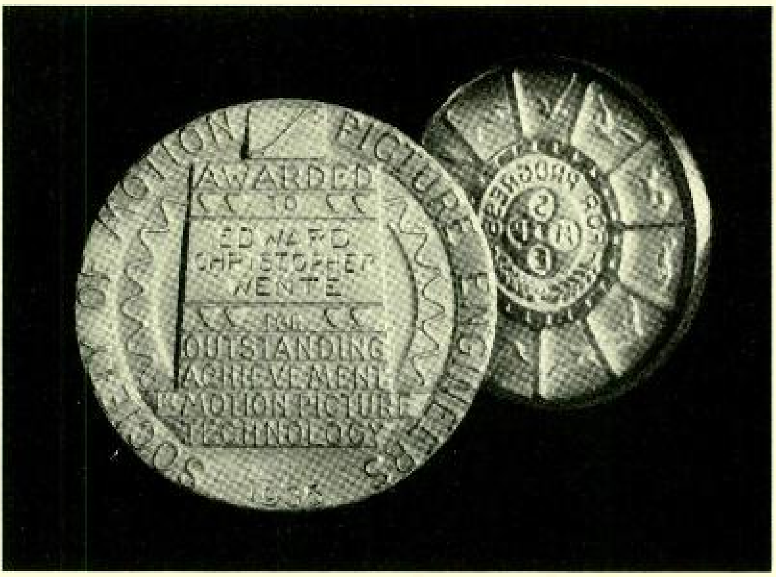
while on the lower section, enclosed by locked gratings, is the rest of the equipment, including everything that is at high potential.

A close-up view of this lower compartment is shown in Figure 3. At the extreme right is the retardation coil in series with the d-c supply, and mounted in front of it are the switches that select a parallel, series, or series-parallel arrangement of the coils. To the left of this unit is the inductance coil under test, and at the extreme upper left is the input transformer. The assemblage of apparatus at the lower left includes the rest of the equipment and may be seen readily in Figure 4. At the left are the resistances making up the three possible values for the arm CD. At the right of this are the detector transformer and the condenser that is in series with it. The assemblage of condensers at the rear are the blocking condenser C_B, the voltmeter condenser and the protecting condenser shunted across the direct-current supply. On top of these condensers is the resistance unit for arm AB in its shielding cover. The doors that enclose this compartment are equipped with door switches that disconnect both the direct and alternating current supplies when the doors are opened.

thus permitting measurements up to 80 henrys. A switch is also provided for changing this resistance to 1 ohm, which permits measurements to be made of inductances below 2 henrys. The permissible amount of superimposed direct current is to a large extent limited by the heat dissipation of the resistance of the arm CD. With the 10-ohm unit, 4 amperes may be applied while with the 1-ohm unit the current may be as high as 12 amperes. With 20 ohms, on the other hand, 2 amperes is about the safe limit. Any frequency from 20 cycles to 1800 cycles may be employed.

The apparatus is made portable by being assembled on a double-decked steel table mounted on large casters equipped with floor locks which prevent it from moving while a test is being made. The general appearance of the set-up is shown in Figure 1. On the top of the table are the standards of capacitance and resistance, the a-c voltmeter, and the detector meter,

This new bridge thus furnishes a convenient means for measuring the inductance of coils over a wide range of current, inductance, and frequency. It eliminates the necessity of using bulky and inefficient inductance standards required with the older direct comparison bridge, and offers the additional advantage of permitting high alternating voltages to be used with safety. Because of its more efficient utilization of applied power, less demand is made upon power sources and less provision is required for dissipation of heat in the bridge. These advantages, combined with simplicity of operation and portability, give the bridge wide applicability wherever inductance measurements with superimposed currents are required.



The Progress Medal awarded to Dr. Edward C. Wente by the Society of Motion Picture Engineers for his fundamental contributions and outstanding inventions in motion picture technology.

