BELL LABORATORIES RECORD

SEQUENCE SWITCH ALIGNMENT
J. T. BUTTERFIELD

TWO-WAY POLICE RADIO SYSTEM
A. B. BAILEY—W. C. TINUS

DIELECTRIC POLARIZATION
A. H. WHITE—W. A. YAGER

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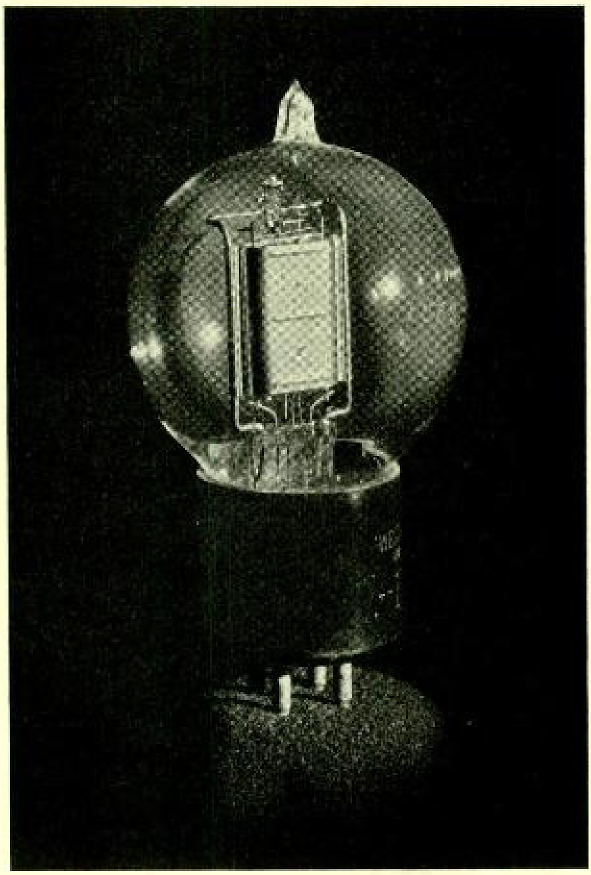

A vacuum tube used widely in telephone repeaters

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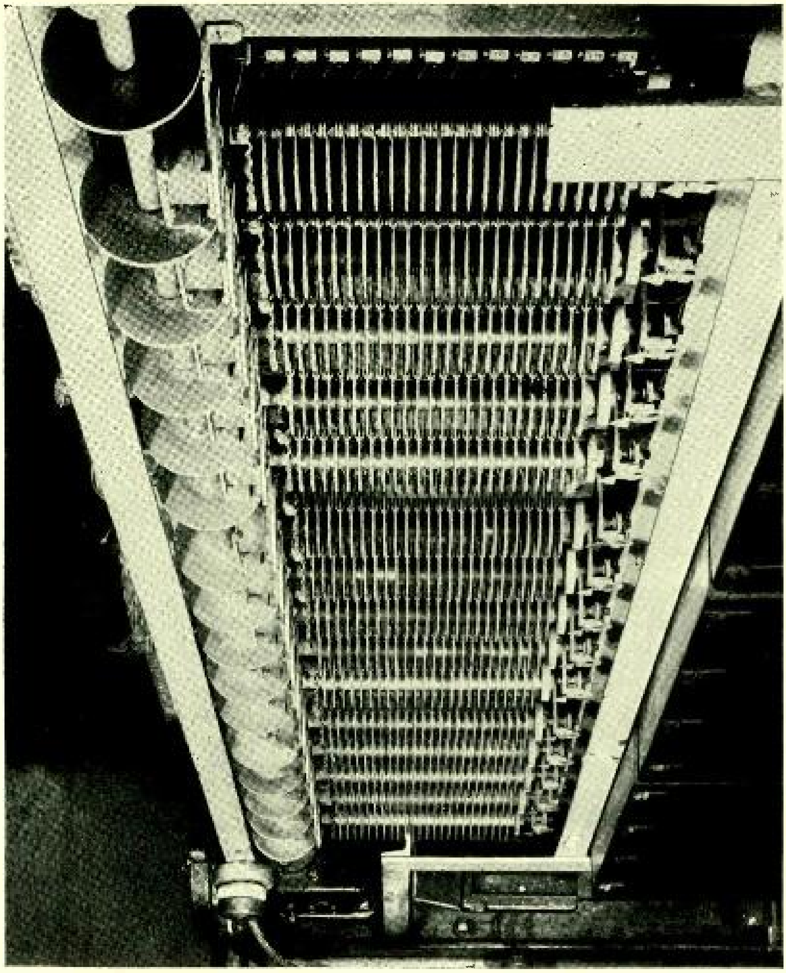


Control of Alignment of Sequence Switch Drives

By J. T. BUTTERFIELD
Telephone Apparatus Development

SEQUENCE switches* are mounted on structural steel frames with a common drive shaft running vertically up one side. The arrangement is shown in the illustration at the head of this article. There may be as many as thirty sequence switches on a single frame, and for each switch a driving disk is mounted on the vertical shaft. This disk, by friction, drives a similar disk on the end of the sequence switch whenever the electromagnetic clutch is energized. The arrangement of a typical sequence switch frame is shown in the plan view of Figure 1 and the photograph of Figure 2. Two

*Record, *December*, 1931, *p.* 119.

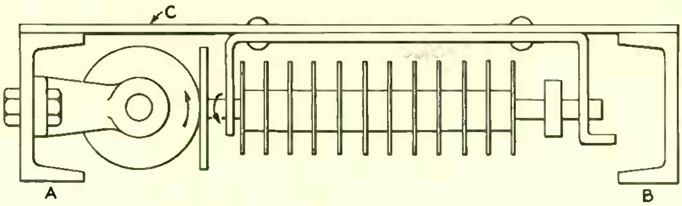


Fig. 1—Plan view of sequence switch frame showing side channels, A and B, and support for sequence switch, C

vertical channel irons, A and B, eleven feet high and eighteen inches apart, run up from the floor. Bearings for the drive shaft are bolted to the inside of one of the channels as shown, and flat strips of steel, C, welded, or in some cases bolted, to the channels form the supports for the sequence switches. The mounting arrangement of the bearings permits sufficient adjustment of position to allow the shaft to be lined up.

The proper action of the friction disk drive requires a fairly accurate alignment. Conditions of correct alignment are shown in Figure 3 in which the area of contact is indicated by a short heavy line. Within this small area all points on both disks are moving in a horizontal direction as represented by the arrow D. In this condition slipping and wear of the disks are at a minimum and no vertical force is transmitted to the drive shaft. With a misaligned condition as shown in Figure 4 this is not true. The motion of the driving disk is still horizontal but the motion of the driven disk at the area of contact is in a direction tangent to the driven disk; it is inclined to the horizontal direction as indicated by the arrow C. In this condition it is obvious that when the disks are rotated in the direction shown by the arrows, with the disks pressed firmly together, there will be considerable upward force exerted on the driving disk.

