BELL LABORATORIES RECORD

THE IONOSPHERE
W. M. GOODALL

DEPICTING TELEPHONE CURRENTS
M. K. ZINN

COTTON AS AN INSULATOR
A. C. WALKER

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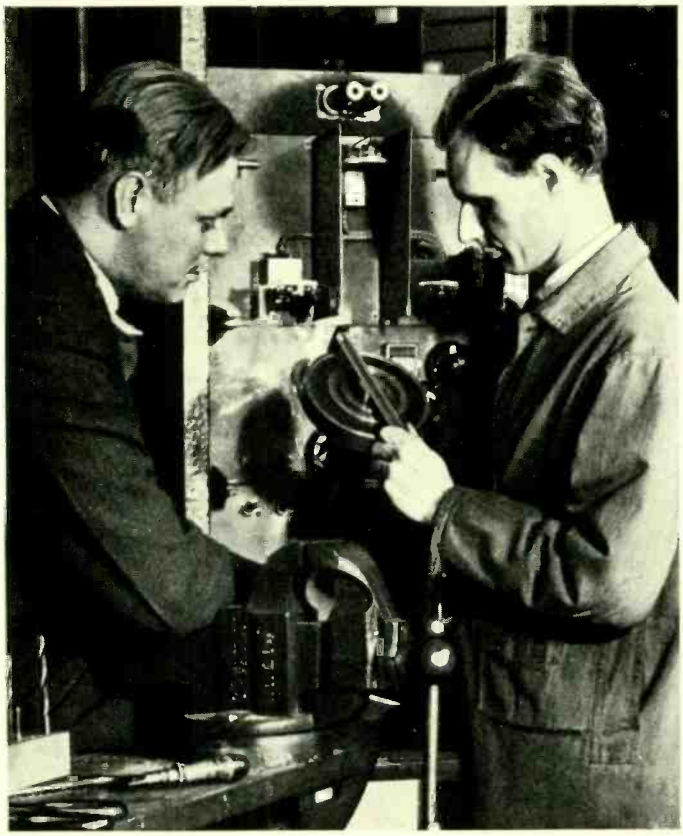

Work in progress on the construction of an experimental repeater for use with a coaxial line

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The Ionosphere

By W. M. GOODALL
Radio Research

WHEN you pick up your telephone and talk with a friend in Europe, South America, or Hawaii, the radio waves commonly employed to carry your voice do not cling to the earth in their journey, but reach their destination after being reflected from some point high in the atmosphere. For short-wave transmission, it has been known for some time that as the receiver is moved away from the transmitter, the received signal becomes weaker and at a comparatively short distance—from 50 to 100 miles—disappears entirely into the background of noise. As the distance is further increased, however, the signal will reappear, and become strong. This phenomenon is known as the "skip" effect. Its observation led to the inference that short-wave signals are returned to the earth at great distances from the transmitter by being reflected from some of the upper layers of the atmosphere. Without such a reflecting region, long-distance radio communication by short waves would be impossible. It is obviously desirable to have as sound a knowledge as possible, both of the physical nature of this region and of the method by which radio waves are propagated through it. With this in view, experiments have been carried on for some time by J. P. Schafer and the writer at the Deal Laboratory.

Early in 1882, Balfour Stewart had suggested the existence of a conducting layer high in the atmosphere to explain variations in the magnetic field of the earth. In 1902, Kennelly and Heaviside had independently also used the assumption of a conducting layer to provide a mechanism capable of reflecting radio waves. In spite of these early suggestions, however, it was not until the last decade that experiments had been carried out which were sufficiently direct to satisfy the few who held to the bitter end that a conducting layer is an unnecessary assumption. Today, however, no one questions its existence. The evidence admits of no other interpretation.

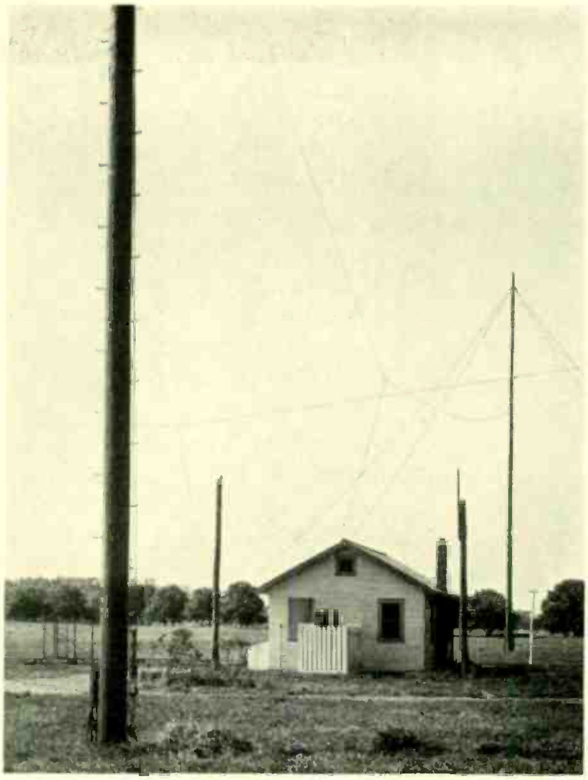


Fig. 2—Ionosphere measurements are made in a small building with transmitting and receiving antennas stretched above it

Present-day knowledge of conductivity in gases suggests that this conducting layer is an ionized region of the atmosphere. Ultra-violet light from the sun is, under favorable conditions, a powerful ionizing agency, and might well produce these ionized regions. From measurements made by the Laboratories during a recent solar eclipse, moreover, it appears that the sun is largely responsible for ionization in at least two of the reflecting regions of the upper atmosphere.

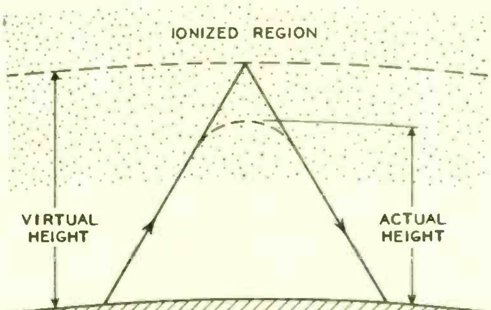


Fig. 1—Radio waves are not reflected as light from the surface of a mirror, but in effect curve around at a decreased velocity

The atmosphere surrounding the earth may be divided into two or more layers. The lower of these, extending upward to about eleven kilometers above the earth, is known as the troposphere. In this region clouds form and temperature decreases in proportion to altitude. In the region above this level, called the stratosphere, the temperature does not vary with altitude and cloud formations of the type found in the troposphere never appear. It is in a still higher region that radio waves are reflected, and it has been suggested that this latter region be called the ionosphere, a name that was derived from its most important attribute—ionization.

A convenient method of studying the ionosphere is to measure the time required for a radio signal to travel to the reflecting layer and back to the earth. Knowing the velocity of the waves, one can easily compute the distance to the point of reflection from the total elapsed time, much as the distance to a mountain could be calculated by timing the return of a sound echo. With radio waves, however, an uncertainty enters because the reflection does not occur sharply at a plane. The wave penetrates the ionized region for some distance and in this region its velocity is reduced.

Because of this, two heights are referred to—the virtual height and the actual height. Virtual height is that calculated on the assumption that the radio wave travels with the velocity of light to the reflecting plane where it is sharply reflected and returns at the same velocity. Actual height is that of the highest point the wave reaches. The situation is suggested diagrammatically in Figure 1. When the virtual height is independent of frequency for a considerable range of frequencies, the virtual height is probably not greatly different from the actual height. When virtual height changes with frequency, it may be several times the actual height. Only the virtual height can be measured directly, but from plots of virtual height against frequency together with certain reasonable assumptions, it is possible to estimate ionic density of the different reflecting regions and to make approximate estimates of the actual heights.

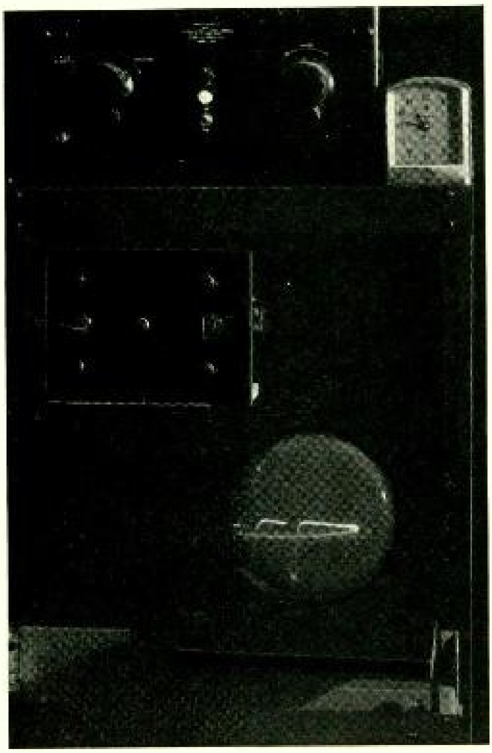


Fig. 3—A pattern on a cathode ray tube furnishes the necessary data for calculating virtual heights

For measuring virtual heights a radio transmitter and receiver are mounted side by side so as to be controlled by a single operator. The arrangement is shown in the photograph at the head of this article. Transmitting and receiving antennas are located above the small building housing the testing apparatus, as shown in Figure 2. Short pulses are sent out from the transmitter at the rate of sixty per second, which travel up to the reflecting layer and back to the ground. The receiver picks up both the direct and the reflected signal, and the time displacement of the two is a measure of the virtual height of the reflecting layer.

The output of the receiver is connected to one pair of deflecting plates of a cathode ray tube, while the other pair of deflecting plates is connected to the sixty-cycle source that controls the rate of emission of the transmitted pulses. When no signals are being sent

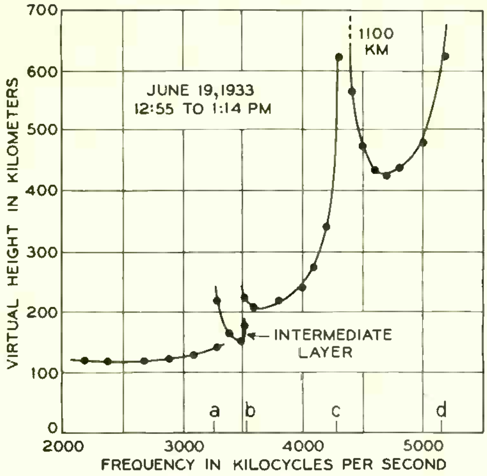


Fig. 4—A plot of virtual height against frequency showing at least three critical frequencies

out, the pattern on the cathode ray tube is a horizontal straight line caused by the electron stream sweeping back and forth across the tube sixty times a second. When pulses are being transmitted, the motion of the electron stream across the tube will be deflected vertically twice or more each trip—once for the direct pulse picked up and once or more for the reflected pulses. The appearance of such a pattern is shown in Figure 3. The time of sending the pulse relative to the sixty cycle current can be adjusted, and is usually chosen to bring the first or direct received pulse near the left edge of the tube and at the zero of the small scale fastened on the front of the tube. The position of the second or reflected pulse can then be read directly from this scale. Since the receiving antenna is immediately adjacent to the transmitter, the direct signals are much stronger than the reflected ones. If the gain of the receiver is increased until the reflected signal produces a satisfactory deflection, however, the overloading effect limits the amplitude of the direct pulse to a satisfactory value.

An extremely useful method of studying the structure of the ionosphere is to measure the virtual height as a function of frequency. To secure such data, the frequency is changed so rapidly that the condition of ionization remains essentially constant during the experiment. A plot of one such set of measurements is shown in Figure 4. The significant feature of the relationship shown is that the virtual height remains essentially constant for a range of frequencies and then suddenly increases. Beyond these critical frequencies the virtual height rapidly decreases, but always to a value higher than that found below the critical frequency. The critical frequency is that at which the lower reflecting layer is completely penetrated, and the virtual height beyond the critical frequency is that of the next higher layer. The large virtual height obtained at the critical frequency is not due to a greater penetration but to a decrease in velocity of travel through the penetrated layer at the critical frequency. From such sets of measurements it becomes evident that there is more than one reflecting layer in the ionosphere.

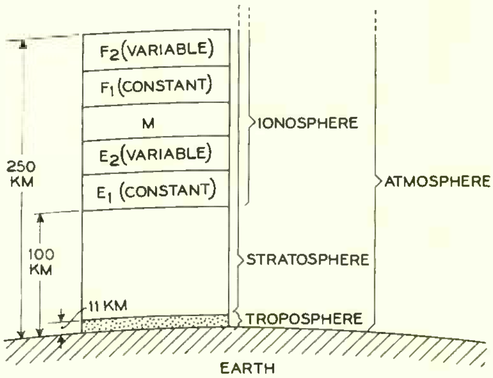


Fig. 5—Positions of various ionized regions in the upper atmosphere

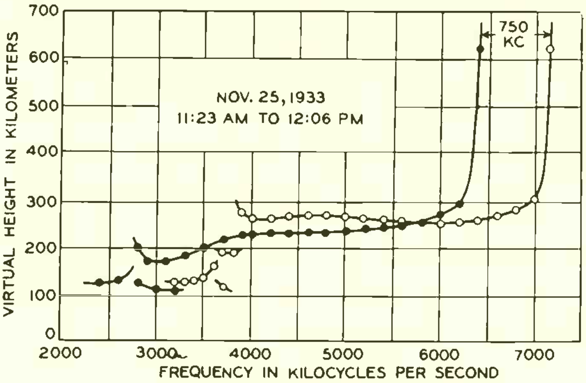


Fig. 6—Virtual height and frequency plot for two components of reflected wave

density in the F_2 region may change as much as fifty per cent in from fifteen to thirty minutes. The maximum for this region usually occurs about noon in winter and about sunset in summer. The ionization of the M region sometimes varies in a constant manner, as does that of the E_1 and F_1 regions, and sometimes varies erratically from hour to hour.