A Radio Transmitter for the Private Flyer

By R. S. BAIR
Radio Development Department

IN recent years the use of airplane radio equipment has steadily increased, and great strides have been made in perfecting suitable apparatus for all types of aircraft from the largest transport planes to the smaller privately owned sport planes. The extensive employment of such equipment has, of course, tended to stimulate development activities in this field, since the greater the demand for any type of apparatus, the more is intensive development economically justifiable. As a result of this interaction of development and demand, and of a wide experience in all fields of radio development, the Laboratories have now made available through the Western Electric Company a new airplane transmitter for the private flyer and other operators of small planes. It measures only 8½ by 8½ by 5½ inches and weighs, complete with shock-proof mounting, less than 14 pounds.

Fig. 1—The 19A radio transmitter in use

This new transmitter, known as the 19A, operates over the frequency range between 2 and 7 megacycles and offers three types of transmission: telephone, continuous-wave telegraph, and modulated continuous-wave telegraph. For either telephone or modulated continuous-wave telegraph, the output carrier power is 5 watts and complete modulation is obtained. For continuous-wave telegraph a carrier power of 15 watts is available. Two jacks are provided on the front of the transmitter, one for a microphone and one for a telegraph key. Primary power is obtained from the 12-volt airplane battery, the filaments being connected in series across the battery, and the high voltage being obtained from a 550-volt dynamotor operated from the battery.

A schematic circuit of the transmitter, designed by W. C. Tinus, is shown in Figure 2. It employs only two vacuum tubes, both of the same type, a recently developed power pentode tube (Western Electric No. 307A) with the suppressor grid brought out for modulation. The first tube is a crystal-controlled oscillator. It acts in conjunction with either of two crystals mounted in the same holder and ground so as to require no temperature control. The desired crystal is selected by a switch on the front of the transmitter. This arrangement permits the pilot to make full use of the two frequencies, 3105 and 3120 kc, assigned by the Federal Communications Commission for calling and working with any Department of Commerce station along the commercial airlines or with any airport equipped for such service. No tuning adjustment is necessary in shifting from the calling to the working frequency. Other frequencies in the band may be used by inserting the proper crystal and readjusting the single tuning control. The second tube acts as either an amplifier, a modulating amplifier, or a modulating amplifier and voice frequency oscillator, depending on the type of transmission being employed.

A three-position control key on the front of the transmitter or at a remote control position, permits selection of the type of transmission required. With this key in either of the telegraph positions, the dynamotor operates continuously, while with the key in the telephone position, the dynamotor operates only when the switch on the microphone is pressed.

When the control key is set for telephone transmission and the microphone is plugged into the proper jack, the voice currents modulate the carrier through the transformer T-1