The magnitude of this upward force

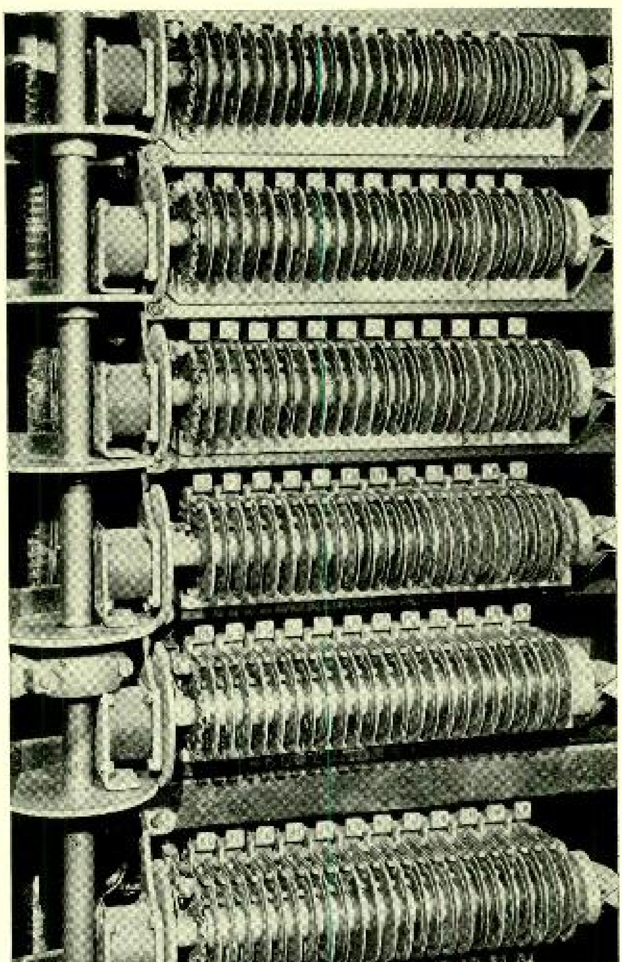


Fig. 2—The sequence switch is driven by friction between two steel disks

cannot, of course, exceed the frictional force between the two disks in the plane of contact, but it may be equal to it. In actual practice it has been found that the operation of two switches will sometimes produce sufficient upward force to lift the weight of the drive shaft unless it is restrained by vertical thrust bearings. If the drive shaft is located behind the axis of the sequence switch shaft, opposite to the position shown in Figure 4, the vertical force on the driving disk becomes downward instead of upward. In addition to the development of vertical thrust on the drive shaft, misalignment of the friction drive produces objectionable wear and squeaking of the driving disks.

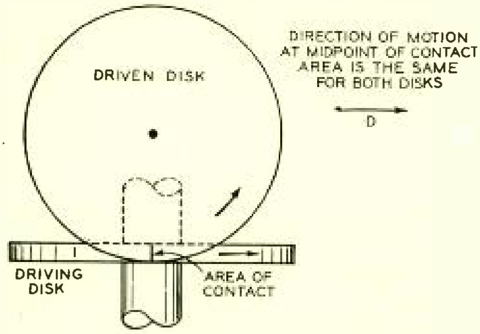


Fig. 3—Correctly aligned, the motion of the driving and driven disks at the point of contact is equal in magnitude and direction

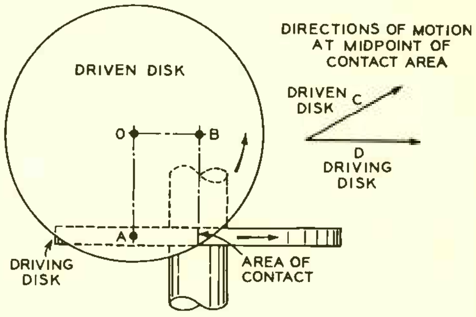


Fig. 4—When the shafts are not in correct alignment slipping will result, which causes a vertical thrust on the driving shaft

The early method of assembling sequence switch frames was to locate the upper and lower drive shaft bearings and to align the drive shaft so that the drives for the top and bottom sequence switches would be in correct alignment within the allowable tolerances. The other drive shaft bearings were then located on a straight line through these two reference bearings. With straight channels and all other parts within allowable limits all of the sequence switches would then be in satisfactory alignment.

It gradually became apparent, however, that the alignment of switches in the telephone plant was not completely satisfactory in certain cases,

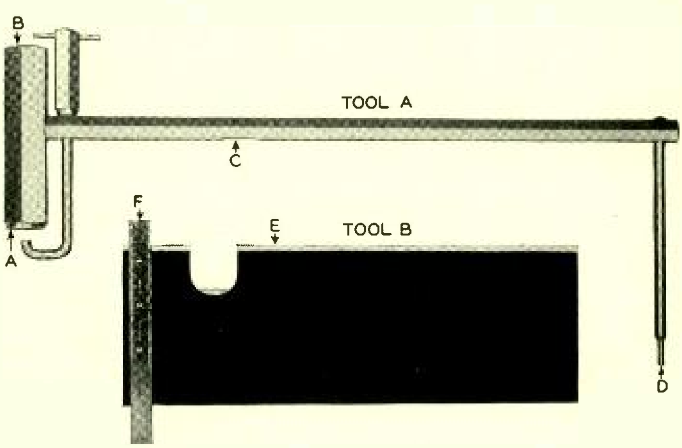


Fig. 5—By use of the upper tool, reference lines are obtained which are used to locate parts of the sequence switch frame. The lower tools permit a simple measurement of the misalignment between driving and driven shafts

and to secure comprehensive data careful measurements were made of a number of representative sequence switch bays of the latest type. Some of these bays contained squeaky switches and others showed no sign of misalignment. To secure the necessary measurements two special tools were developed as shown in Figure 5.

Surface "A" of the upper tool is placed against the front of the channel carrying the drive shaft and fastened to it by the clamping arm. Surface "D" rests against the front of the sequence switch supporting bar just inside the other channel. A similar tool is mounted at the bottom of the frame and strings stretched between the edges "C" of the two bars form reference lines from which the distances to the front of the channel and to the front of the sequence switch supporting bars are readily determined and measured.

The distance from the front edge of the sequence switch cams to the front of the driving shaft was measured by the tool shown in the lower part of Figure 5. This tool consists of a sheet of phenol fibre with a straight edge "E." A steel scale placed on the gauge as shown with its end "F" resting against the driving shaft completed the equipment. A line "G" was marked on the phenol fibre at a distance of 3″ from where the front of the drive shaft would be if the alignment with the axis of the sequence switch cam shaft were perfect. The distance between the 3″ mark on the scale and the above mentioned line is the amount of misalignment.