Because of this variation in ionic density, it is not always possible to find all the regions at the same time. If, for example, the ionic density of the E_2 region should be greater than that of any higher regions, signals that completely penetrated the E_2 layer would not be returned to the earth, giving no indication of the existence of higher levels. In general a signal that completely penetrates one layer will be reflected only by a layer of higher density.

At one time it was thought that there were two general ionized regions, an upper and a lower, designated the F and the E respectively. As a result of studies made by the Laboratories, however, it is now known that the ionosphere is composed of at least five, and possibly more, reflecting regions. Their heights are not constant and may even shift relative to each other, but a typical indication of their arrangement is shown in Figure 5. The various regions differ not only in their heights but in the manner in which their ionization varies.

In regions E_1 and F_1, the ionization throughout the day varies uniformly with time in a manner that would be expected if the ionizing agent were the sun. The same cycle of ionic density repeats itself day after day, attaining a maximum shortly after noon. Tests made during the solar eclipse a few years ago indicate strongly that ultra-violet light from the sun is the ionizing agency. In the other regions, the ionization varies in an erratic manner from day to day and even from hour to hour. During winter the ionic

Besides this complexity of reflecting regions, there is an additional complication caused by the effect of the earth's magnetic field. In such a field the signal is split into two components, each of which in general is reflected at a different virtual height and has a different critical frequency. This is indicated in Figure 6, where one com-

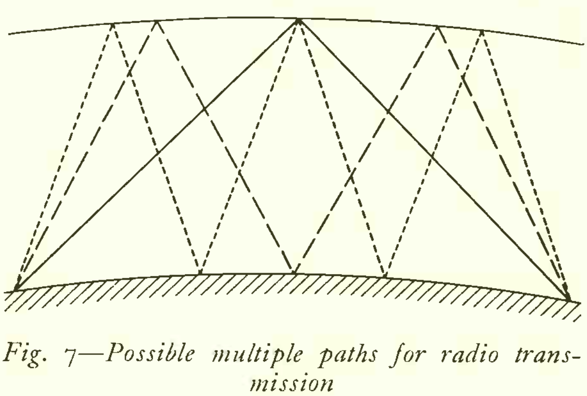


Fig. 7—Possible multiple paths for radio transmission

ponent is indicated by black dots and the other by circles.

The effects described so far are detected when the transmitter and receiver are side by side, and the signal is transmitted up and back vertically. When the receiver is at a considerable distance from the transmitter, however, the reflection phenomena are further complicated by there being a number of paths which use different parts of the ionosphere for reflection as shown in Figure 7. When it is remembered that the reflection along all of these paths encounters the diversity of reflecting regions and the splitting effect of the magnetic field already described, it becomes apparent that the transmission of short waves must be a very complicated process. Fundamental studies of the elements of this type of propagation should contribute materially to the improvements in long-distance radio transmission which the next few years should bring forth.

Laboratories Men and Radio Compass Aid in Marine Rescue

How help was directed to the fishing trawler *Plymouth*, is a story of unusual telephone service involving two Coast Guard boats, the Marshfield marine radio telephone station and the marine position of the Boston toll board, described in detail in *Telephone Topics* of the New England Telephone and Telegraph Company.

On the trawler, disabled on January ninth 250 miles east of Boston Light, was a Western Electric radio telephone with its associated radio direction finder; the latter newly installed and as yet unadjusted and unfamiliar to those aboard. On the U.S.C.G. *Mojave* cruising near shore was a radio telegraph equipment. But no direct communication was practicable between these two boats.

The Coast Guard patrol boat *Faunce*, off the Maine Coast, in addition to her radio telegraph was equipped with radio telephone service through the shore station at Marshfield and thus could act as a relay between the *Plymouth* and *Mojave* or between the Marshfield station and the *Mojave*. The problem was to give the *Mojave* sufficient information as to its radio bearing from the *Plymouth*, to enable them to direct their course through 200 miles of fog, to the spot, then only approximately known, where the fishing boat was drifting.

The prime necessity was for a means of determining the bearing of the trawler, so that the *Mojave* might direct her course to come alongside the *Plymouth* with practically no visibility. Someone on the trawler had to be taught how to operate the radio compass sufficiently well to enable someone at the Marshfield station to interpret the observation recorded.

H. B. Coxhead and G. M. Hafner were at Marshfield and it was quite obvious to Mr. Coxhead that sufficient instructions could be given to the *Plymouth's* engineer to enable him to take bearings on radio signals, as transmitted from the *Mojave*.

A few minutes before four o'clock, Mr. Coxhead talked with the engineer on the *Plymouth*, and instructed him as to the operation of the radio compass and he was able to get an approximate bearing during the four o'clock schedule. The engineer was instructed to read the radio loop scale and telephone this information to the Marshfield station, together with the reading of the magnetic compass. A few minutes of practice and further suggestions from Mr. Coxhead resulted in good bearings on the remaining schedule that had been set up. Mr. Coxhead, after determining these bearings, would transmit them by radio telephone to the *Faunce* where they were relayed to the *Mojave* by radio telegraph.

Observations were made at six o'clock, hourly from eight until eleven, half-hourly until twelve, quarter-hourly until two and more frequently until 2:35 A.M. when the *Plymouth* reported "*Mojave* is now alongside."

A Mirror for the Voice

By R. F. MALLINA
Physical Research

IT IS a curious fact that one cannot, by merely speaking and listening, hear one's own voice as others hear it. Because the sound is conducted to the ear by the bones, and because the presence of the head makes the aerial path from mouth to ear a round-about one, a speaker can only hear his own voice "properly" if it is thrown back at him while he is silent, as in an echo. Naturally occurring conditions rarely produce an echo sufficiently strong, delayed, and faithful to give one more than a tantalizing taste of what one's voice might be, and hence many visitors lingered fascinated in the Hall of the Electrical Echo at A Century of Progress, hearing for the first time their voices as others hear them.

To enable more persons to have this valuable and singular experience, equipment similar to that used in Chicago* has been put into convenient portable form. One such set has been used by the Laboratories in several demonstrations, and another has been permanently placed in the museum of the Franklin Institute in Philadelphia. The apparatus consists of a recording and reproducing machine in which a magnetic tape forms the recording medium, a moving-coil microphone, and an amplifier and loud speaker. A person can speak into the microphone for five seconds and then immediately hear his remark reproduced from the loud speaker. All he need do is start the machine and talk; a signal light above the loud speaker tells him when to stop talking, and the machine then switches itself from the recording to the reproducing condition.

The steel tape on which the speech is recorded, eighty-one inches long, one-twentieth of an inch wide, and 0.0015 inch thick, is welded to form an endless belt. From the tape supply reel

*Record, *June*, 1933, *p.* 308.

(Figure 1), around which several layers are wrapped, the tape passes through the recording unit, and thence around the propulsion roller and back to the supply reel. The propulsion roller is driven by a small electric motor making seventy-eight revolutions per minute and carrying the whole length of tape through the recording unit in five seconds. Small variations in speed are prevented from reaching the tape by using a flywheel and by driving the roller and flywheel through a ring of felt.

Fig. 2—The recording and reproducing halves of the switching cam are colored respectively black and white, so that a speaker can readily observe the position of the cam and know how much longer he may talk

Geared to the motor shaft is a cam making one revolution every ten seconds, having a slightly larger radius over one half than over the other half of its circumference. A cam follower operates a multi-contact switch which is so connected (Figure 3) that when the follower rides on the small radius of the cam the machine will record, and when it rides on the large radius it will reproduce. During the recording half of the cycle, the microphone is connected to the recording unit through the amplifier, which is adjusted to give a gain of about forty decibels. In the recording unit any previous record is wiped out, and the varying voice current then produces a correspondingly varying magnetization along the tape.

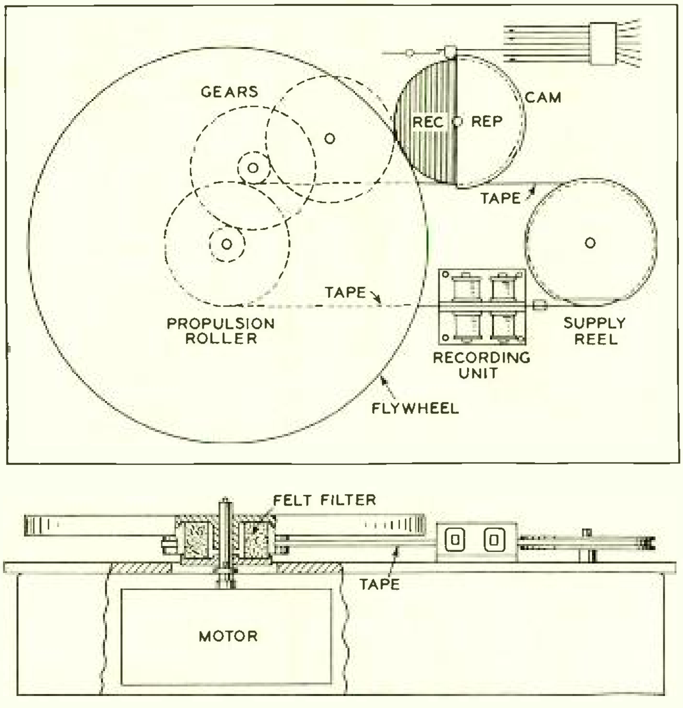


Fig. 1—In the recording machine an endless belt of steel tape passes through a magnetic recording unit

For reproduction, the recording unit is connected to the loud speaker through the same amplifier as was used in re-

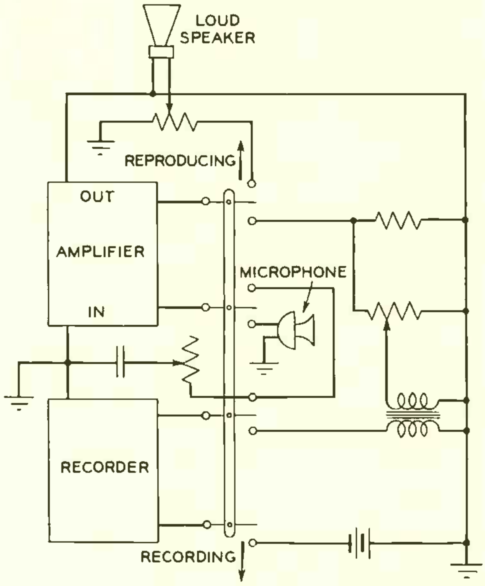


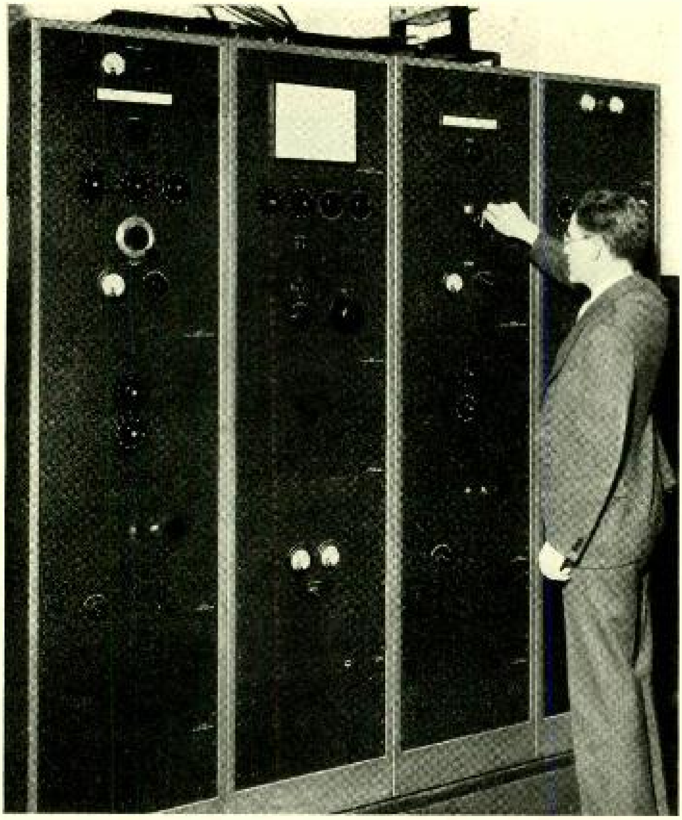
Fig. 3—This simplified schematic shows how the machine switches itself from the recording to the reproducing condition

cording, which is now allowed to give its full gain of about eighty decibels. In the apparatus which has been used for demonstration, the two halves of the cam are distinguished by two different colors, and the person talking can readily see the position of the cam relative to the follower and thus tell how much longer he may talk. The cam may be held in the reproducing position by the operation of a lever, thus allowing the record to repeat. In the Franklin Institute Museum the apparatus is concealed, and the indicating lamp tells the speaker when to stop talking.

Such a machine as this may well be found useful for more practical purposes than discovering how one's voice sounds to others. Students of elocution and foreign languages, of singing and musical instruments, should find it a valuable tool. For such uses, its convenience and instant operation offer distinct advantages over other methods of recording and reproducing sound. There are no records to be changed; the tape need not be rewound, nor the volume controls adjusted; no switching is necessary. The student need only watch the cam or the signal lamp; the machine performs all the remaining operations.

The John Price Wetherell Medal

has been awarded by the Franklin Institute to Dr. F. F. Lucas "in consideration of his development of a technique of microscopy and photomicrography."