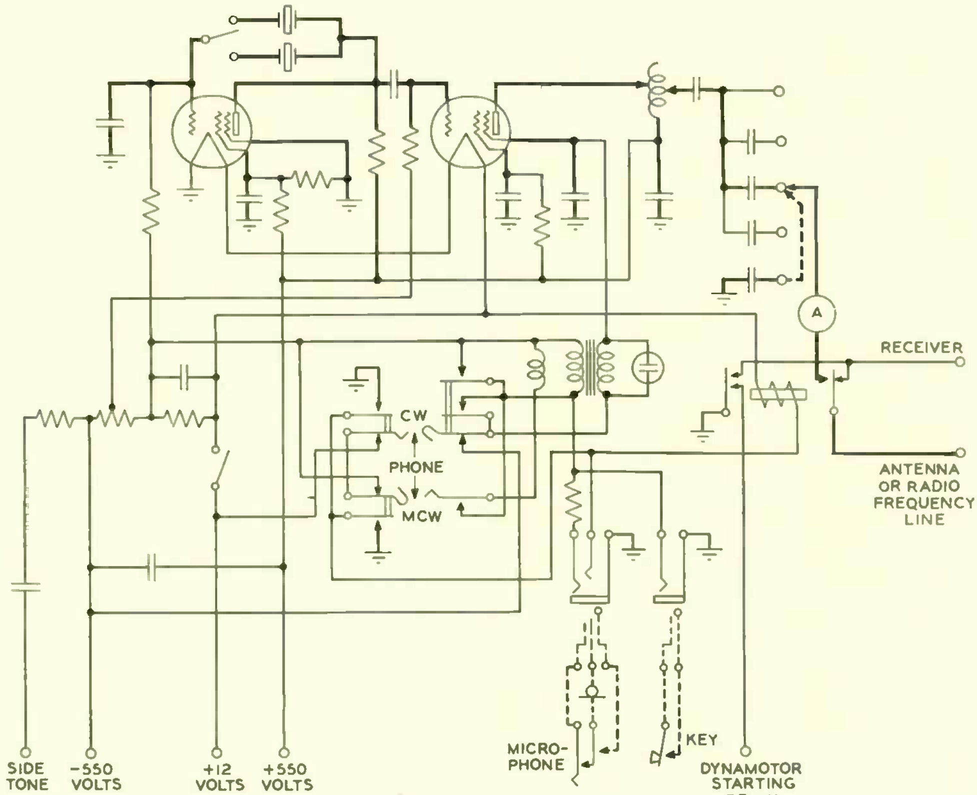


Fig. 2—Simplified schematic of 19A radio transmitter

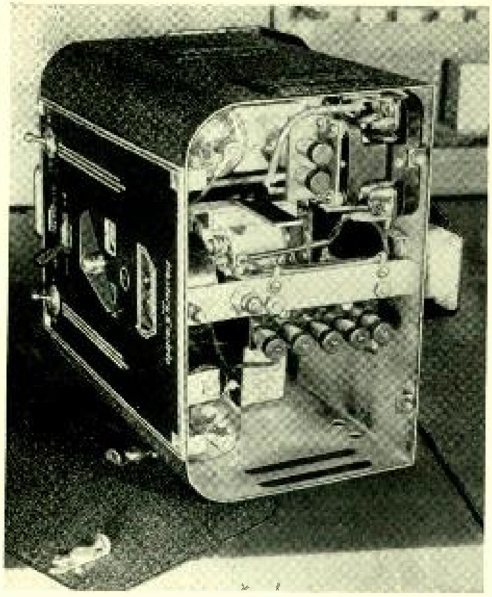


Fig. 3—Interior of 19A transmitter from the top, showing compact grouping of the apparatus as laid out by C. E. Cerveny

and the suppressor grid of V-2. In this way complete modulation is obtained without the use of an audio amplifier tube and with very good quality. The frequency characteristic is that of the transformer and microphone, which is flat to within 3 db from 350 cycles to 5000 cycles.

With the control key set for modulated continuous-wave telegraphy, the circuit is arranged so that when the telegraph key is up both tubes are biased below cut-off. When the telegraph key is down, the bias is reduced to the operating value and in addition the second tube is made to oscillate at about 800 cycles. The signals sent out are thus the carrier modulated completely with 800 cycles.

With the control key set for continuous-wave telegraphy, both tubes are biased to cut-off as for modulated continuous wave, but when the telegraph key is down, the second tube acts as a carrier amplifier only, and the negative bias is decreased so that essentially full output of the tube is obtained. This results in an output power of 15 watts for continuous-wave telegraphy.

An interesting feature of this transmitter is that no adjustment of the oscillator is required. The only frequency control is the switch to select either of the two crystals available in the crystal holder. Another feature of interest is the output tuning coil. This is tuned by contacts rolling on the turns of the coil—a method already described in the Record.* The coil itself is rotated by a handle on the front of the transmitter and two rolling contacts ride on its turns, one connected to the amplifier plate and one to the antenna. These rollers move together as the coil is turned, but provision is made for raising one of the rollers out of contact to allow the distance between contacts on the coil to be adjusted as required. Several antenna coupling condensers are provided to accommodate the various types of antennas which may be installed on different planes.

An antenna relay is included in the transmitter to switch the antennas from the receiver to the transmitter. This relay is associated with the circuit that starts the dynamotor so that the antenna is switched whenever the microphone switch is pressed with the control key in the telephone position, or whenever the control key is in either of the telegraph positions.