The results of the measurements obtained with these tools were plotted to scale, a separate graph being made for each frame. One of these graphs is shown in Figure 6, in which AA and DD are the reference lines for the measurements. This graph indicates a commonly found condition that the channels are not always straight but are often slightly bowed as the result of their rolling in manufacture and because of the operation of welding the cross bars to the channel. The earlier method of assembly resulted in the drive shaft being located along a chord of the arc of the bow of the channel, while the sequence switches, being fastened to bars welded to the faces of the channels, followed the curvature of the channel. There thus tends to be a progressive misalignment of the sequence switches toward the center of the frame as shown in Figure 6 in which the location of the drive shaft in accordance with the earlier practice is indicated by the line BB. However,

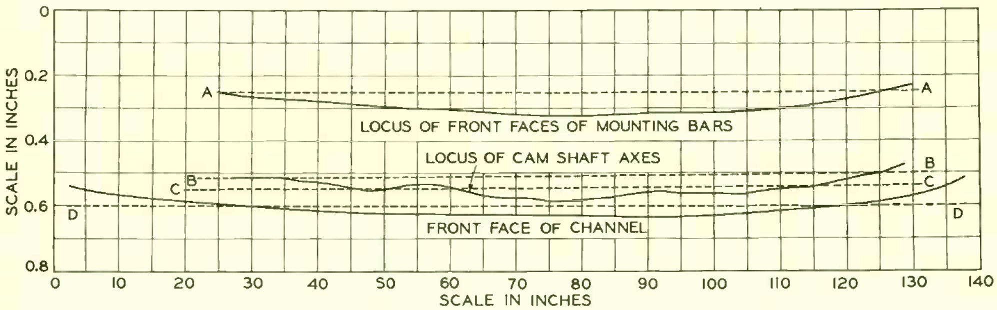
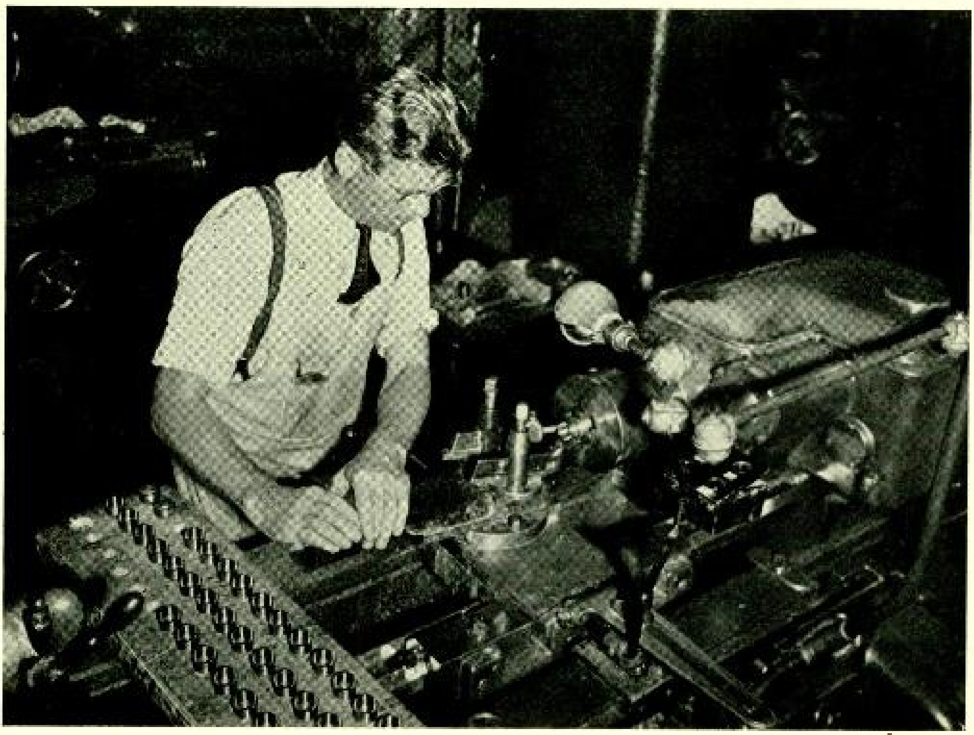


Fig. 6—Method of plotting measurements made on sequence switch frames by use of the tools shown in Figure 5

if a direct reading gauge similar to that of Figure 5 is applied to this frame, more favorable locations for the drive shaft bearings are readily indicated, and the shaft is finally assembled in the favorable position CC of Figure 6 in which all of the sequence switches of the frame are in satisfactory alignment.

As a result of this investigation a commercial tool has been developed by W. T. Pritchard, and the Bell System Practices have been revised to include the use of this tool.



Copper electrodes for the copper-to-glass seal used in water-cooled vacuum tubes being machined in the Development Shop

Two Types of Dielectric Polarization

By A. H. WHITE
Chemical Laboratories

THE only substance whose dielectric constant does not change with temperature or frequency is no substance at all—a vacuum. In all other cases there is involved some arrangement of atoms and molecules, random or regular and varying with temperature; and the dielectric constant is a measure of the ability of the electric charges in the material to be rearranged: for the material to be "polarized" or "depolarized." Because of inertia or viscous resistance, a finite time, the "time of relaxation," is required for the charges to rearrange themselves, and the dielectric constant therefore depends on the rapidity with which the applied electric field varies. Since an alternating field varies more rapidly as its frequency increases, the dielectric constant of any substance is greatest for static fields where sufficient time is allowed for even the most sluggish rearrangements to take place, and small at the frequency of light where distortion of the atoms is the only change that has time to occur. If it changes at all, the dielectric constant must decrease with increasing frequency, except for regions near certain resonance frequencies.

The sort of change of dielectric constant with frequency which occurs in the range from power to radio frequencies, is illustrated at the top of Figure 1. A material may exhibit such a change for one or both of at least two distinct reasons. One, the more familiar, is that the material is a "polar" substance, that is, its molecules are "permanent dipoles." This notion and these terms were introduced into dielectric theory by P. Debye, and have already been described in the RECORD.* In accordance with them, materials can be classified into non-polar substances, in whose molecules the center of gravity of the positive charges coincides with that of the negative charges, and polar substances in which those centers do not coincide. When a potential is placed across a sheet of a polar substance, the molecules tend to rotate into alignment with the electric field. The resulting total displacement of charges, and thus the dielectric constant, may be far larger than in a non-polar substance, where the only effect of electrical stress is to force the positive and negative charges within the molecules slightly in opposite directions. It is supposed that the orientation of dipoles is possible in most substances only when in the fluid state, for the dielectric constant of most polar materials abruptly drops when they freeze.

The other source of a change of dielectric properties with frequency to be considered here resides in certain gross structural features of the dielectric. In the condenser of Figure 2A charges migrate through the dielectric at a rate determined by its conductivity. Since this is everywhere the same, there is no accumulation of charges within the dielectric, and its capacity is determined

*RECORD; *June*, 1931, *p.* 462; *July*, 1931, *p.* 535.

by the distance between the outer surfaces where the charges do accumulate. But in the condenser of Figure 2B, where the lower half of the dielectric of Figure 2A is re-

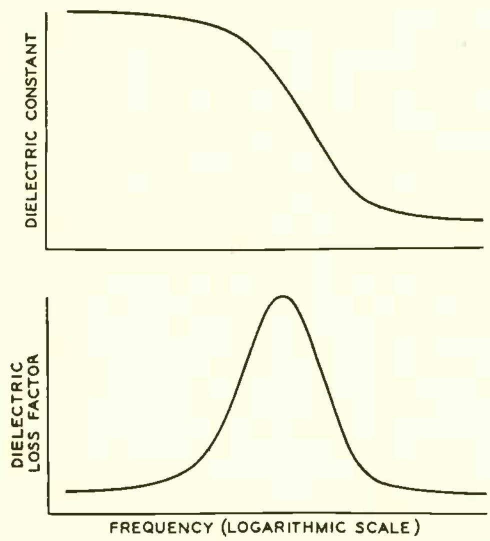


Fig. 1—As the frequency at which the dielectric properties of a mixture or a polar substance are measured is increased, a frequency is reached at which the dielectric constant (above) declines, and the dielectric loss factor (below) reaches a maximum

placed by a layer of another dielectric of greater conductivity, charges migrate more easily and rapidly in the latter layer, and consequently there is a change in the rate at which the complete polarization is built up. It can be shown that, even when the dielectric constant of each layer alone does not change with frequency, the effective constant of both layers together does change, again in the manner shown in Figure 1. In the limiting case, when the conductance of one layer is very much greater than that of the other, the accumulation of charges at the interface is so rapid that the second layer acts like the electrode, and the effective capacity of the condenser is greater because the effective separation is smaller.