An Adjustable Oscillator of High Precision

By L. ARMITAGE
Telephone Apparatus Development

IN DETERMINING the characteristics of high precision filter elements, recently developed for carrier-on-cable and other projects, the frequencies at which measurements are made must be very precisely known. Moreover, in regions where the properties of the apparatus vary rapidly with frequency, measurements must be made at very small frequency intervals over a band twenty to thirty cycles wide, which may be located anywhere in the range of ten to a thousand kilocycles. To make such measurements an oscillator was required having an accuracy of about three cycles. At the high end of the frequency range this accuracy corresponds to three parts in a million, which is about the same as one inch in five miles.

The difficulty in measuring within a given absolute error depends on how great this error is in relation to the quantity being measured. Thus an accuracy of three cycles in three thousand, or 0.1 per cent, is fairly easy of attainment, while an accuracy of three cycles in a million, or 0.0003 per cent, is exceedingly difficult. There is one exception to this rule. If a constant frequency is available, such as the Laboratories' frequency standard, any exact multiple or sub-multiple of that frequency may be obtained to a precision equalling that of the standard. Advantage is taken of these facts in the design of the new oscillator by employing a series of discrete frequencies of high precision derived from the primary standard, and a low range adjustable oscillator to overlap the gaps between them.

The method employed can be illustrated by an analogy. Suppose it were desired to strike off a line having a length within the range of ten thousand to a million units, and that the required accuracy in establishing the length of this line is two or three units regardless of its total length. To measure this line there is available a standard a million units long, which is marked, starting at 10,000, at certain discrete points along its length. These markings are relatively few but the distance between any two is never greater than 3,400 units. Suppose that besides this basic standard there is available an accurately calibrated scale 3,400 units long. This shorter scale is employed by placing one end on one of the marked points of the long scale and marking the correct distance beyond this point by the short scale. From its method of use this shorter scale may be called the overlapping scale.

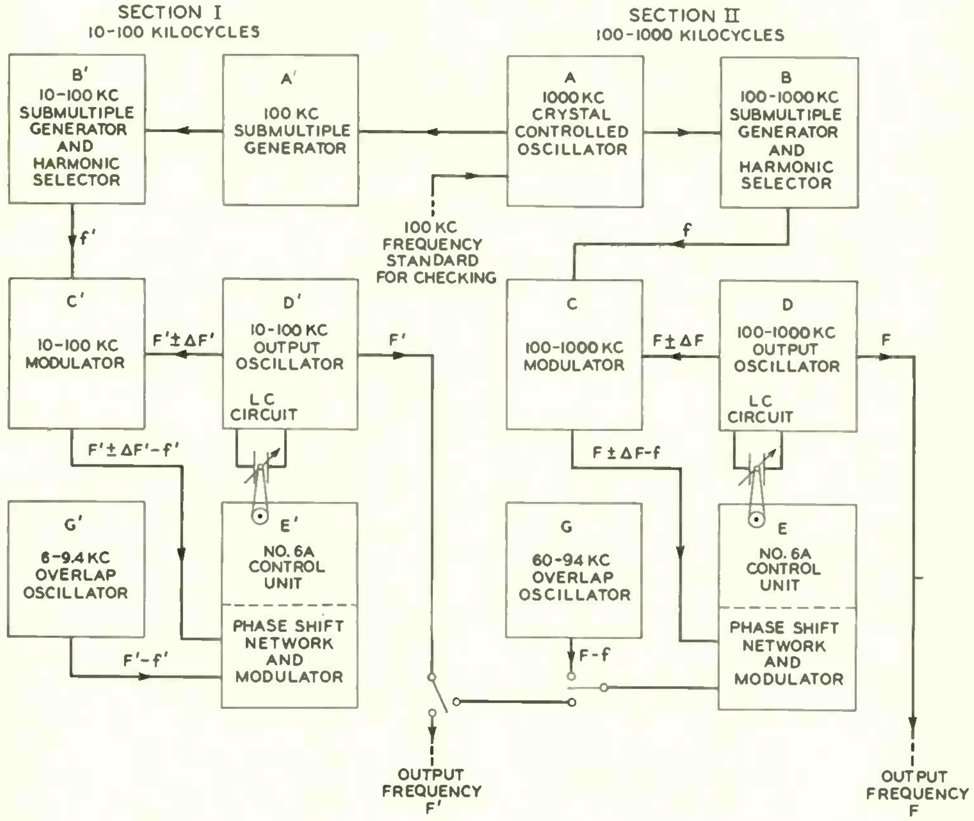


Fig. 1—Block schematic of new oscillator showing division into two sections—one with a frequency range from 10 to 100 kc and one from 100 to 1,000 kc

In the design of the new oscillator the complete range of 10 to 1,000 kc is divided into two sub-ranges: one from 10 to 100 kc, and the other from 100 to 1,000 kc, and except for the control oscillator, separate apparatus is employed for obtaining frequencies in these two ranges. The two sections are essentially alike except for the frequency values. In the photograph of the complete oscillator at the head of this article, the two panels at the left comprise the lower range section, and those at the right, the higher range. A schematic of the separate pieces of apparatus comprising the oscillator is shown in Figure 1, where again the low section is at the left and the high section at the right. The primary frequency control is a 700A Oscillator* indicated as A in Figure 1. This is a 1000-kc crystal-controlled oscillator, and corresponds to the 1,000,000-unit scale in the analogy. A 100-kc sub-multiple frequency of this oscillator, obtained from the sub-multiple generator A′, is checked at intervals against the Laboratories' standard by a beat-frequency circuit. This 100-kc frequency also serves as the standardizing frequency for the lower section, and the 1000-kc from the oscillator, for the higher section.

The equivalents of the marked points on the long scale in the analogy are obtained from a sub-multiple generator and harmonic selector, B′. With the former, any sub-multiple (n), from the sixth to the fifteenth inclusive, of the standardizing frequency A′ of Figure 1 may be obtained, and by the harmonic selector any harmonic (m) of this sub-multiple frequency up to the fourteenth may be selected. Since the frequency obtained from the harmonic selector unit has a definite relationship to the control frequency, its accuracy is essentially that of the control frequency itself—or about one-half cycle.

*Record, *December*, 1931, *p.* 106.

The sub-multiple generator unit B′ is calibrated to furnish frequencies

Frequencies of 10-100 *kc Sub-multiple Generator*

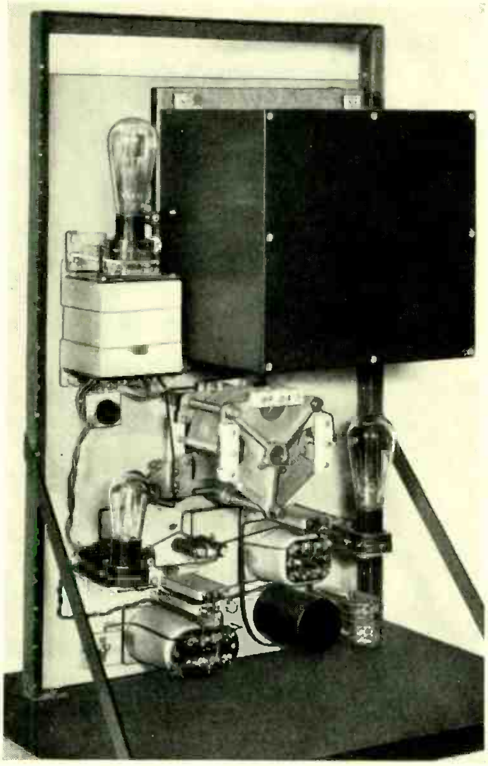
f	*m/n*	*f*	*m/n*
8333	1/12	50000	3/6
10000	1/10	53333	8/15
11111	1/9	55556	5/9
14286	1/7	58333	7/12
16667	1/6	60000	6/10
20000	3/15	61539	8/13
23077	3/13	63636	7/11
25000	2/8	66667	4/6
27273	3/11	70000	7/10
30000	3/10	73333	11/15
33333	2/6	75000	6/8
36364	4/11	77778	7/9
38462	5/13	80000	8/10
40000	4/10	83333	5/6
41667	5/12	86667	13/15
44444	4/9	90000	9/10
46667	7/15	93333	14/15

Table I—Series of fixed and precise frequencies that may be obtained from the harmonic selector of Section 1

which in no case are more than 3,400 cycles apart. These frequencies and the m/n ratios used in producing them are shown in Table I.

To serve as the short, or overlapping scale, a second oscillator unit G′ is provided. This is adjustable, to within one cycle or better, between 6 and 9.4 kc—a range of 3,400 cycles. By "adding" the numerical value of a definite frequency from this overlapping oscillator to one of the fixed frequencies obtained from the sub-multiple generator, any desired frequency may be obtained to the required overall precision.

Considering Section 1 only, there is an output oscillator D′ variable over the entire range of the section, from ten to one hundred kc. This oscillator may be set approximately to any of a large number of frequencies by a calibration chart. It is provided with two

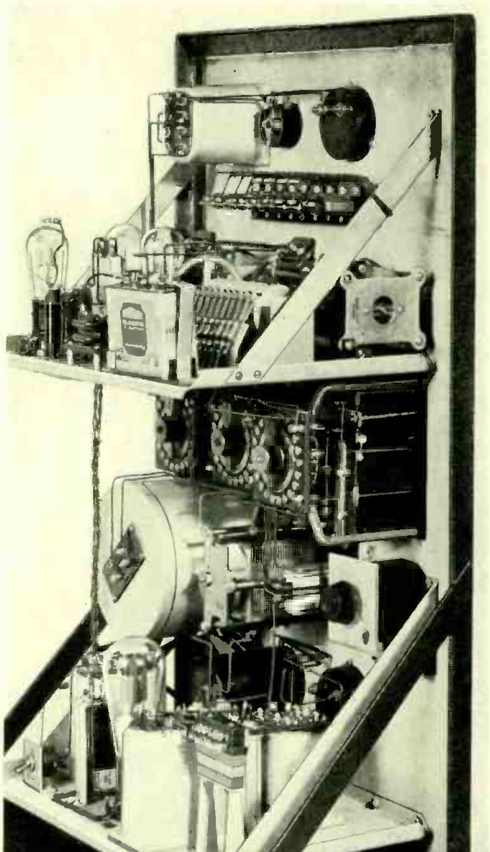


Rear view of 6-9.4 kc overlap oscillator

output circuits; one serves as the main output, and the other is utilized, in conjunction with other apparatus, to bring this oscillator accurately to the required frequency.

In the tuned circuit of oscillator D′ is an air condenser which is rotated by a synchronous motor of the two-phase type. This motor is self-starting in either direction at frequencies from zero up to about twenty cycles. It is operated by a control current which varies in frequency depending on the difference between the frequency of D′ and the desired frequency F′. When these are the same, the frequency of the control current becomes zero and the motor stops. Any tendency of the frequency of D′ to vary from its correct value at once starts the motor to turn the condenser in a direction to bring the output frequency back to its correct value.

The control current that operates the synchronous motor is obtained by a double modulation. A frequency f′ is selected from the sub-multiple generator B′, that is between 6 and 9.4 kc below the desired output frequency F′. This is modulated with the frequency from D′ in modulator C′. The overlap oscillator G′ is then set by its calibration chart at a frequency equal to F′–f′, the difference between the desired output frequency and the frequency selected from B′. This fre-

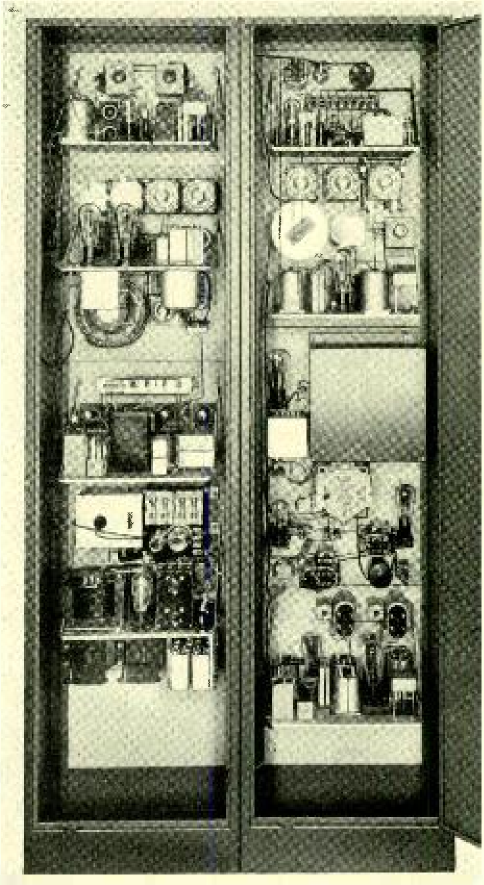


Rear view of 10-100 kc sub-multiple generator unit quency is modulated with the output from modulator C′, and the resulting difference frequency, after passing through a phase shifting network to secure two components 90 degrees out of phase, is the control frequency which operates the synchronous motor.

The difference product of this second modulation will become zero only when the frequency of oscillator D′ is at the desired value. At any other output frequency it will operate the motor in a direction such as to bring the output frequency to the correct value. When first set up, this difference frequency may be greater than 20 cycles, and in this case a manually controlled vernier on the output oscillator is operated to adjust the frequency until it is within 20 cycles of the desired value. From there on the motor will automatically hold it at that value.