While this transmitter was designed primarily for the private flyer for use in conjunction with the 17A Radio Receiver, its small size, light weight and simplicity of operation make it suitable for other applications where space is limited and high power is not essential, as on harbor craft.

*Record, *September*, 1935, *p.* 17.

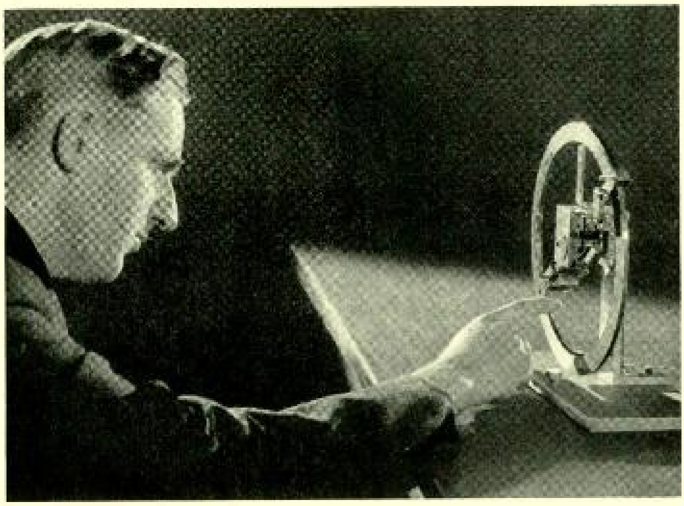
A Bend Tester for Vacuum Tube Wires

By W. J. FARMER
Materials Engineering

A VACUUM tube that spends its days and nights in a telephone repeater, firmly mounted in a steel-and-concrete building, has a much easier life than its fellow in a radio set, jostled and bounced in an airplane or a police car. With the growing use of Western Electric tubes in these mobile installations, more severe requirements had to be met by the mechanical structure of the tubes. Strains encountered in handling and shipping the tubes must be withstood, while too much rigidity of the internal structure tends to transmit to the electrodes vibrations encountered in service and so to produce microphonic noise-currents. In manufacture, the growing complexity of tubes calls for close and accurate spacing between elements. These are supported from the glass envelope by wires bent into the desired form by a tool or mechanism which is so designed that when its force is removed the wire will spring back exactly to the proper configuration. Thus considerations of manufacture, shipment and use all require close control of the stiffness of the supporting wires.

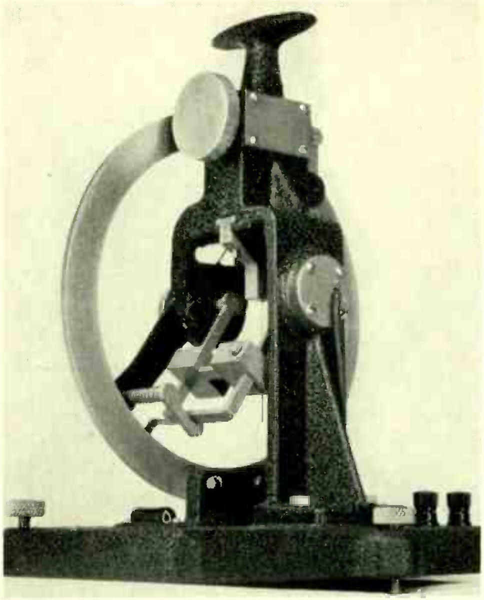
Over many years the hardness of wires for vacuum tubes has been designated by manufacturers as "quarter-hard" or "one hole hard" and some such designation has been used in purchase specifications. For the purchaser to check a specimen of wire against this sort of description was impossible. Feeling the need for a test which could be readily applied by both buyer and seller, and which should have some relation to the actual use of the wire, the Vacuum Tube Development Department investigated a number of such tests which had been proposed by manufacturers or users of wire. All of these had limitations which made it difficult to reproduce their results.