Described first by Maxwell, such accumulations of charges, or polarizations, have been more recently treated by Wagner, who has shown that they can be expected to take place at the interfaces in any heterogeneous material when it is subjected to a potential. Examples of such materials are furnished by the most widely used of all dielectrics, paper and cotton. As can be seen in Figure 3, paper is really a two-layer dielectric laid out in less formal fashion than that in Figure 2B: a mixture of an insulating layer of cellulose particles and a more conducting layer of water or an aqueous solution.

Just as the dielectric constants of polar substances and mixtures vary in much the same way with frequency (Figure 1), so also other dielectric properties are similar for the two types of substance. Thus it becomes rather difficult to tell by tests whether the dielectric phenomena observed in a given material are due to polarizations of the Debye or of the Maxwell-

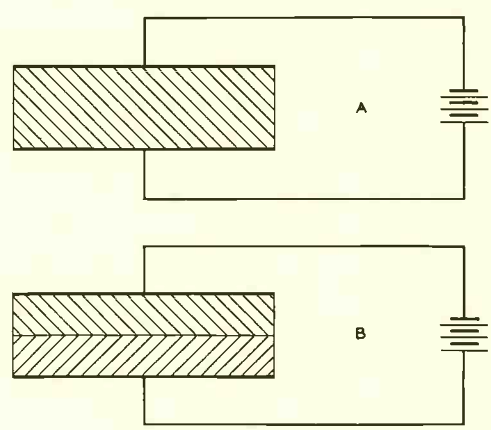


Fig. 2—The capacitance of a condenser occupying a given amount of space can be increased by forming it of two or more layers, using a second dielectric of higher conductivity

Wagner type. In some cases, however, it seems that it should be possible to decide this question of polarization by studying the variation of the dielectric constant with both frequency and temperature.

In measuring the dielectric constant of a polar substance at increasing frequencies, the molecules are asked to orient themselves in the alternating electric field more and more rapidly. This orientation is impeded by friction in the material itself. The friction determines the relaxation time: the time required for an assemblage of polar molecules to resume a practically random orientation after removal of a potential; or conversely the time required after the application of the field for the alignment of polar molecules with this field to become complete, insofar as thermal motion permits. The reciprocal of the relaxation time is the critical frequency above which the molecules begin to show greater and greater difficulty in following the alternations of the field. That difficulty is evidenced by a rapid decline of the dielectric constant with increasing frequency, as shown in Figure 1. The same sort of behavior is shown by mixtures whose dielectric properties are largely accountable to the Maxwell-Wagner type of polarization. There the relaxation time is determined by the time required to build up the charges at the interfaces.

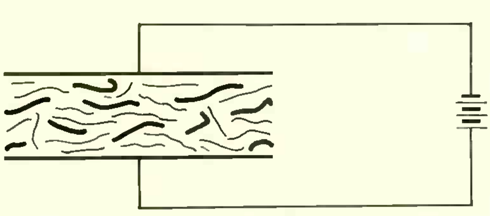


Fig. 3—The dielectric properties of paper are due in part to the fact that it is an informal condenser, with "plates" formed by its conducting constituents close together, "insulated" by its non-conducting constituents

Because of the friction or resistance impeding the rotation of the molecules, power is dissipated in polar dielectrics. In alternating current measurements, this power loss appears as a conductance which increases with increasing frequency, or with increasing r.p.m. so to speak, but the increase is not linear because of the effect of relaxation time already mentioned. The deviations from linearity can be revealed by dividing the conductance by the frequency and plotting this (called the dielectric loss factor) against frequency. As might be expected, a plot of this factor shows a maximum at the same critical frequency as that about which the decline of dielectric constant is centered. Such a plot is shown in the lower half of Figure 1. Again the Maxwell-Wagner mixtures show the same phenomenon.

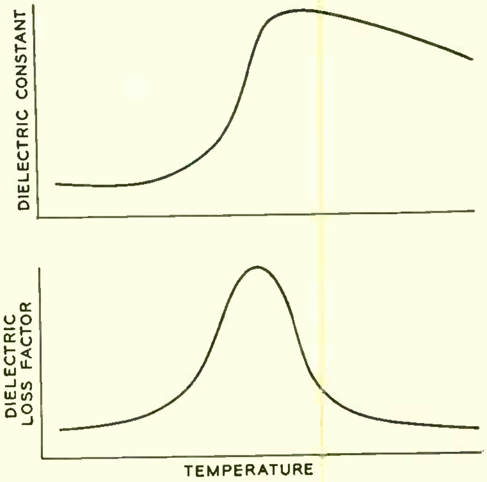


Fig. 4—The variation of dielectric properties with decreasing temperature is roughly similar to their variation with increasing frequency (Figure 1)

When the variation of the dielectric constant with temperature is studied

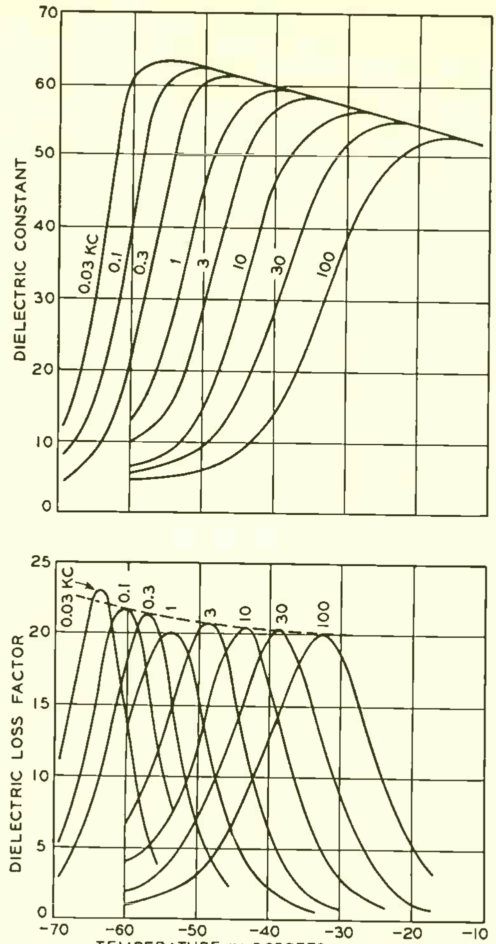


Fig. 5—With decreasing temperature, there is a decrease in the frequency at which the dielectric constant of glycerine declines, and at which the dielectric loss factor reaches a maximum. The maximum value of the loss factor increases with decreasing temperature, as shown by the dotted line, in a fashion characteristic of polar substances

at any particular frequency, similar phenomena are observed. As the temperature is decreased, the viscosity of the material increases, making it more difficult for the molecules to align themselves with the field. Thus, decreasing the temperature has an effect roughly similar to that produced by increasing the frequency: a critical temperature is reached at which the loss factor is a maximum and in the neighborhood of which the dielectric constant rapidly declines (Figure 4). For higher frequencies the critical viscosity will be reached at a higher temperature. This behavior is well illustrated by glycerine (Figure 5), a viscous polar substance.