The apparatus of Section 2 is identical in function to Section 1. Because of the higher range, however—running from 100 to 1000 kc—the overlap oscillator has a range of 34,000 cycles, or from 60 to 94 kc. It can be set by its calibration chart to anywhere within ten or fifteen cycles of the desired value. A frequency between sixty and ninety-four kc, however, is within the range of Section 1, and so where greater precision than ten or fifteen cycles is required, Section 1 is substituted for the overlap oscillator of Section 2. The switching by which this is done is indicated in Figure 1. Since the output of Section 1 is accurate to within one or one and one-half cycles, the output of Section 2 will be held to practically a like accuracy.

The principle of operation adopted for this oscillator has quite appreciably reduced its cost by making it unnecessary to employ filters, which are generally required to eliminate the unwanted products of modulation. With this oscillator the two frequencies modulated are in every case quite close in value, and of at least mod-



Rear view of Section 1 of oscillator

erately high frequency. As a result, there is a wide spread between the difference frequency and the other modulation products. The spread is so great that the necessary discrimination is obtained in the modulator output circuit without tuning. An example will illustrate this feature and, in addition, will show the general method of operation.

Assume a frequency of 92,105 cycles

is desired. From Figure 2 it is quickly seen that the frequency obtainable from B′ which will be less than 92,105 by 6 to 9.4 kc is 83,333 cycles. The output oscillator, on the other hand, can be set from its calibration chart at approximately 92,500 cycles. When these two frequencies are combined in modulator C′, the difference frequency is 9,167 which is sufficiently spaced from the other products to make it a simple matter to allow the output circuit of the modulator to make the necessary discrimination.

The frequency selected from the G′ oscillator is 92,105 – 83,333, or 8,772 cycles. This in turn is combined with the 9,167 modulation product, and results in a difference frequency of 395, which again is low enough compared to other products to make discrimination easy without filters. This 395-cycle current is applied to the synchronous motor but is too high in frequency to operate it. The vernier on the output oscillator is thus manually operated to reduce this frequency. When the output frequency gets as low as about 92,125 cycles the synchronous motor will operate, and will then reduce the frequency to the desired 92,105 and hold it there.

The precision of setting of the overlapping oscillator unit of Section 1 is very high. There are on the average forty-five marked divisions on a precision air condenser of this unit per cycle. This is equivalent to approximately two and one-half linear inches per cycle. For the entire range of the oscillator, from ten to one thousand kc, the equivalent length of the scale is thus approximately forty miles. A heterodyne oscillator of this range, allowing an average of only one-thirty-second inch per cycle, would require a dial eight hundred feet in diameter. If placed horizontally such a dial would require about fifteen acres of ground, while twelve square feet of floor space is all that is needed for this new oscillator.

Ionosphere Measurements During Eclipse

Ionosphere measurements made at the radio laboratory at Deal, N. J., by J. P. Schafer and W. M. Goodall during the partial eclipse of the sun on February 3, 1935, lend further support to the theory that the ultra-violet light of the sun is an important cause of ionization in those layers of ionized air above the earth's surface which are so necessary to radio communication.

Critical ionization frequencies were measured on the day of the eclipse and also on the two following days. The results show that the eclipse was accompanied by a decrease in the maximum ionic density of 20 to 25 per cent and that the minimum ionization occurred at or shortly after the eclipse maximum. The percentage decrease was progressively greater from the lowest to the highest layer, perhaps due in part to the fact that the eclipsed area of the sun was 29 per cent at the surface of the earth and 31 per cent at a height of 250 kilometers.

These results confirm similar observations made on the lower layers of the ionosphere during previous eclipses, and give more definite indications of the existence of a solar effect in the upper layer which is at a height of approximately 250 kilometers.

50 KW TRANSMITTER
BUILT BY
WESTERN ELECTRIC
FROM DESIGNS BY
BELL TELEPHONE
LABORATORIES
FOR
STATION

W O R

OWNED BY THE
BAMBERGER BROAD-
CASTING SERVICE

I

*Front view of the oscil-
lator-modulator unit.*

II

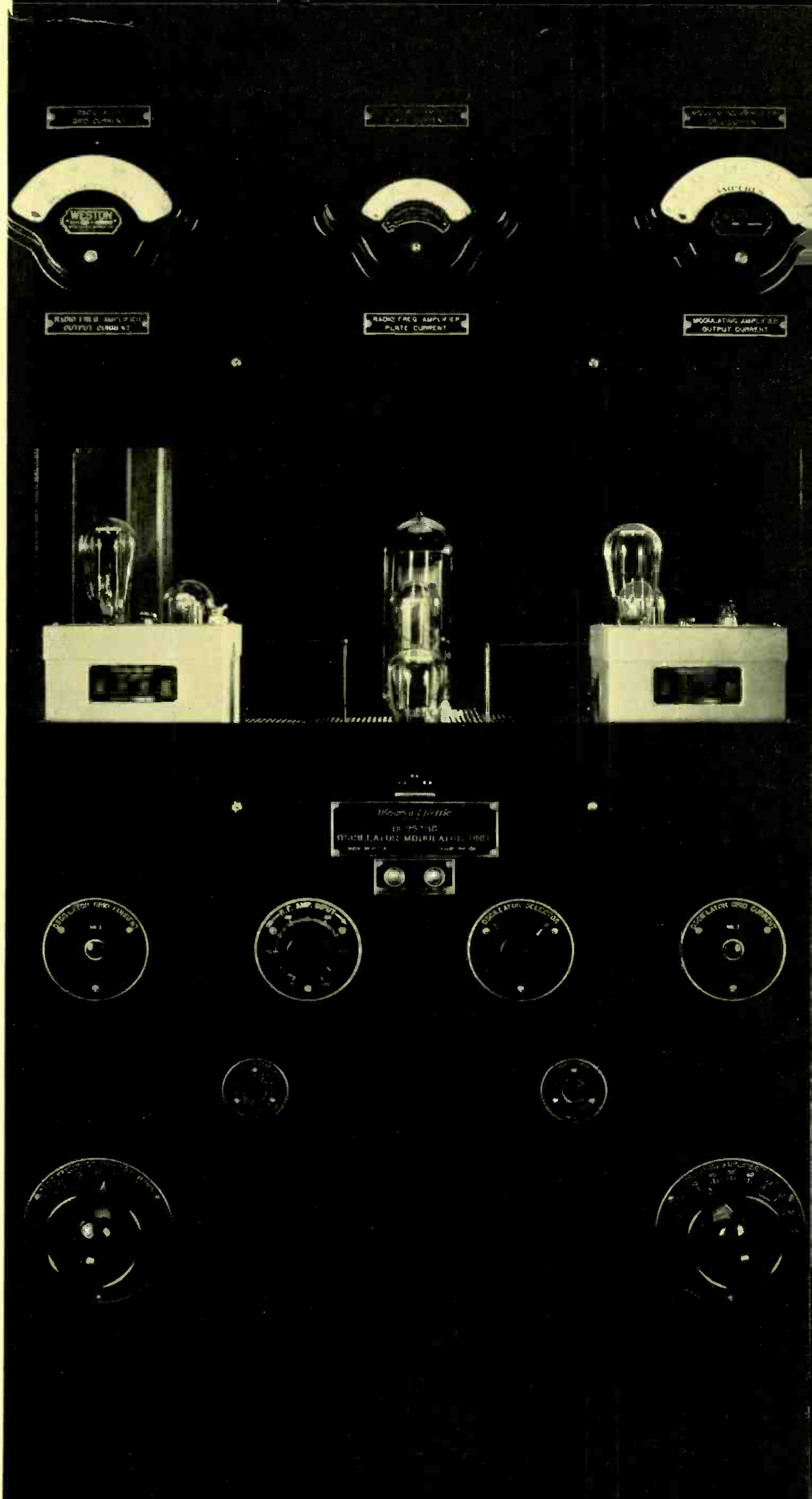
*Dummy antenna used
o test the transmitting
equipment before the sta-
ion was put on the air.
At the right, tanks of
nitrogen to fill the insu-
lating space of the con-
centric transmission line
o the real antenna.*

III

*Tuning unit for the
hird power amplifier.*

IV

*Transmitter control
oom, as it appears from
he speech input room.
From the master control
lesk in the foreground
he operator can in emer-
ency control the out-
oing transmission.*