Eventually a machine was designed to bend a sample by the force of a known and reproducible impact, and a model was built in the Development Shop of the Laboratories. The com-

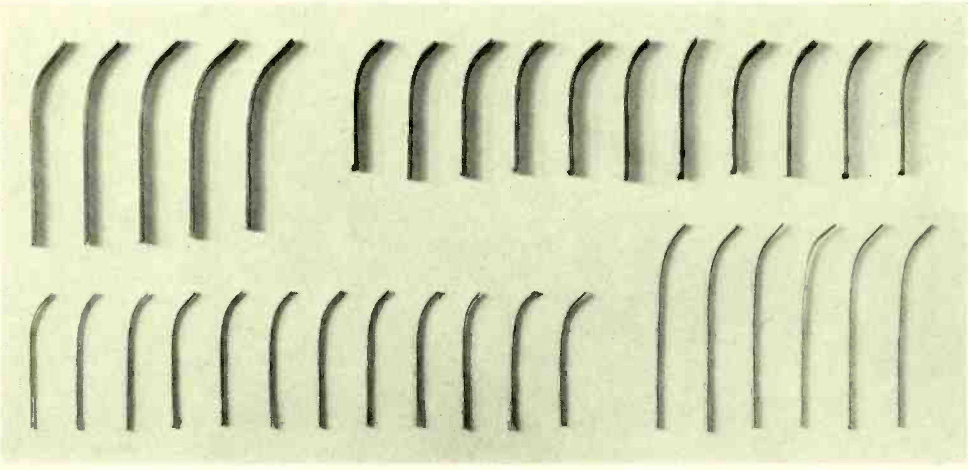


D. A. S. Hale of the Vacuum Tube Development Department with his early model of the bend tester for vacuum tube wires mercial design of such a machine, to cover the complete diameter and length range of support wires in which we were interested, was undertaken by the Materials Engineering group. The resulting machine is shown in the illustrations; it is designed primarily for measuring the bend which a test sample will receive when struck by a mass falling from a given height. The dial gives the bend in degrees.

Support wires whose temper lies within the useful range, whose lengths range from one to five centimeters, and whose diameters are from 0.003 to 0.125 inches can be tested. The energy of impact may be varied in two ways: first, by increasing the angle through which the pendulum falls from 20 degrees to 120 degrees in half-degree steps and, second, by maintaining a constant angle of fall of the pendulum but varying the distance from the center of the pendulum weight to the center of rotation. The machine weighs approximately twenty pounds and occupies a space of approximately one cubic foot. A handle is incorporated which affords ease in carrying the tester to any location in the shop, inspection department or laboratory. The only adjustment necessary before making a test, besides setting the pendulum weight and the angle of fall, is to level the



A sample is clamped in the jaws by turning the knurled knob at the top, and the pendulum is then released from the latch



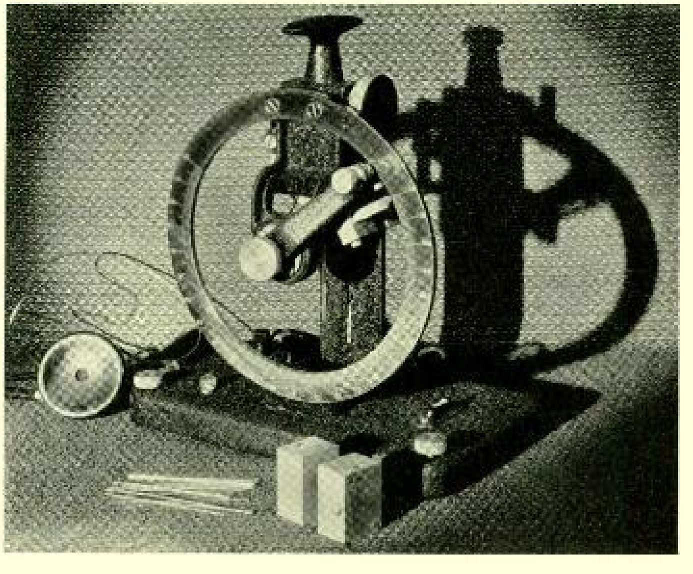
Specimens of pure annealed nickel wire after testing. The larger samples are 0.050-inch wire; the smaller, 0.020-inch. The angle of fall was adjusted to give approximately a 40-degree bend in each case. In each group, the angle fell within a range of ± ½ degree machine; this is accomplished by manipulation of the levelling screws and is indicated by spirit levels.