It is when the variation of the maximum values of the loss factor is studied on such curves as these that a difference between the two types of polarization may appear. For polar substances the maxima of the loss factor become larger as the temperature and the corresponding critical frequency are reduced, following in the case of glycerine the dotted line in Figure 5. This is because, at the lower temperatures, thermal agitation of the molecules interferes less with their orientation at the critical frequency, and the more complete orientation involves more friction and a greater loss.

As a mixture of solids and fluids is cooled, on the other hand, one or another of its fluid constituents usually freezes out gradually, in amounts and at temperatures depending on the nature of the constituents and the proportions of the mixture. Sometimes even a solid constituent changes from one solid state to another. Now it often happens that when a substance changes from the liquid to the solid state, or from one solid state to another, there is a large reduction in its conductivity. An examination of Wagner's equations for the maximum value of the loss factor shows that a reduction in the conductivity of any constituent would also reduce the value. Mixtures of this sort may therefore be expected to exhibit a decline in the maximum value of the loss factor with decreasing temperature, in contrast to the increase in that maximum value that is exhibited by normal polar substances.

On the experimental side, paper, a mixture of cellulose with absorbed water*, confronts the investigator with just the sort of decline in the maximum value of the loss factor with decreasing temperature that has been described, as is shown by the dotted line in Figure 6. Other samples of paper containing less moisture show the same tendency for the loss-factor maxima to decrease with temperature. Moreover the values of the maxima decrease with the water content of the paper. In Figure 7 the maxima for one frequency, ten kilocycles, are shown for different periods of drying, the highest being for the original undried sample and the lower curves for successively longer drying periods. The upper curves of Figure 7 show that the capacity of a paper-insulated condenser also decreases with progressive drying. With long continued drying both the dielectric constant and loss factor approach limiting values but the changes with temperature and frequency remain. The dielectric behavior summarized in Figures 6 and 7 appears best fitted with other relevant facts by explaining it in terms of the Maxwell-Wagner type of polarization, although this is not the only explanation.

*Record, *November*, 1934, *p.* 72.

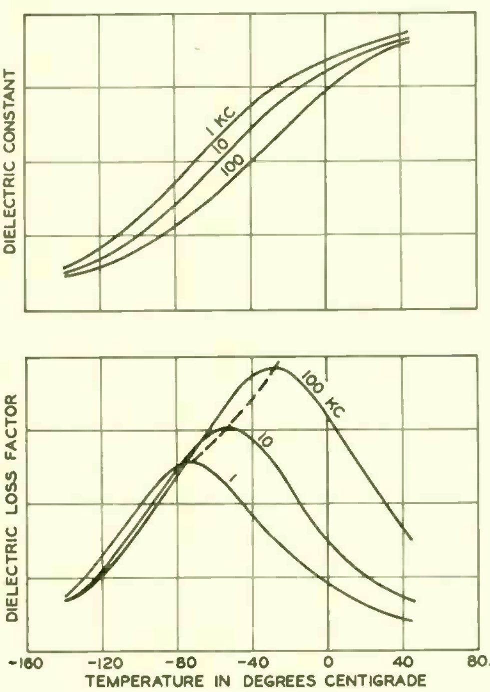


Fig. 6—The dielectric properties of paper behave, in a qualitative way, like those of glycerine (Figure 5), except that the maximum value of the dielectric loss factor decreases with decreasing temperature

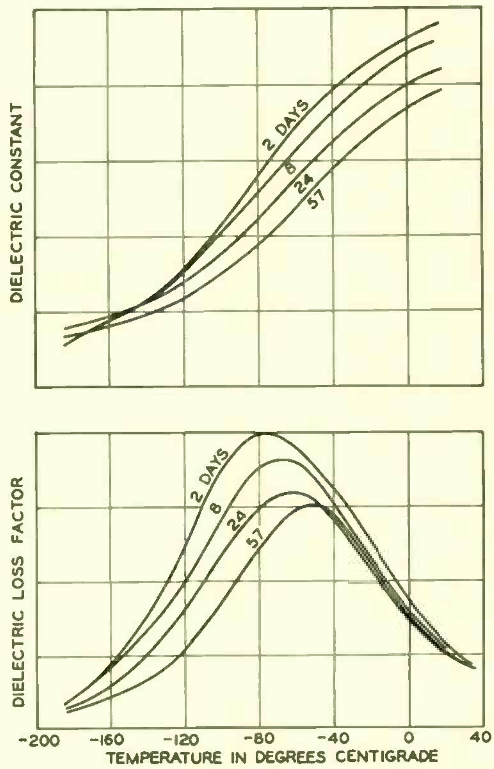


Fig. 7—Variation of the dielectric constant and loss-factor of paper after different periods of drying, measured at ten kilocycles

In general, then, the maximum value of the dielectric loss factor in a polar substance will increase with decreasing temperature, while the maximum in heterogeneous mixtures may decrease with decreasing temperature. The type of study which has elicited this information forms part of a broad program of investigation into the nature and behavior of dielectrics, conducted by the Chemical Laboratories. The information is of a sort which will probably play a large part in the development of improved dielectric materials.

F. H. McIntosh inspecting equipment used to synchronize Station WBBM in Chicago and Station KFAB in Lincoln, Nebraska

Two-Way Police Radio System

By ARNOLD B. BAILEY
Radio Development

WESTERN Electric police radio transmitters have been widely employed in recent years and have given universal satisfaction. They are available in sizes ranging from 50 to 1000 watts in the band 1500 to 3000 kc. and from 5 to 500 watts in the band 30 to 42 mc. Some of these transmitters have already been described in the RECORD.* They are usually installed at police headquarters or at one or more precinct stations, and police patrol cars, equipped with small radio receivers, cruise over assigned areas ready to speed to any scene of crime. For many locations such an arrangement is entirely adequate, but recently certain cities have felt that increased efficiency would be obtained if the patrol cars could communicate directly with their headquarters, as well as receive instructions from them. To make this possible the Laboratories have developed a small, light weight radio transmitter for installation in patrol cars.

This new transmitter, known as the 18A, has an output of five watts, and is designed for operation at frequencies between 30,000 and 42,000 kc. It is only eleven inches wide, seven high, and six deep, and may be mounted in any convenient place in the car, although the rear is generally most desirable. An "on-off" switch is mounted on the instrument panel of the car but no controls requiring regular attention are on the transmitter itself. A quartz-crystal oscillator maintains the frequency constant to better than .025%, which is well within the legal tolerance. This extremely close regulation of the carrier frequency means that the signals are held at all times to within less than ± 11 kc. of the assigned frequency—a band far narrower than has previously been attained in commercial apparatus oper-

*RECORD, *May*, 1935, *p*. 273.