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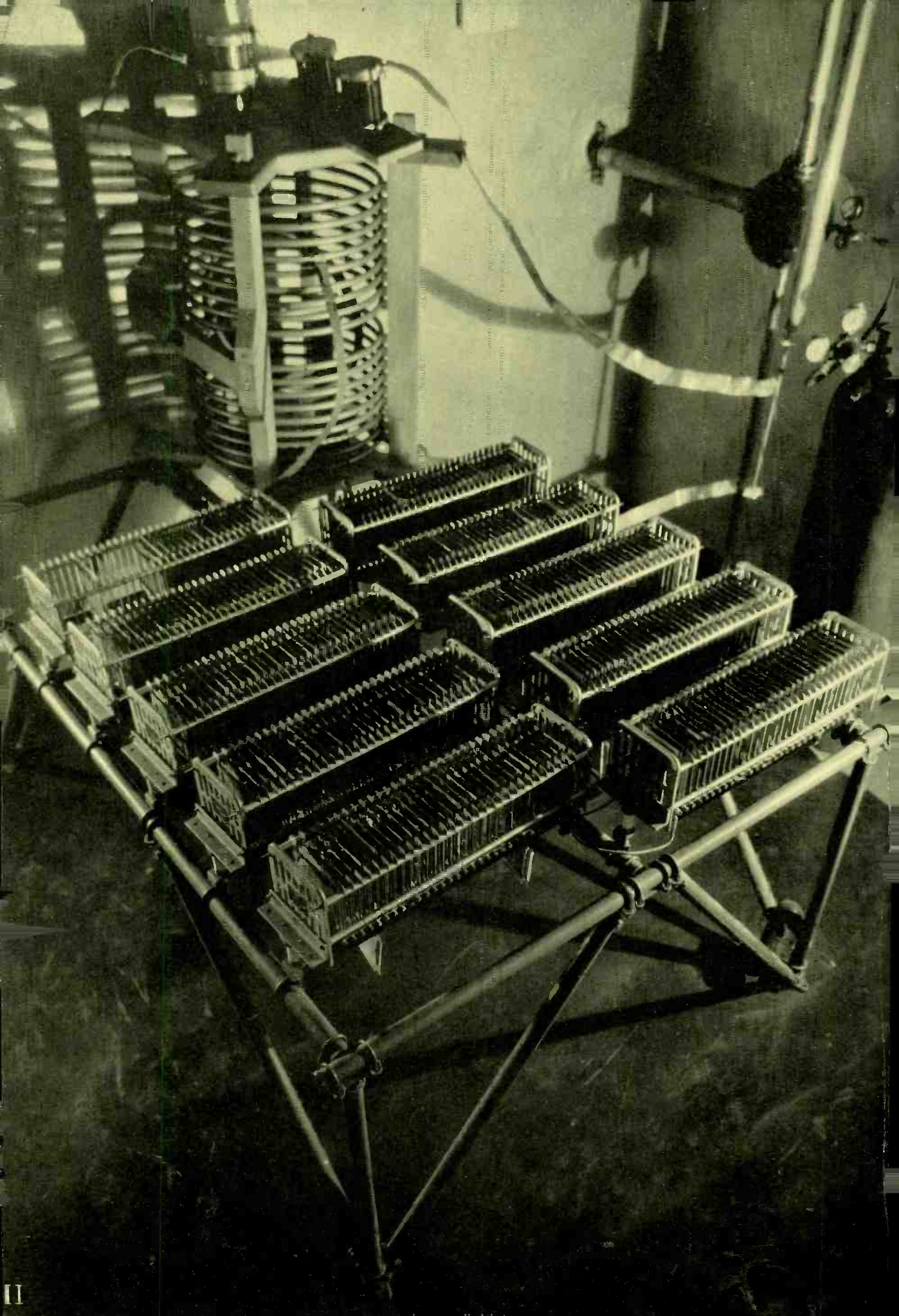
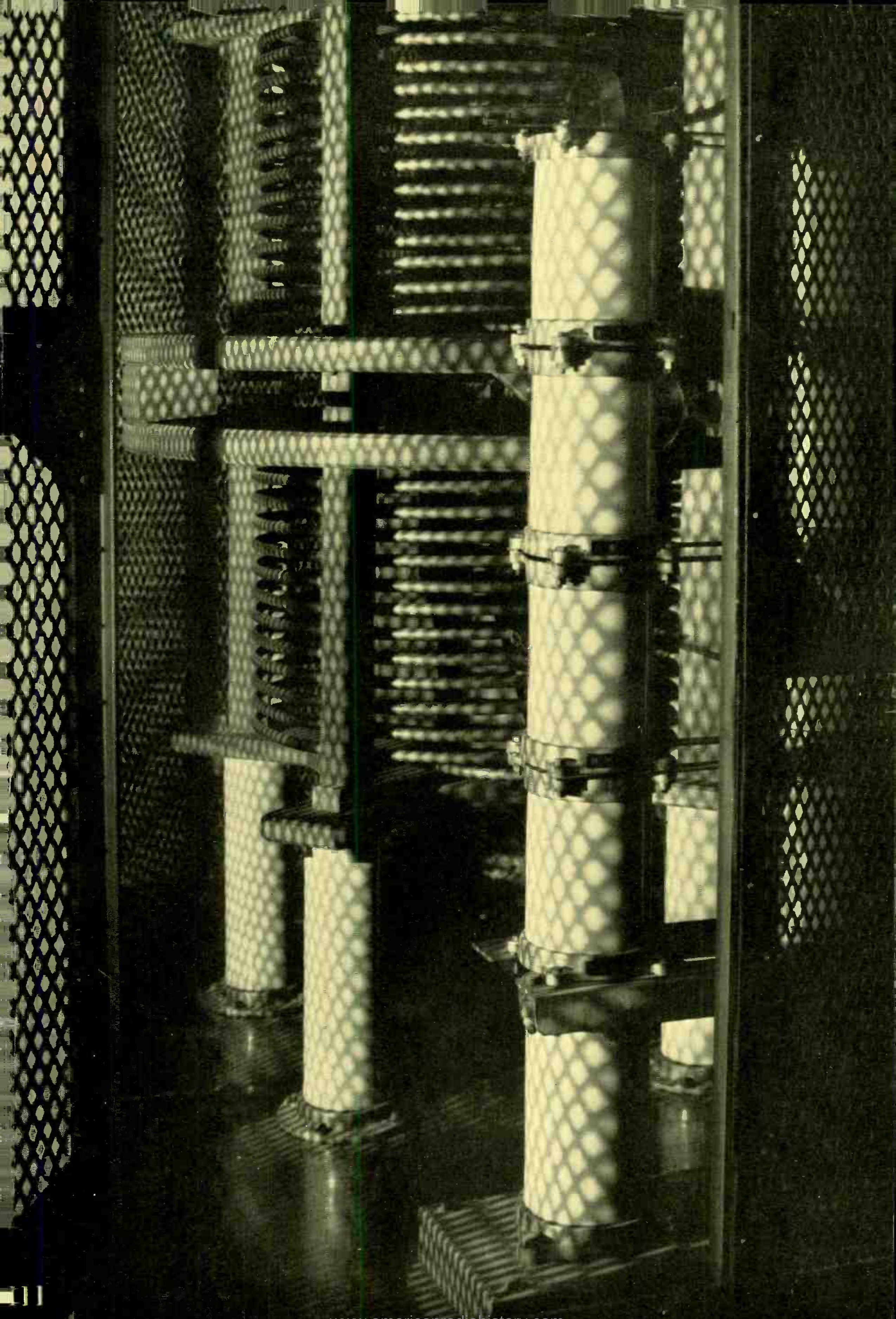
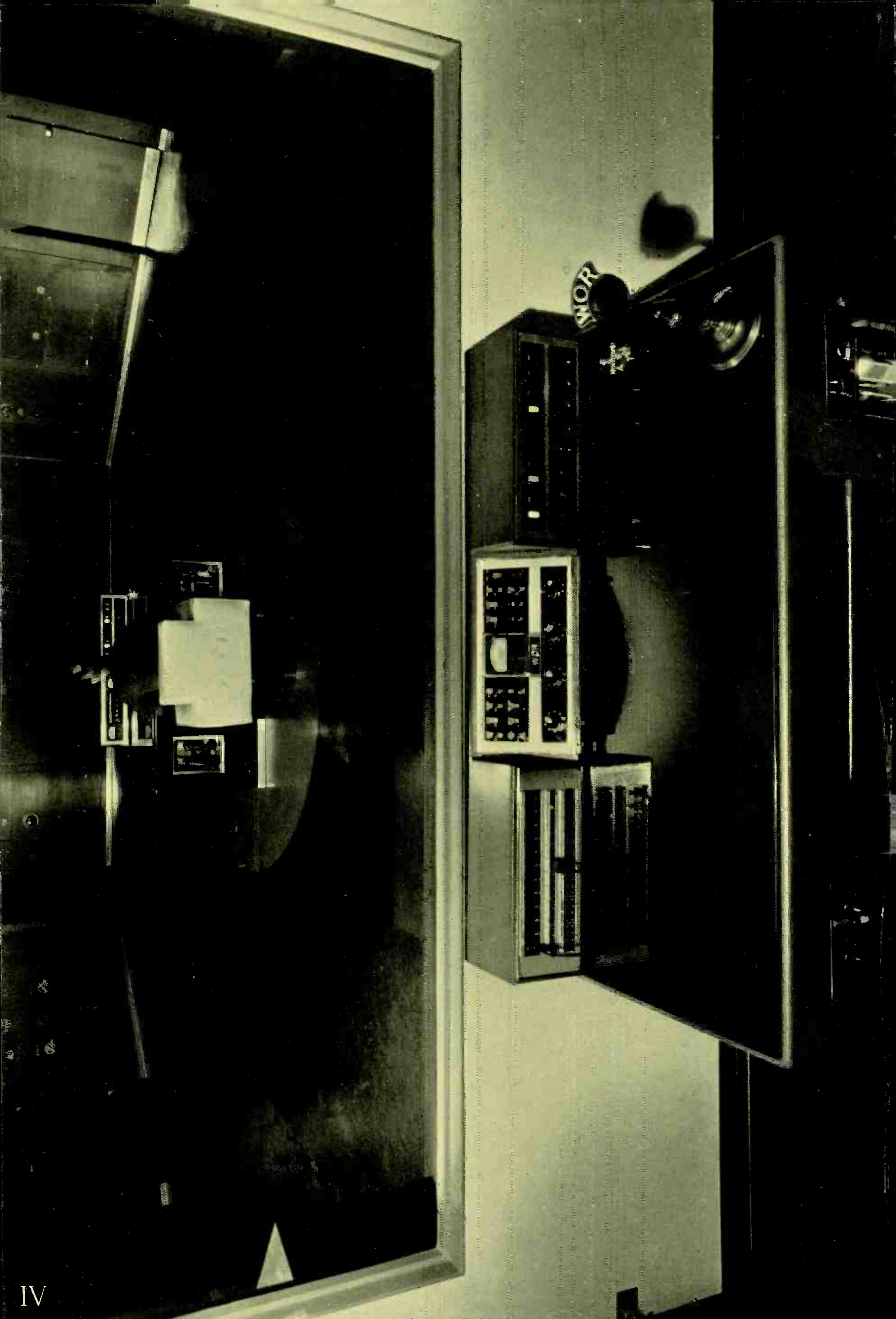





WOR

Insulation Resistance of Cotton

By A. C. WALKER
Telephone Apparatus Development

THE great improvement in the electrical insulating properties of cotton secured by washing under certain prescribed conditions has led to its extensive use in replacing the far more costly silk previously required in the manufacture of telephone apparatus. The improvement has resulted directly from studies which made it clear that the electrical properties of textiles depend principally on three factors: chemical composition, moisture content, and small amounts of water-soluble materials present in the fibers through natural growth or contamination. Further studies of the effects of the last two factors on the insulation resistance of cotton have yielded precise and in some respects unexpected information.

The ash content of cotton in its natural state is surprisingly close to one per cent, whatever the source or type of fiber. These inorganic materials occur in the cotton as a result of the processes of natural growth. Three-fourths of the ash consists of water-soluble alkali salts, mostly potassium salts and some sodium chloride. The remaining quarter is insoluble calcium, magnesium, iron and aluminum salts. Since the water-soluble alkali impurities are mostly strong electrolytes, washing with distilled water removes all but traces of them, thus producing an improvement of fifty to a hundred fold in the insulation resistance of the fiber. The remaining traces consist mostly of potassium silicate, the least soluble of the akali salts present.

Even washing with commercial waters accomplishes the same result, if the water contains a considerable excess of soluble calcium or magnesium salts over the sodium salts always present. Such processing results in an increase in the calcium or magnesium content of the cotton, and these materials produce a slight beneficial effect upon the insulating quality of the textile, probably because the calcium or magnesium salts present in the water enter the cotton by ionic interchange, and remain in the form of organic salts which are insoluble and therefore not electrolytic. For example, after cotton is washed with a water containing an appreciable amount of calcium sulphate, the calcium content of the cotton is nearly double its initial value, the sulphate content is unchanged, and the magnesium content is reduced by an amount almost exactly equal to the increase in calcium. Conversely if the water contains magnesium sulphate, the calcium content of the cotton is decreased by an amount equivalent to the increase in magnesium content. In either case, of course, the initial sodium and potassium content of the cotton is removed almost completely, mostly by simple solution of these salts in the water, and to a small extent by the ionic interchange of calcium or magnesium for potassium.

Ionic interchange is a well-known

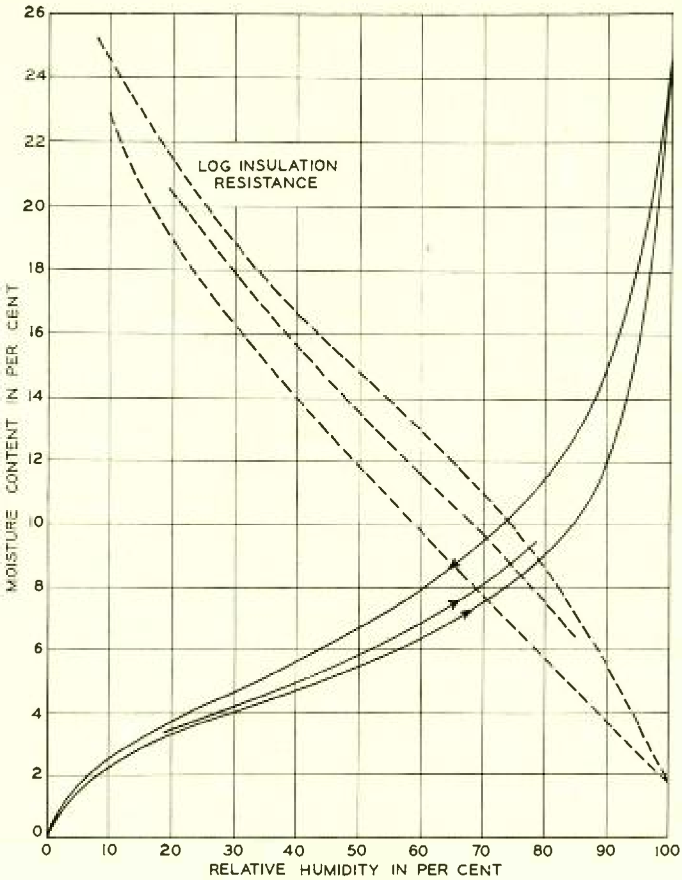


Fig. 1—The moisture content of the same sample of unwashed cotton, at the same relative humidity and temperature, will have one of three definite values (solid curves) depending on the humidity history of the sample. The three corresponding curves for the variation of insulation resistance are dotted, the lower corresponding to the higher moisture content

calcium or magnesium in the water. The cotton in this process is thus analogous to the sodium aluminum silicate used as the exchange base in water-softening systems, since it performs a "water-softening" function when it is washed.

The increase in insulation resistance of 50 to 100 fold obtained by washing cotton to remove electrolytic impurities is often called the "electrolytic" improvement. The improvement is a permanent one, so long as the cotton does not become subsequently contaminated by electrolytes.

In addition, however, the electrical insulation resistance of cotton is critically dependent upon its moisture content, and this in turn is a function of atmospheric humidity.

chemical principle, and is of economic importance in water-softening processes. It is interesting to notice that in water-softening the object is to replace the calcium and magnesium salts in the hard water, which become less soluble and form a scale when the water is boiled, by the more soluble sodium salts which do not deposit scale. The object in washing cotton is just the reverse; hard water is desirable for the washing process, and the replacement is one of soluble sodium or potassium in the cotton by

Investigations into these properties have recently been made with the aid of unusually sensitive equipment for measuring and maintaining atmospheric humidities,* and for measuring the moisture content and insulation resistance of fibrous materials. The accompanying curves summarize the results obtained. The curves for washed and unwashed cotton are of the same form, but the curves for the latter are more complete since its lower insulation resistance permits study over a

*Record, *February*, 1933, *p.* 169.

wider range of humidity conditions.

The curve representing the relation between atmospheric humidity and moisture content for fibrous material is of familiar type. If a sample of cotton is carefully dried at a temperature slightly above the boiling point of water, or at room temperatures in a stream of thoroughly dry air, a consistent, reproducible "dry" weight may be secured. If the material is then successively equilibrated with increasing values of atmospheric humidity at constant temperature, the values of moisture content will fall on the lower of the three curves in Figure 1. When the sample is exposed to an atmosphere saturated with water at this temperature, its moisture content will be somewhat more than twenty-four per cent.

If cotton saturated with water is progressively dried and its moisture content is determined at successively lower equilibrium values of humidity, the moisture contents will fall along the upper of the three curves in Figure 1. If the cotton is finally dried after such high humidity exposure, any subsequent increasing moisture contents will fall on the middle curve in Figure 1, higher than the first and lower than the second.