The procedure in conducting an inspection test on a shipment of wire as received from a source of supply may be briefly described as follows: Upon referring to the specification under which the material was purchased, the striking edge is located on the pendulum arms to the specified distance from the edge of the jaws and the latch device which holds the pendulum is set at the specified angle of fall. The test sample is then clamped vertically between the jaws. The release latch is operated and the pendulum falls, striking and bending the sample. Since the pendulum must strike the specimen only once, it is arrested manually as it swings back. The final step in the test is to move the pendulum toward the bent specimen until contact is indicated by lighting of a lamp, or a click heard in a telephone receiver. The amount of the bend is then read directly from the dial with the aid of the pendulum index pointer. Experience has shown that the angle of fall and the distance from the striking edge to the jaw should be so arranged that the resultant angle of bend of the sample will be somewhere between thirty and sixty degrees.

Since the reliability of the method depends on the constancy of velocity of the pendulum, it is important that friction should be both small and constant. To this end the pendulum system turns in two self-aligning ball bearings. Were friction entirely absent the pendulum when swinging freely would rise to the same height as that from which it fell. A series of tests showed that the pendulum regained from 90.3 to 99.6 per cent of its initial height, the lower values being recorded for smaller initial heights and shorter radii of the striking edge. In all cases where the drop was from an angle of 50 degrees or more, the height regained was greater than 95 per cent.

In order to determine whether or not results obtained with this machine are satisfactorily reproducible, specimens of straight, dead soft annealed nickel wire were tested at various lengths. Some of the bent specimens, illustrating the uniformity of the test, are shown in Figure 1.

This machine can be used for control of hardness of temper of material for vacuum tubes, and for analysis of these materials after they have passed



The bend tester with its accessories: a head receiver and an extra-heavy pendulum weight for large specimens. A number of test-specimens appear in the foreground through manufacturing processes or have been in service for a period of time. It will also satisfactorily test wire of any temper or composition as well as sheet material three-eighths of an inch or less in width, the testing procedure being the same as described for the vacuum tube support wires.

At the annual meeting of the American Society for Testing Materials, held in Detroit during June of this year, the bend tester was exhibited and demonstrated. Much interest was shown at the time, and the machine has been recommended by a subcommittee of that Society for the testing of vacuum tube support wires. Tests of magnet wires have shown that the machine offers promise as a specification instrument in that field.

Contributors to This Issue

H. T. Wilhelm joined the Electrical Measurements group of the Laboratories in 1922. In 1924 he left to complete his studies at the Cooper Union Institute of Technology, working at the Laboratories during the two following summers. Upon graduation in 1927 with a B.S. in E.E. degree, he resumed his work with the Electrical Measurements group. He has since been engaged in measurement and calibration work, preparation of testing specifications, and in the design and development of impedance bridges. During this time he has taken graduate work in physics and electrical engineering.

During the summer of 1923 while still enrolled at the University of Michigan, Charles R. Burrows worked at Rocky Point in the development of the long-wave transatlantic radio transmitter. On receiving the degree of B.S.E. in electrical engineering in 1924, he returned to the Laboratories and undertook the design of the test oscillator for the Rugby long-wave transmitter. He began research on short-wave radio with the inception of intensive work along these lines. His analyses of short-wave propagation to Europe and South America formed the basis on which these short-wave trans-oceanic services were established. The article in this issue of the Record gives some of the propagation characteristics of ultra-short waves. He has also developed methods of measuring the amount of phase modulation in the output of a radio transmitter and was in charge of a theoretical investigation of multiple tuned antennas which resulted in means of predicting the transmission characteristics of this type of antenna. In 1927 he received the degree of A.M. in Physics from Columbia for studies conducted there on a part-time basis. This June the University of Michigan conferred on him the degree of Electrical Engineer.