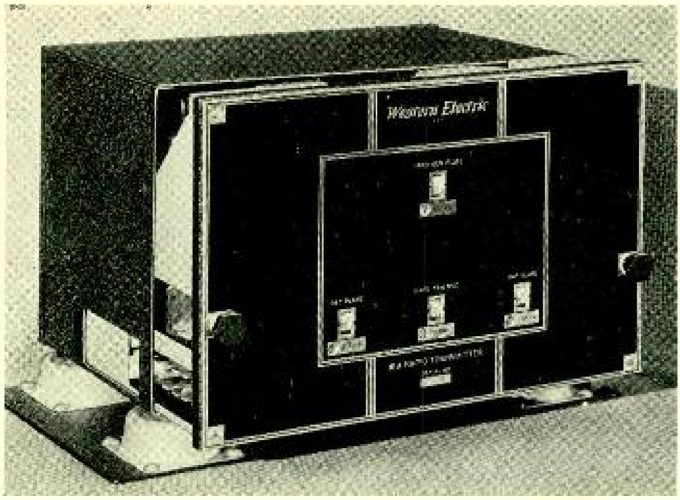


Fig. 1—The 18A transmitter is mounted on a metal chassis which may be slid from its housing by turning two knobs at the side of the front panel

ating at these high frequencies. No manual adjustment of frequency is required at any time. The Western Electric 306A vacuum tubes employed have quick heating filaments. They reach their operating temperature almost instantaneously, and are thus particularly suited for intermittent operation. All power and control connections to the transmitter are carried through a single plug, which enables the unit to be quickly removed for inspection or maintenance.

A handset, mounted on the instrument board, is used for talking. The receiver of the handset is permanently connected to the radio receiver. The loud speaker, normally used with the latter in one-way installations, is arranged to be disconnected automatically when the transmitting switch is turned to the "on" position. If preferred, the system may be wired to allow the loud speaker as well as the handset receiver to be left on continuously except when the car transmitter is on the air. Under talking conditions, the handset is used as it would be for any telephone call, while with the transmitter "off," announcements may be heard over either the loud speaker or the handset receiver.

The headquarters transmitter used with this two-way system may be of 50 watts or greater capacity, and it might seem that with only a 5-watt car transmitter, it would be impossible to hear the cars unless they were fairly close to headquarters. This is not the case, however. Extensive tests have shown that the 5-watt car receivers may be as effective in reaching headquarters as 50-watt station transmitters are in reaching the cars. The explanation is that the

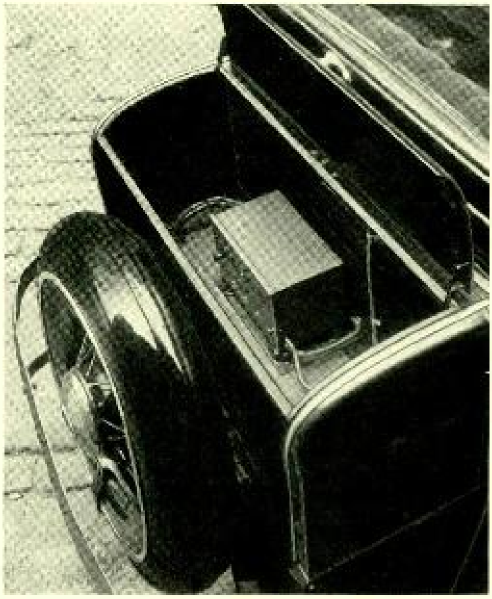


Fig. 2—An installation of the 18A transmitter in the rear of the Laboratories test car

effective range of a signal depends not only on the field strength but on the noise level at the point of reception. In the streets, where the cars must receive, the noise level is high, while at the headquarters location, high above the streets in a comparatively quiet location, the noise level may be low. This difference in noise level, therefore, entirely justifies the difference in the power output of the station and car transmitters.

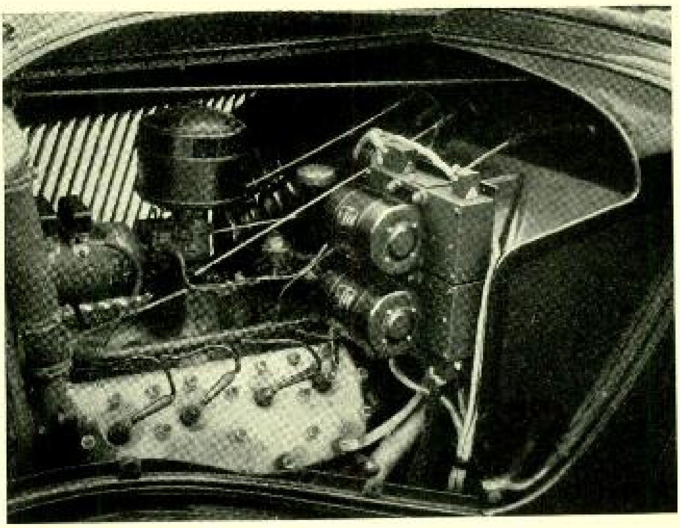


Fig. 4—Dynamotors for the two-way police radio system as installed in the Laboratories test car

With a two-way single-frequency system it is necessary to disable the radio receiver while the transmitter is on the air, and two ways of accomplishing this are optional with the Western Electric equipment. One provides a "press-to-talk" switch which is incorporated in the handle of the handset. When this is pressed the radio receiver is disabled and the high voltage is applied to the radio transmitter so that it is at once in a transmitting condition. As soon as this switch is released, the transmitter goes "off the air" and the receiver is connected. The operation of the relays controlled by this switch is practically instantaneous so that the flow of conversation is nearly as regular as in an ordinary telephone conversation.

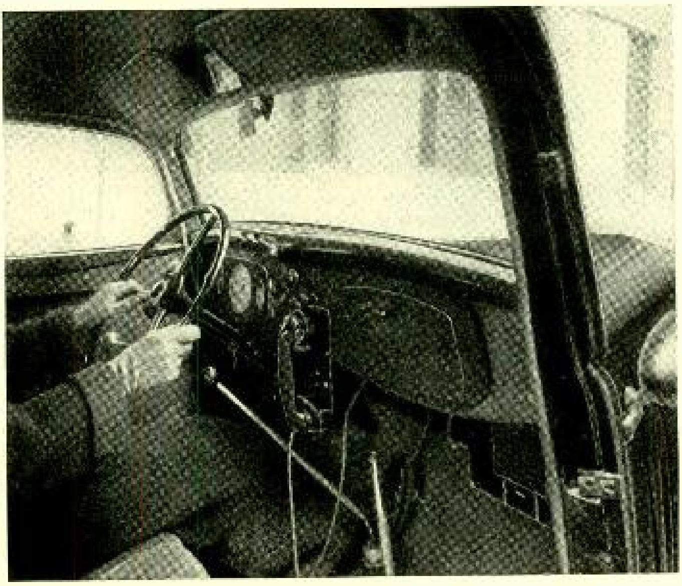


Fig. 3—The "on-off" switch for the transmitter is on the plate that carries the handset, where it may be flipped on by the fingers in taking hold of the handset

The alternative method employs no manual switch but utilizes the voice currents themselves to actuate the relays necessary to switch back and forth between transmitter and receiver. Both types of control are furnished with the transmitter, and the type of control desired is selected by operating a switch in the radio transmitter. The voice-operated control gives an automatic transfer from the receiving to transmitting position, which greatly facilitates the natural flow of conversation.