The lower and upper curves constitute a hysteresis loop characteristic of cotton and many other materials which absorb moisture in a similar fashion. The area between the lower and middle curves, which though incomplete would no doubt continue along the course between the upper and lower curves, measures the extent to which the hysteresis loop is irreversible. The irreversible portion of the loop, found with raw cotton, is not found with washed cotton, probably because of its previous contact with

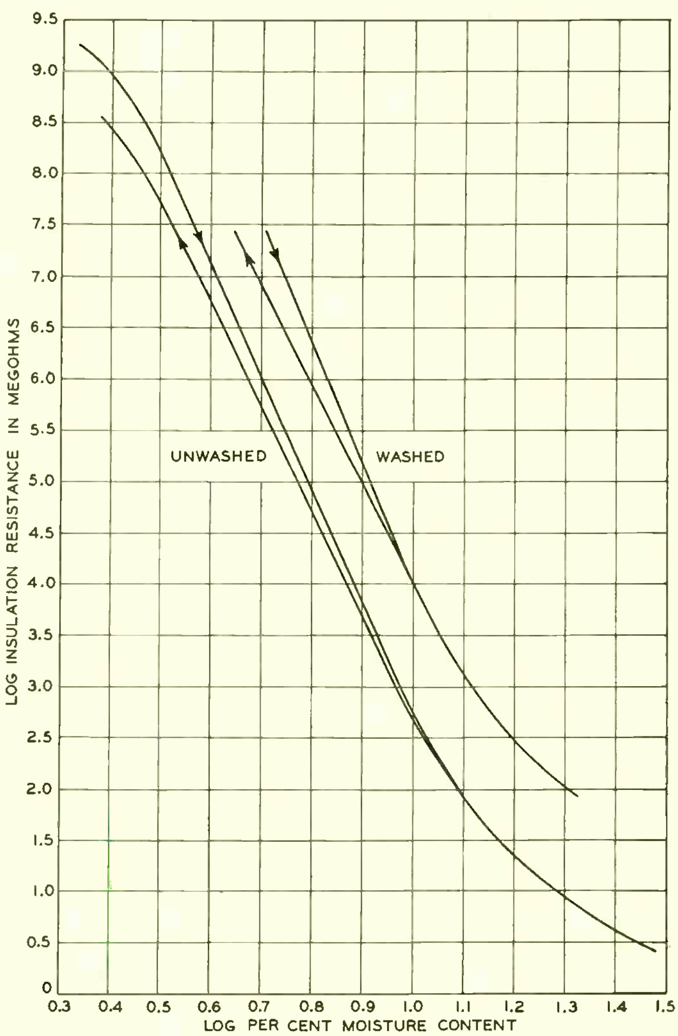


Fig. 2—Even for the same moisture content, the insulation resistance of a sample of cotton may have either of two values, depending on its moisture history

water. The area of the reversible portion of the hysteresis loop, however, and even its location, are substantially in agreement with those for washed cotton.

Curves for the variation of insulation resistance with relative humidity (Figure 1) exhibit the same sort of hysteresis loops, with an irreversible portion. Since the relation between insulation resistance and moisture content is in a general way inverse, the two types of curves are opposite in direction but otherwise closely similar. The similarity suggests that the relation between moisture content and insulation resistance should be somewhat more simple than their respective relations with relative humidity. Indeed, Figure 2 shows that over much of the experimental range the relation between their logarithms is linear.

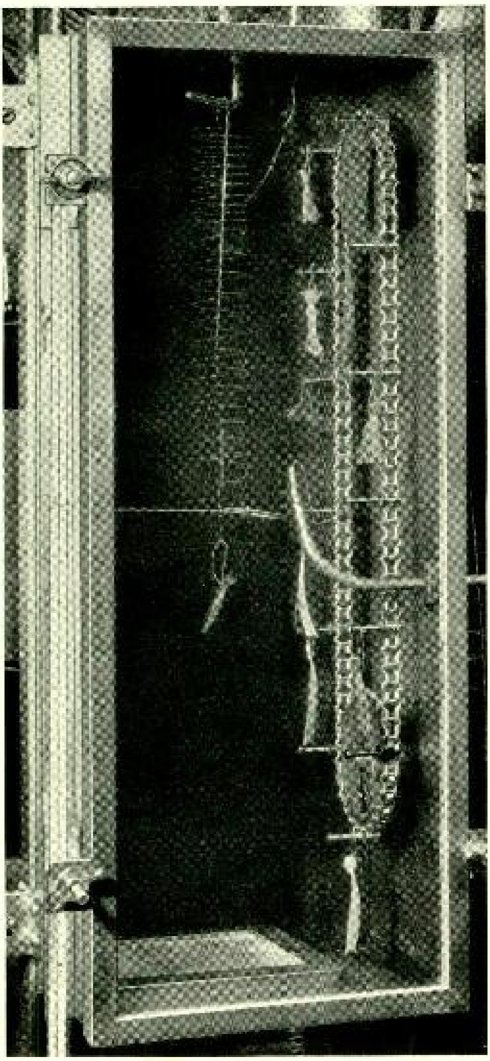


Fig. 3—In this chamber thirteen different textile samples are equilibrated with a carefully controlled humidity and then successively transferred from the conveyor by the selector arm to a quartz balance on which they are weighed

Curiously enough, however, this relation also exhibits hysteresis, a fact of some significance in testing the insulation resistance of washed textiles. At any single moisture content, the insulation resistance of cotton may have one of several definite values, depending on the previous treatment which the cotton has received. Thus, if cotton is dried very carefully and then successively equilibrated at increasing humidities, a curve such as the upper one for unwashed cotton in Figure 2 will be secured. Once the cotton has been exposed to a saturated atmosphere, it returns along a drying curve somewhat lower, and thereafter it will never return along the initial curve. If the cotton is wetted with liquid water and then properly dried, it may be restored to the "upper-curve" condition; but wetting raw cotton would destroy the possibility of checking this relation in such a diagram as Figure 2, since the water would remove some electrolytes and the position of the curve for unwashed cotton in Figure 2 would be altered.

Since the relations expressed by the curves of Figure 2 are logarithmic, the actual insulation resistance values of washed cotton which are found on the

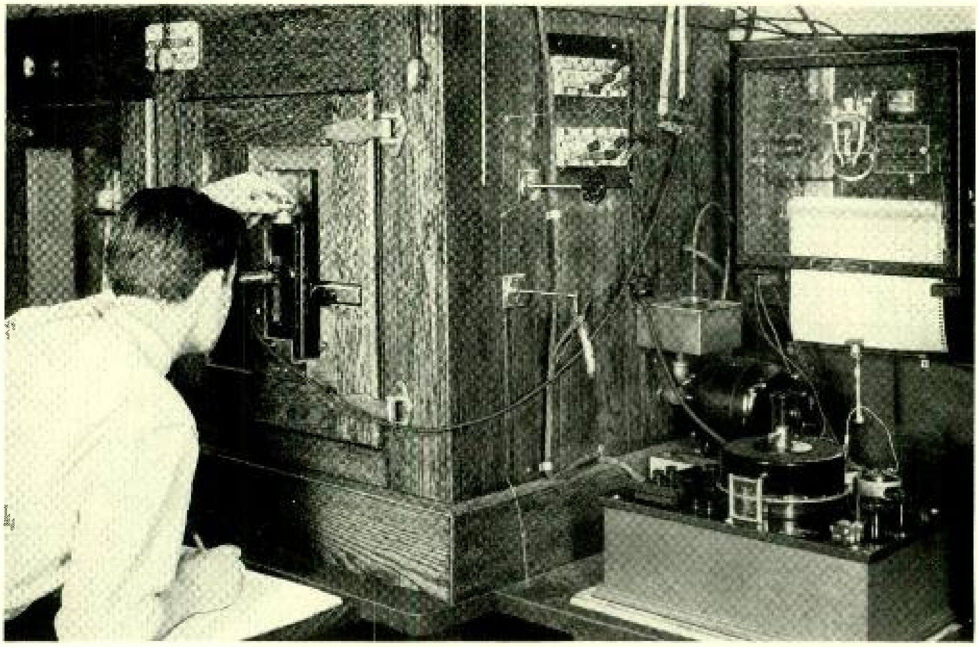
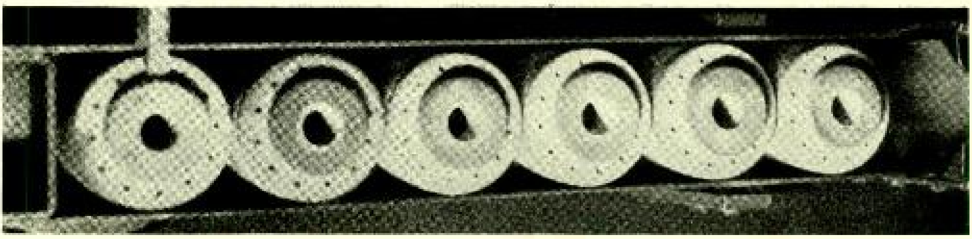


Fig. 4—The deflection of the quartz balance in the humidity cabinet is measured by G. E. Kinsley with a cathetometer which determines the weight of the sample within six millionths of a gram

ascending and descending branches may differ by as much as two to three fold. In other words, properly dried washed cotton may have resistance values two to three times higher than those of the same cotton after it has been exposed to humidities in the neighborhood of saturation. Indeed in a few cases reductions to as little as one tenth have been observed. Since cotton is generally exposed to atmospheric conditions which may influence the resistance of the textile in this way, estimates of the improvement which may be secured for practical purposes in the insulation resistance of cotton by washing and drying it, must take into account all the factors so far discussed. In summary, it can be said that the insulation resistance of cotton may be improved very greatly by washing and properly drying the material. The total initial improvement consists of a major portion, of great commercial importance, called "electrolytic"; and a lesser portion, whose significance is only partially understood, called "transient." The electrolytic improvement is in general between fifty and a hundred fold.

In making electrical measurements on textiles under definite humidity conditions, it is important to remember that the amount of moisture absorbed, and thus the insulation resistance, depend upon the direction from which equilibrium is approached, and on whether the textile has been exposed to saturated atmospheres. A clear appreciation of this latter effect has been particularly useful in securing more consistent results in the electrical tests which are employed in inspecting cotton, commercially purified for use in electrical equipment.



Heat Treatment

By R. O. GRISDALE
Chemical Laboratories

IN CELEBRATING the discovery that a pig acquires desirable characteristics when a house is burned down about it, Charles Lamb detailed one of the earliest applications of heat-treatment to develop valuable properties in materials.* Succeeding generations, building upon this discovery, have improved the means of heat-treatment through the wood fire and primitive roasting spit to the ovens of the modern kitchen and the furnaces of the factory. Since industry seldom wishes part of its product rare and part well done, it has been especially active in developing means for giving many samples of material identical heat-treatments in identical gaseous environments.

*Charles Lamb, "A Dissertation on Roast Pig."

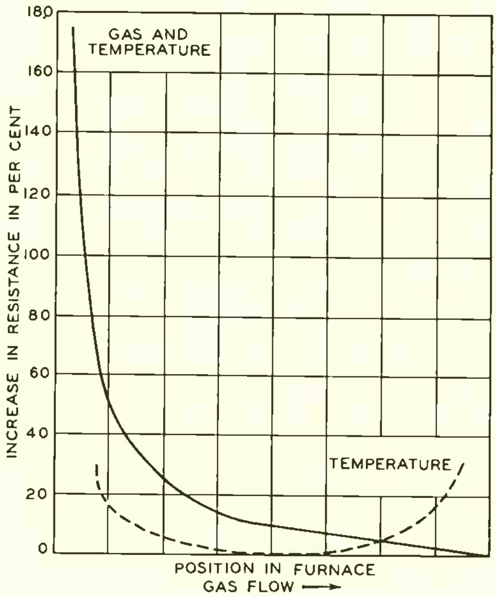
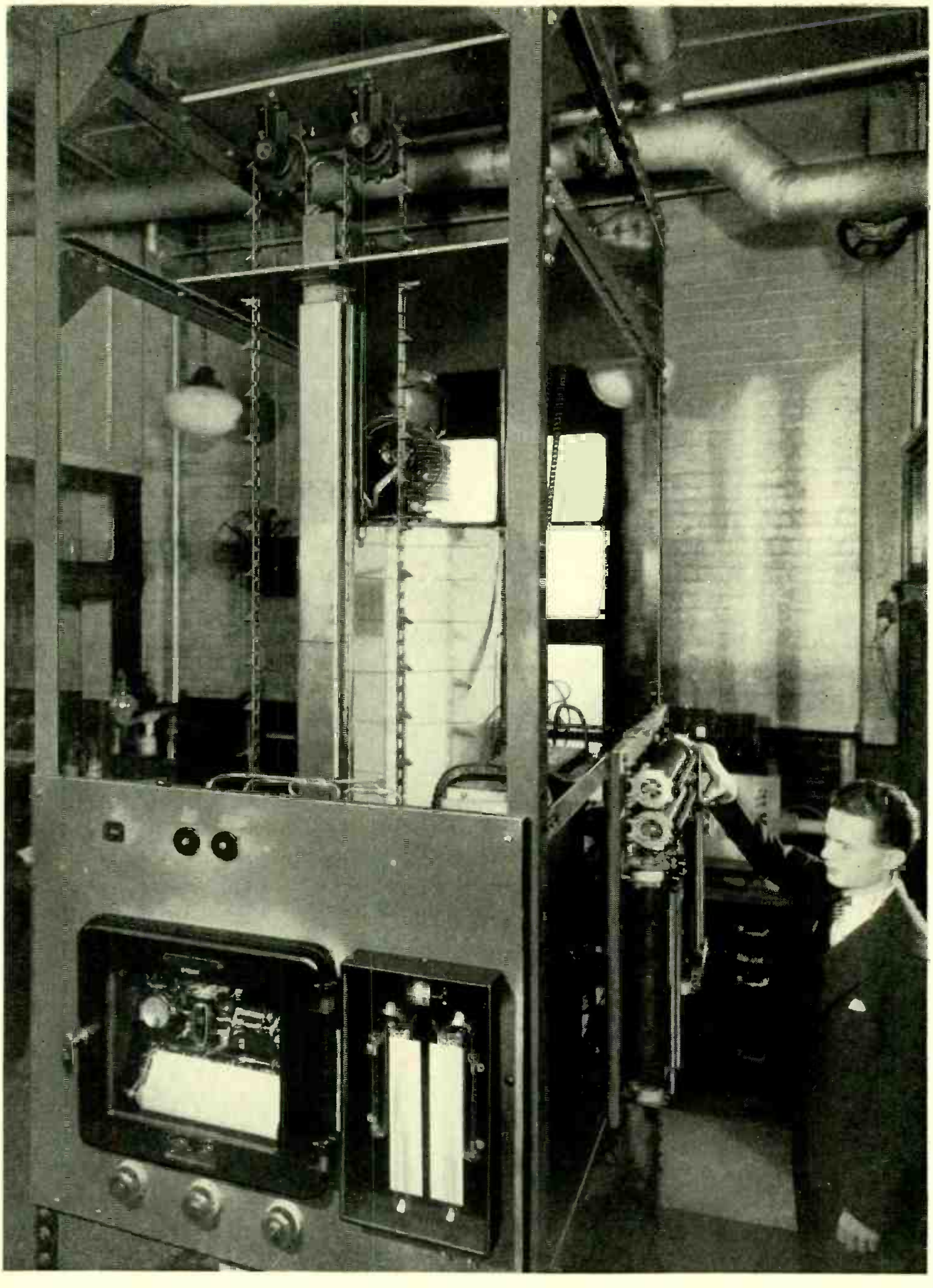


Fig. 1—Different samples of certain resistance materials heat-treated in a batch furnace will differ widely in their properties on account of differences in the temperature and atmospheric composition at various points of the furnace

It is the usual practice to approximate these means with batch furnaces. In the laboratory such a furnace often takes the form of a refractory tube, with a resistance winding along its outside, and with crucibles of the material to be treated distributed along its inside; the desired mixture of gases is admitted at one end and removed from the other. Each batch of crucibles is carried through the cycle by systematically varying the temperature of the furnace.