For over thirty years F. F. Lucas has been engaged in activities associated with telephone work. After operating experience with various companies, in 1910 he joined the Western Electric Company. While in charge of inspecting timber products for this company he purchased a microscope to study the product and thereby started work in the field of microscopy which he has pursued with such brilliant success for the past twenty years. His improvements in technique have greatly increased the magnification used in high-power microscopy and he is also responsible for the practical development of ultra-violet-microscopy. In the course of this work he originated and designed, in coöperation with the staff of the Zeiss Company, the largest and most powerful microscope in the world for the study of metal structure. These developments have been of vital importance in studies of the microstructure of materials used in the telephone plant. Dr. Lucas was given the degree of Sc.D., honorary, in 1931. He holds four medals for outstanding contributions to the field of photo-micrography.

For slightly more than a year in 1923-

H. T. Wilhelm

C. R. Burrows

F. F. Lucas

1924 F. B. Woodworth was a member of the Research Department. He left in September, 1924, for Schenectady and started on the Electrical Engineering course at Union College. For three summers while at college he worked with the New York Telephone Company. Following his graduation in 1928 he became a member of the Radio Development group and worked on radio-beacon and aircraft radio-telephone development at Hadley Field. At present he is engaged on the development of radio-telephone apparatus for harbor craft. Mr. Woodworth's trip to Alaska in connection with a trial installation of the radio telephone on the fishing boats of Libby, McNeil and Libby, described in this issue, took place during the past summer from May 9 to August 5.

R. S. Bair graduated from the Electrical Engineering course of Newark Technical School in 1915 and came to West Street the following year. In 1917 he joined the Research and Inspection Division of the Signal Corps and spent the following two years in France. On returning to the Laboratories he entered the Research Department where he engaged in radio development. In 1922 he went to Rio de Janeiro for a year where he was engaged in two-way radio communication and broadcasting in connection with the Centennial Exposition celebrating the independence of Brazil. At the present time he is supervisor of the group developing aircraft transmitters.

F. B. Woodworth

R. S. Bair

Mary K. Corr

Mary K. Corr became a member of the headquarters staff of the American Telephone and Telegraph Company in 1921. Until 1932 her work was connected with the development of loading for telephone circuits. About the middle of that year when she was transferred to the high-frequency transmission group, an investigation was under way of the nature of earth currents and their relation to magnetic conditions and radio transmission. The article in this issue of the Record indicates the nature and results of this study on which she has continued to spend much of her time since she became associated with the Laboratories in 1934. Miss Corr was graduated from Hunter College with a B.A. degree.

S. C. Hight received the B.S. degree in Electrical Engineering from the University of California in 1930, and at once joined the Technical Staff of the Laboratories. Here with the radio research group he engaged in the study of quartz-crystal oscillators and their associated circuits, and at the same time took post-graduate work at Columbia, receiving the A.M. degree in Physics in 1934. He is still assisting the research on crystals that has recently resulted in radical improvement in the temperature coefficient of frequency.

Upon returning from overseas service with the American Expeditionary Forces, W. J. Farmer entered Pratt Institute from which he graduated in 1922. Then entering the Specifications Group of the Laboratories, he prepared specifications for the manufacture of general and special apparatus. With the organization of the Materials Engineering Group in 1924 he transferred to it, and for several years has acted as a consultant for other groups on problems relating to aluminum and its alloys. Among these were the selection of the proper alloy, its heat treatment and the manufacturing processes for diaphragms used in various microphones and transmitters. He took an active part in the development and manufacturing technique for the production of the high strength aluminum alloy used in the various light valve ribbons for sound pictures. This development he described in the Record for January, 1929.

From June, 1931, to October, 1933, he was connected with the Apparatus Analysis Group. Recently he has been concerned with development problems on cable sheathing materials, fatigue studies and general test methods as well as the design of special testing equipment and field studies of strain in aerial cable sheathing.

S. C. Hight

W. J. Farmer