Although the five-watt car transmitter has been designed primarily for use in two-way, ultra-high frequency systems, it may be added to the car installations of one-way systems operating in the 2-megacycle band to provide the "talk back" feature. Thus, such systems can be converted for two-way communication without replacing any of the apparatus in use. With a converted system of this kind, the transmission from headquarters to the car is carried on with a frequency in the 2-megacycle band; and only in the transmission from the car back to the receiving points is an ultra-high frequency utilized.

The ultra-high frequency radio receiver employed for the two-way police system, type 18, is the same as that used with the one-way ultra-high frequency system, and may be mounted either under the instrument panel or behind the seat. It is similar in appearance to the transmitter and is of the same height and depth, but is two inches narrower. An extremely wide-range automatic volume-control circuit insures a constant volume of audio output for substantially all signal strengths. This receiver also contains a noise-suppression circuit which greatly reduces the noise output commonly present in high gain receivers with automatic volume control when the carrier is off. Although a tuning control covering a limited frequency range is provided, the tuning is sufficiently stable to make adjustments unnecessary as a usual thing.

The only controls requiring attention are an "on-off" switch and a volume control—the latter being used only to make volume adjustments to override various conditions of street noise. Normally these controls are mounted on the front of the receiver but they may be extended to a control unit on the steering wheel if desired. Since they are rarely manipulated, however, the use of steering wheel units is not ordinarily recommended. The loud speaker is also normally mounted in the receiver but may be furnished as a separate unit if desired. The same antenna is usually used for both receiver and transmitter, being switched from one to the other during the two-way conversation.

Power supply for the patrol car radio equipment is obtained from the 6-volt car battery, two small dynamotors being used to furnish plate supplies—one for the receiver and one for the transmitter. A charging generator is driven by the motor so that it will charge the battery at relatively low cruising speeds. The dynamotors, battery-operated, are started when the "on-off" switches on the receiver and transmitter are turned to the "on" position. They are usually mounted in the rear of coupes and under the hood of sedans, where they are readily accessible for any maintenance work that may be required.

Bell Telephone Laboratories has for many years carried on radio research and development as part of its general communication studies. It is only natural, therefore, that the new radio apparatus for police service should incorporate the latest knowledge and technique, and represent the present maximum in quality and dependability available for this class of service.

I

Western Electric No. 20A Radio Transmitter for broadcasting. Its output power is 100 to 250 watts.

II

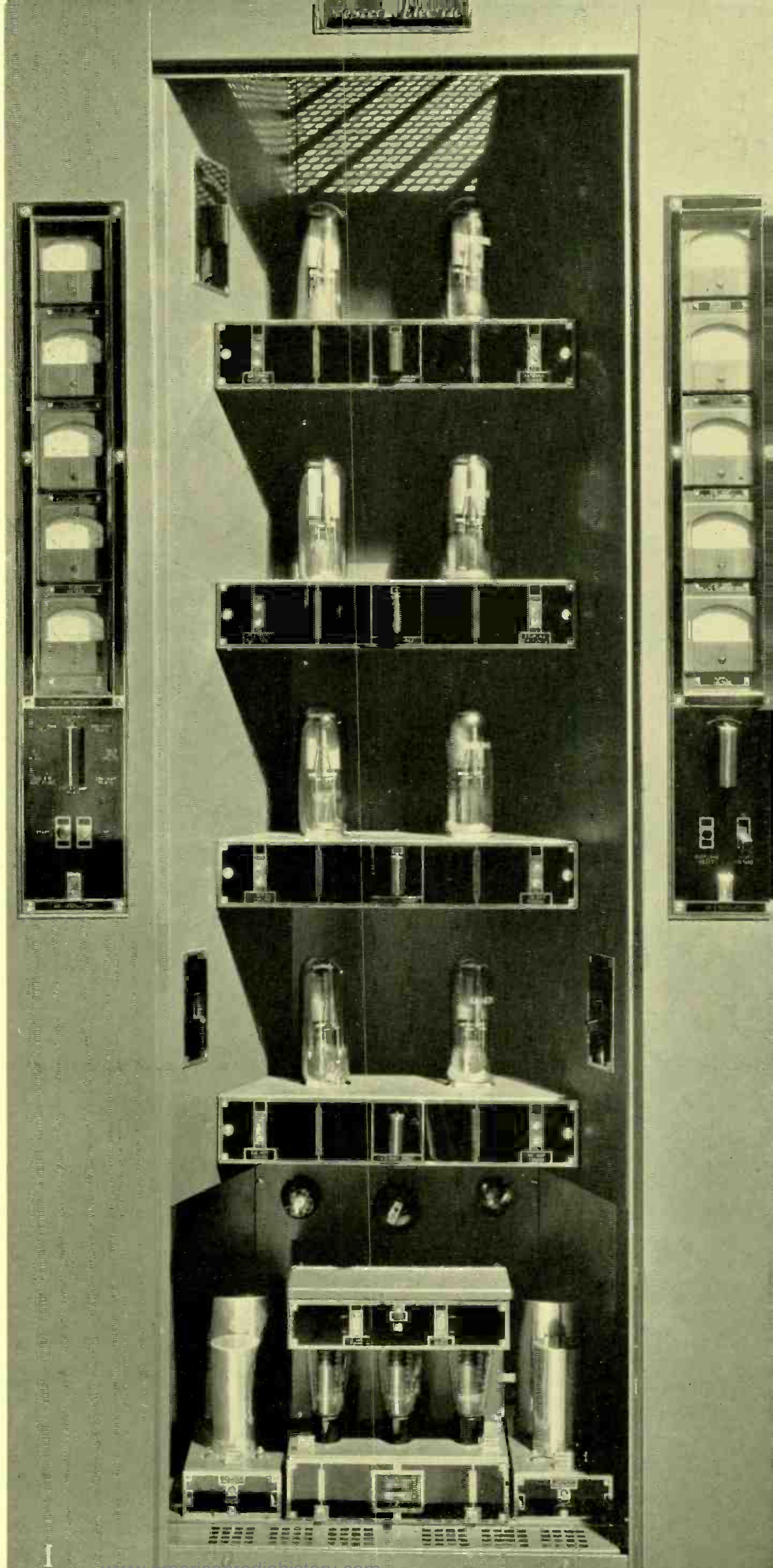
Calibrating a receiver with the telephone transmission reference system.