Usually, however, such a furnace will not carry all the crucibles of a batch through identical cycles, and in many cases the various samples so treated have been found to differ importantly in their properties. In the first place, when the furnace is heated, its temperature will rise at the outset more rapidly in the center than at the ends, and thus the central crucibles

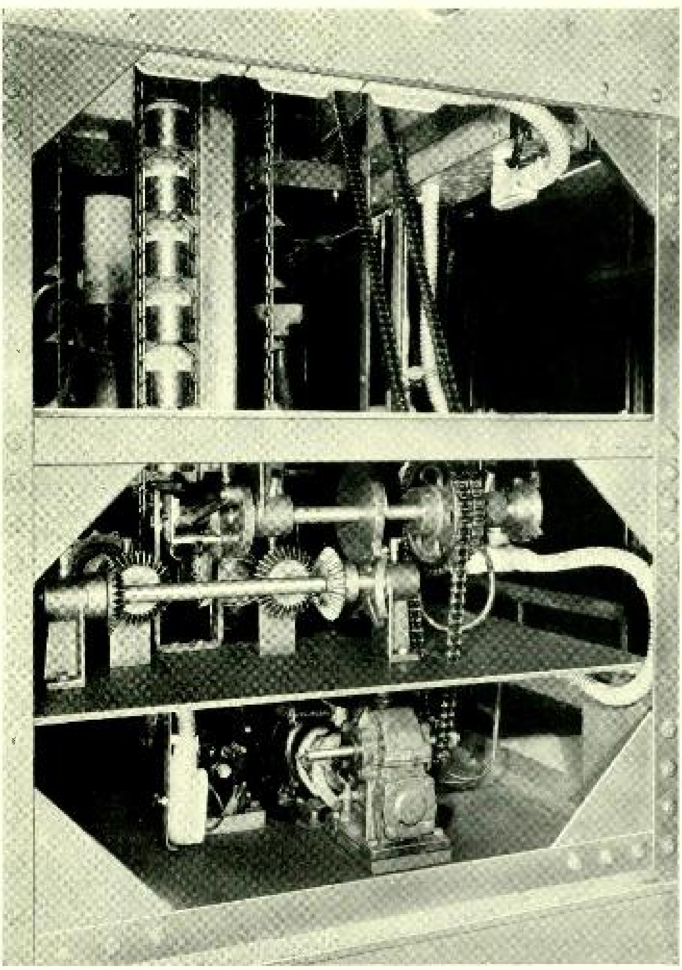


In the new continuous furnace, crucibles are passed up through the furnace (rear) and are carried down for readmittance by a chain conveyor (center). The temperature of the high-temperature zone is automatically controlled and recorded, and the composition of the atmosphere supplied is measured by flow meters (front) will receive more prolonged treatment at the higher temperatures than the crucibles at either end. In the second place, if the material reacts with some constituent of the atmosphere, the atmosphere will contain progressively less of that constituent and more of the reaction products as it passes through the furnace, and crucibles near the outlet and those near the inlet will be exposed to different atmospheres.

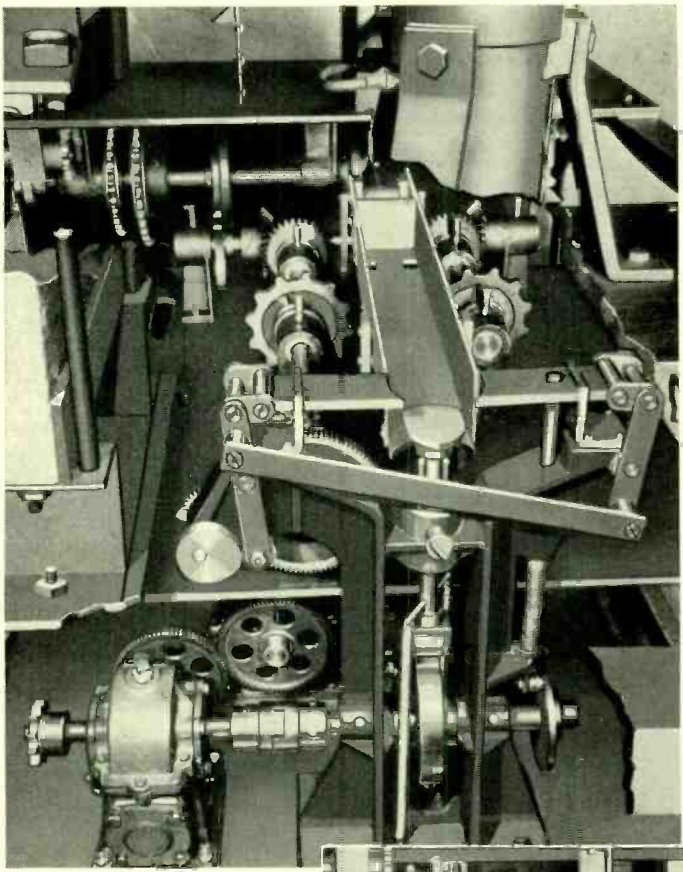
The total effect of these variations is a variation in the properties of the resulting samples according to the positions which they occupy in the furnace while undergoing treatment. That the resulting samples may differ considerably is shown in Figure 1 for a resistance material heated to about 1200° C. in an atmosphere of nitrogen and hydrogen. In this particular case the unsymmetrical variation, due to change in atmospheric composition through the furnace, considerably overshadows the symmetrical variation due to lower temperatures at both ends of the furnace.

The batch furnace can be modified in various ways so that the treatment it gives will be less preferential. Booster windings can be added at the two ends to equalize the temperature, and indeed this was done in the furnace with which the data shown in Figure 1 were obtained. To equalize the atmosphere, gas can be admitted and withdrawn at more points. At best, however, perfect uniformity can never be assured throughout the furnace, and perfect duplication of conditions for successive batches can never be obtained. When a material is very sensitive to small differences of temperature and atmosphere, satisfactorily uniform samples cannot be produced.

The uniformity can be obtained, however, by inverting the rôles of the furnace and



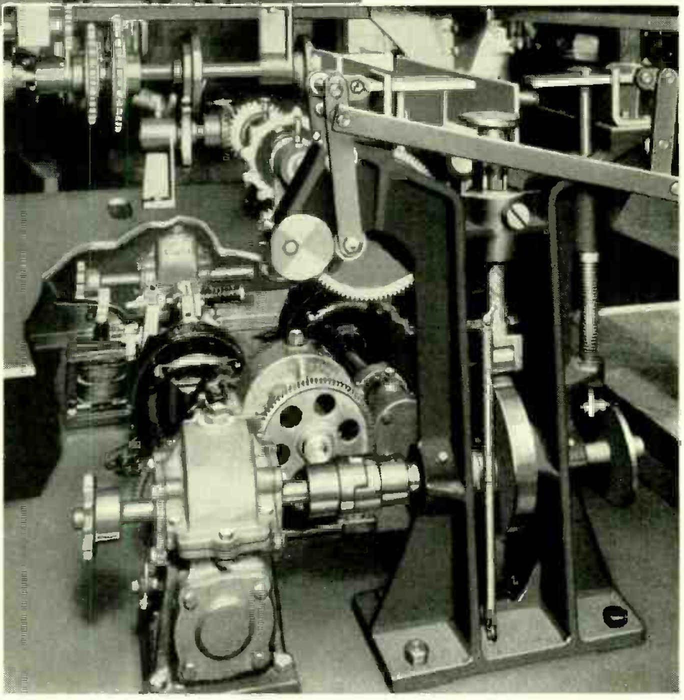
Interior view of heat-treating apparatus



relatively unaffected by variations in temperature and atmosphere between the center and the edge of the furnace. Such a furnace can moreover be readily adapted to furnish the great convenience of continuous operation.

The fundamental idea of this type of furnace has been embodied in many industrial processes, often in a highly mechanized form. Similar considerations have determined the procedures used by the Western Electric Company and others for baking japans, preheating copper bars for wire,

Cut-away views of the interior of the apparatus



material, so to speak. If, instead of placing the samples in fixed positions and varying the temperature of the furnace, the furnace is held constant and the samples are moved uniformly through it, all samples will successively pass through identical zones of temperature and atmosphere. Furthermore, if the samples pass through the furnace in single file, they will be annealing coils of wire, electroplating various parts, and the like. The same principle is also employed in the furnaces for roasting transmitter carbon already described in the *Record*.*

The continuous furnace recently constructed for the cyclical heat-treatment of special materials in these Laboratories is shown in the accompanying illustrations. Essentially its function is to pass crucibles containing the materials at known rates through a heated zone maintained in constant thermal equilibrium, in a direction counter to that of a stream of gas of the desired composition. An ingenious mechanism† automatically admits the crucibles to the furnace, passes them through and out, and, after a lapse of time sufficient for discharging and recharging the crucibles, readmits them to the furnace.

The material is placed in nickel crucibles with perforated sides, and with perforated ceramic covers. The crucibles are slowly and continuously pushed upward through a vertical refractory tube. Gas is admitted at the top and escapes at the bottom of the tube, which is made gas-tight by a gland at each end, consisting of a series of compressed felt rings through which the crucibles are forced. The crucibles are cooled at the top of the tube, and are discharged from it onto a horizontal trough, from which a chain conveyor ultimately returns them to a similar trough for readmission to the tube. Since the motion of crucibles in the troughs and conveyor is intermittent, they can be emptied and refilled while at any position in these parts of their cycle.

The furnace is heated electrically by three resistance windings on a spirally grooved refractory tube surrounding that through which the crucibles pass. The first winding is of Nichrome wire designed to attain a maximum temperature of about 950° C. The other two windings, designed for a maximum temperature 200° higher, are of an alloy of platinum and rhodium. The temperature of these units is accurately and automatically controlled.

The heating units and the mechanism are operated entirely on alternating current, and the necessary fuse boxes, control resistances, and transformers are integral parts of the furnace. It is possible to vary the temperature and length of the heated zone, and the rate at which the crucibles pass through it, over wide ranges. Facilities are provided for mixing the gases to be passed through the furnace and measuring their several proportions with capillary flow meters. Precautionary devices prevent damage due to thermal expansion of the refractory materials or to failure of the operating mechanism.

Although the furnace was primarily designed to facilitate the preparation of identical samples of a limited class of materials, its application is not necessarily so narrowly restricted. The substitution of ceramic crucibles for nickel, which can be used only in reducing atmospheres, would permit the use of oxidizing atmospheres. The temperature flexibility would admit of heat treatments in which the maximum temperature lies anywhere between 200° C. and 1250° C.

*Record, *February*, 1932, *p.* 200.

†Designed by H. A. Schultz of the Research Laboratory Engineering Group.

Depicting Currents in Telephone Lines

By M. K. ZINN
Local Transmission Development

A FUNDAMENTAL working idea used by telephone engineers almost daily is that of phase relationship. The notions of phase, amplitude, vector and the like, are so familiar that most engineers never stop to recall how they arose.

The idea of phase is associated with a wave having the form of a sine curve. One reason why this particular form of wave is so popular with engineers is because a wave having any other form can be regarded as made up of a number of sine waves. Calculations can be simplified by performing them for these sine waves and compositing the results. Two such waves of the same frequency are said to differ in phase when one is displaced from the other so that they do not go through their crests and troughs at the same time. These differences are shown up in a particularly instructive manner by representing sine waves in terms of rotating lines.

When the radius of a circle rotates at a uniform speed, the length of its projection on a diameter of the circle varies with time according to the sine law, and can be used to represent a sine wave of current or voltage. In that use, the rotating radius is called a "vector." [Strictly speaking, it should not be called a "vector," as this term has a prior use for designating a directed quantity in the classical theory of waves in three-dimensional space. Nevertheless, the engineering use of the term is widespread.] Evidently, if two sine waves of the same frequency differ in phase, the corresponding vectors differ in angular position, by an amount which remains constant as they rotate. The advantage of representing sine waves by vectors results from this constancy, which eliminates the time factor from the problem.

The vector scheme is particularly useful in illustrating how a sine wave

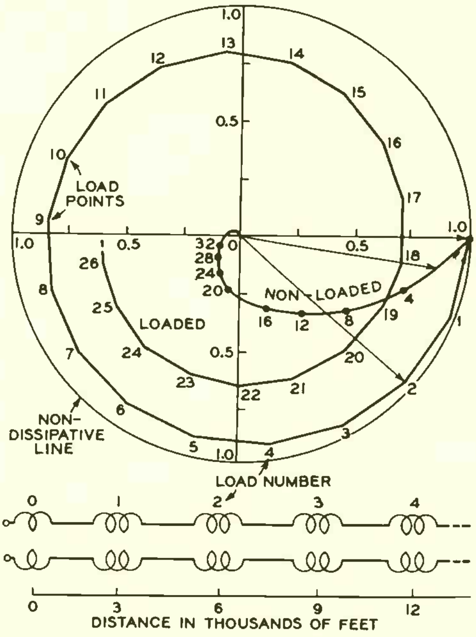


Fig. 1—By plotting the end points of vectors representing the currents in loaded and non-loaded telephone lines, their relative amplitudes and phases at different points in the line are made clear. The plot above is for currents alternating at a thousand cycles per second

travels along a transmission line. Since the wave takes time to proceed from point to point, a given crest or trough of the wave reaches different points in the line at different times. The currents or voltages at these points differ in phase, therefore, and the vectors used to represent them occupy different angular positions. The accompanying illustrations show how simple and compactly vectors can be used to picture the relationships between the currents flowing along telephone lines.

When a sine wave of voltage is applied to one end of a line, the current or voltage at any point along the line goes through a transient stage and very quickly builds up to a sine wave. Thereafter the waves travel down the line with a definite speed that depends upon the electrical constants of the line. This "steady-state speed," or "phase speed," must be distinguished from the transient speed, that with which the head of any kind of suddenly impressed wave travels down the line. Some sign of any such disturbance appears at the far end of a line after a very short interval corresponding to the speed of light, but an appreciable amount of current arrives only after an interval corresponding to the steady-state speed, which is always less than the speed of light. In a pair of large, well-insulated, copper wires on poles, the steady-state speed closely approaches the speed of light, but in some loaded cable circuits the speed is only about one-twentieth as great.

The phase differences among the current waves at various points along two types of line are shown in Figure 1. Here are plotted the end points of the vectors representing the currents in typical loaded and non-loaded lines, when the currents are alternating at a rate of a thousand cycles per second. The actual currents at a given instant are the projections on the horizontal diameter of the vectors whose end points are plotted. How the currents at various points in the line vary with time can be visualized by imagining the entire system of vectors to rotate in the counter-clockwise direction at a uniform speed of a thousand revolutions per second, keeping the lengths and relative posi-

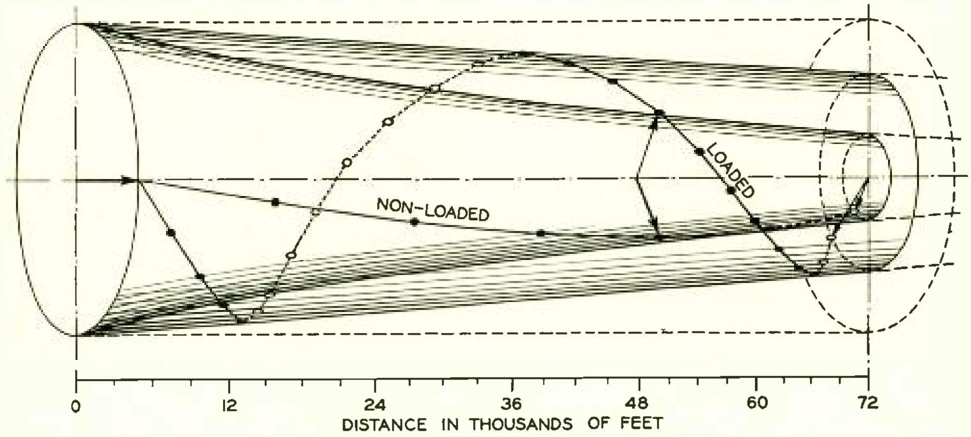


Fig. 2—From this development of Figure 1, *it can be seen that the current waves proceed less rapidly but with less attenuation in loaded than in non-loaded lines*

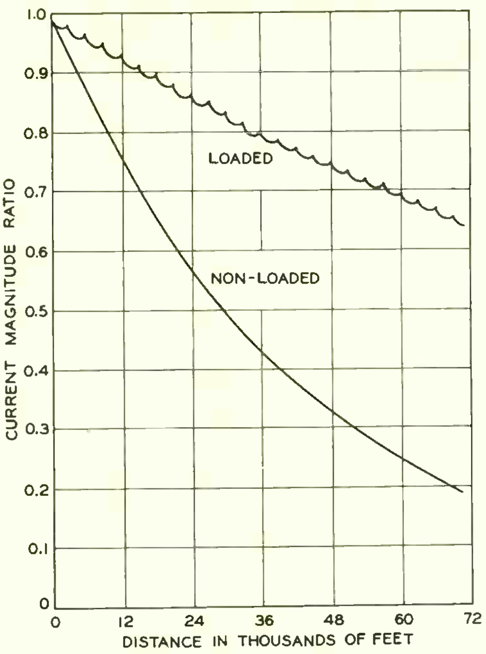


Fig. 3—The variation of amplitude with distance is shown by this plot of the lengths of the vectors of Figure 1

is represented by the difference between the two corresponding current vectors.

For the loaded circuit, the plot of the current at points between two loads has been shown as a straight line. Actually the portions of the curve between load points are not quite straight for a real dissipative circuit with distributed inductance, but usually their deviations are within the width of line on the drawing.

By developing Figure 1 into Figure 2, where a dimension has been added to show the distance along the line, a still more graphic picture is obtained of the change in amplitude and phase of the current as it traverses the line. Here the two spiralling curves, if viewed at right angles to the circular end of the cone shown on the left, would appear as the exponential spirals shown in Figure 1. The vectors lie in equally-spaced planes at right angles to the axis of the cones.

tions of all the vectors just as they are shown in the diagram. Since the maximum lengths of the projections so obtained exactly equal the lengths of the vectors, the latter represent the amplitudes of the current waves.

It is apparent from the figure that the current at any point along the line lags in phase and has a smaller amplitude in comparison to the current entering the sending end of the line. The phase shift reflects the steady-state speed of the current waves, and the diminishing amplitude reflects their attenuation. The magnitude and phase of the current that is "shunted off" by the cable section between two points

From Figure 2, a practical advantage of the loaded over the non-loaded line is immediately apparent. By loading, the attenuation of the line is made less (as indicated by the less rapid taper of the cone), at a sacrifice in the velocity of propagation (as shown by the lower pitch of the spiral).

Since the initial current in the

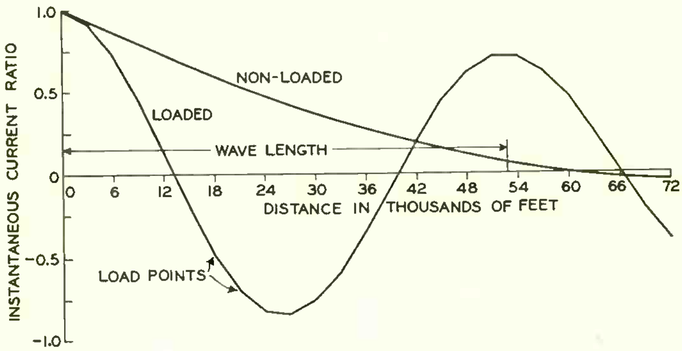


Fig. 4—The instantaneous values of current along a line can be obtained by plotting the projections of the vectors of Figure 1

loaded line has been taken at a mid-load point, the end of the current vector for any other mid-load point along the line must fall on the surface of the outer of the two shaded cones. The straight lines that give the current at points between loads fall inside the surface of the cone. The inner, more rapidly attenuated, cone has the same significance for the non-loaded line; but, since the line is of uniform instead of periodic construction, the end of any vector representing the current at any point along the line must fall on the surface of this cone.

The lengths of the vectors shown in Figure 1, that is the relative magnitudes of the currents that would be measured at various points along the loaded and non-loaded lines, are plotted in Figure 3. The curve for the loaded line has a dip between loads because the impedance of the loaded line at mid-section points is higher than at mid-load points. For a given amount of energy, the current is therefore less at mid-section points than at mid-load points.

In Figure 4 are plotted the projections of the vectors shown in Figure 1. These are the instantaneous real currents (relative to the sending end current) at various points along the loaded and non-loaded lines, at the particular instant when the current delivered to the sending end reaches its maximum positive value. The term "real" is used to emphasize the fact that this is the actual, instantaneous, physical current as distinguished from the fictitious current plotted in Figures 1 and 2.

To explain why it is proper to represent sine waves by vectors, or a real current by a fictitious one, requires a somewhat closer statement than has thus far been made. A vector can be regarded as the sum of two components: its projection on a horizontal diameter of the circle, called the "real part"; and its projection on a vertical diameter, the "imaginary part." If two vectors of the same length start from the horizontal diameter and rotate with the same speed in opposite directions around the circle, their real parts are always equal and their imaginary parts equal and opposite in sign. Consequently, their sum is a real number that varies with time according to the sine law. From this reasoning voltages or currents that are assumed to be sine waves can be replaced by the sum of two oppositely rotating vectors.

Now someone discovered long ago that the solution to circuit problems could be obtained indirectly, and in a particularly simple and instructive manner, merely by throwing away one of the vectors and carrying out the mathematical work with the other one alone. When the solution is finally obtained, it is only necessary to add the other vector, called the "conjugate vector," to get the real current desired. It should not be forgotten that currents and voltages are always measured by real numbers. No such thing as an imaginary current or voltage exists physically; they are merely mathematical fictions introduced to facilitate the solution.

In arriving at this trick for solving circuit problems a choice had to be made as to which vector to throw away. It was, of course, an arbitrary choice, like that of positive and negative in a direct-current circuit. Whoever first hit upon the trick happened to decide to throw away the vector that rotates clockwise. If he had chosen instead to throw away the counter-clockwise one, our inductive reactances would be negative and our capacitative reactances positive.

Contributors to This Issue

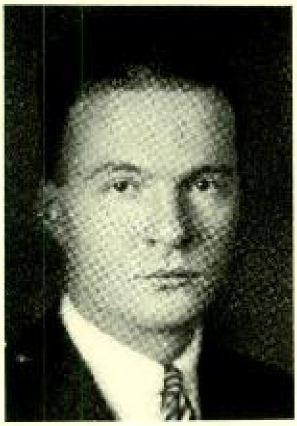
After two years at the University of Colorado, A. C. Walker went to Massachusetts Institute of Technology, where he received the B.S. degree in Chemical Engineering in 1918. After a year in the chemical warfare service, and two in chemical research for a paper mill and a firearms plant, he went to Yale University for graduate study in physical chemistry, and received the Ph.D. degree in 1923. Coming to these Laboratories in that year, he has since been concerned with research on paper and textiles, first with the Chemical Laboratories, and since 1929 with the telephone apparatus development group. He has had a large part in developing and applying methods of purifying textile insulation, and methods for the inspection control of commercially purified textiles for telephone apparatus.

Immediately after receiving the B.S. degree from Harvard University in 1930, R. O. Grisdale came to New York to join these Laboratories. Here, in the Chemical Laboratories, he has been concerned with the investigation of the conductivity of solids, particularly that of the semi-conductive and composite materials.

Joining the Western Electric Company in 1913 as Laboratory Assistant, L. Armitage spent five years in various development undertakings among which was that of iron dust cores. During this period he received the degree of B.S. from Cooper Union. After a year's absence in military service he returned to West Street and spent two years on the mechanical design of carrier equipment. For the next six years he was in business for himself, manufacturing radio sets. He returned to the Laboratories in 1927. Since then he has been employed in the development of impedance bridges and frequency equipment.

M. K. Zinn was graduated from Purdue University in 1918 and, after a brief period of training in the U. S. Army Air Service, joined the Engineering Department of the American Telephone & Telegraph Company in 1919. His work has had to do mainly with submarine cables, loading, and transformers. Recently he has been engaged in studies of

A. C. Walker



R. O. Grisdale

L. Armitage

M. K. Zinn

W. M. Goodall

R. F. Mallina

the effect on service of non-linear and transient distortion in transmitters and receivers. Last spring he became a member of the Laboratories.

W. M. Goodall joined these Laboratories immediately after receiving the B.S. degree from the California Institute of Technology in 1928. Since then he has been chiefly engaged in radio transmission studies of the ionized medium at the Deal Laboratories. In addition, he has engaged in the design of long-wave antenna and in the development of radio-frequency measuring equipment.

R. F. Mallina received an M.E. degree from the Vienna Technical College in 1912 and then studied textile engineering for two years at the Textile Engineering College in Austria and at the London Institute in England. He came to this country in 1922 and was engaged as designer and engineer by several concerns, spending over two years with the Victor Talking Machine Company. In 1929 he joined the technical staff of Bell Telephone Laboratories where with the Apparatus Development Department he worked on disk recording and call announcers. At the present time he is with the Acoustical Research Department.

F. B. Llewellyn

Between 1915 and 1922 F. B. Llewellyn, whose article *Vacuum Tubes at Very High Frequencies* appeared in the February Record, alternated the study and the practice of electrical engineering. During several years he acted as a radio operator, in ship-and-shore communication, for the Marconi Company, the Navy, and the Independent Wireless Telegraph Company. In 1922 he received the M.E. degree from Stevens Institute of Technology, and after a year with the Vreeland Laboratory, he joined the Engineering Department of the Western Electric Company, now these Laboratories. Here he has since been occupied with research problems in the radio field, notably those concerned with detection, constant frequency oscillators, and ultra-high frequency electronics. In 1928 he received the Ph.D. degree from Columbia University for studies conducted there on a part-time basis.