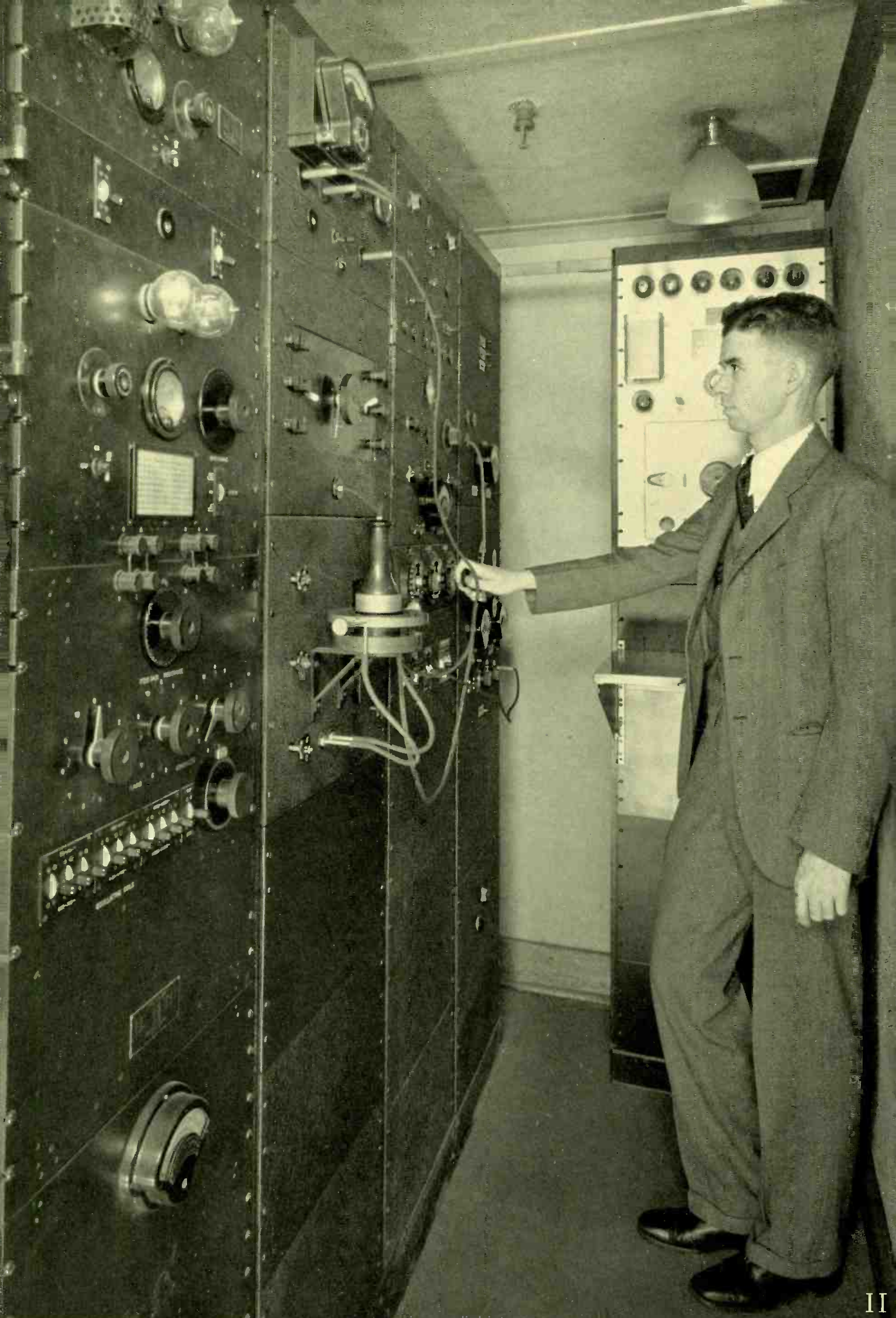
III

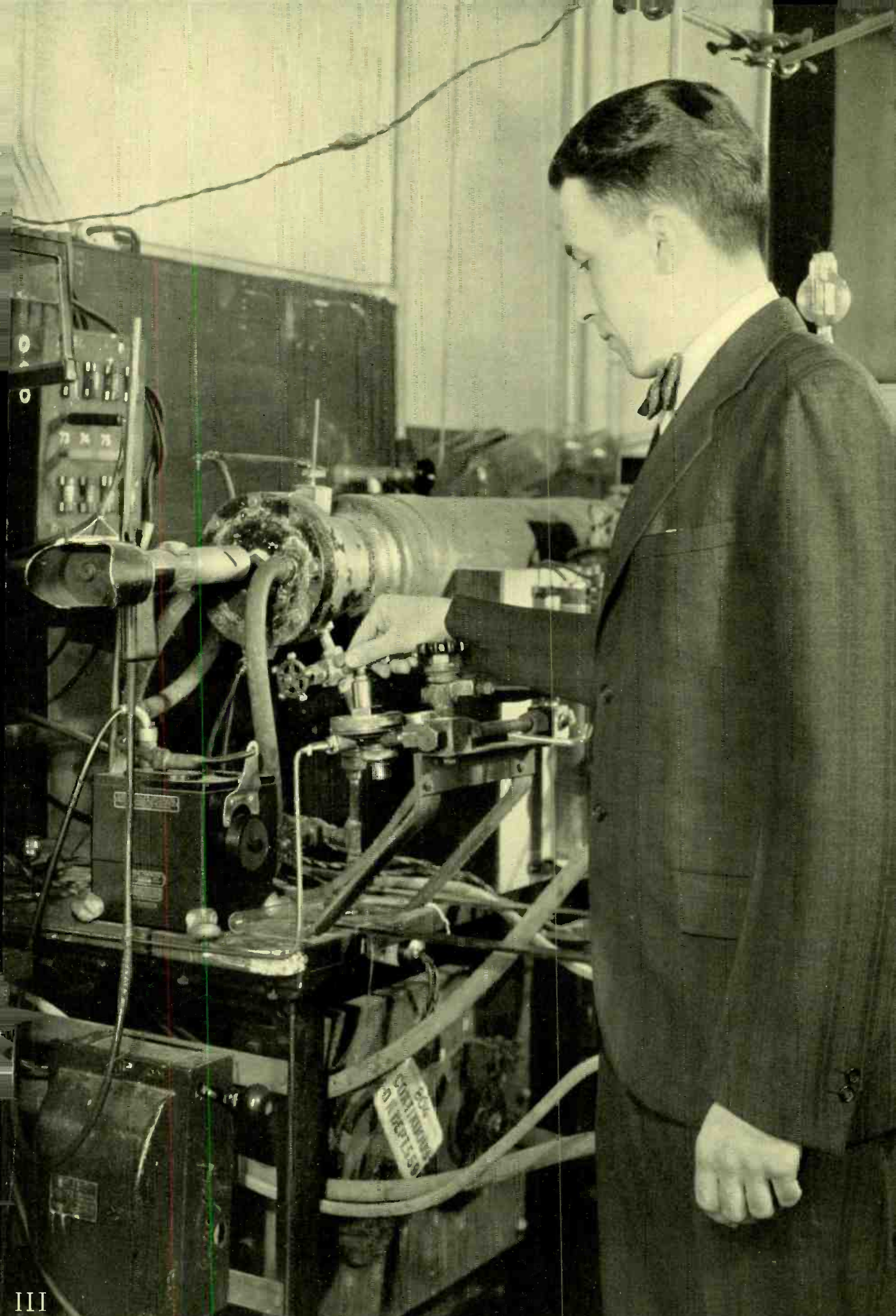
Experimental furnace for heat treating magnetic materials in hydrogen at about 1500 *degrees C.*

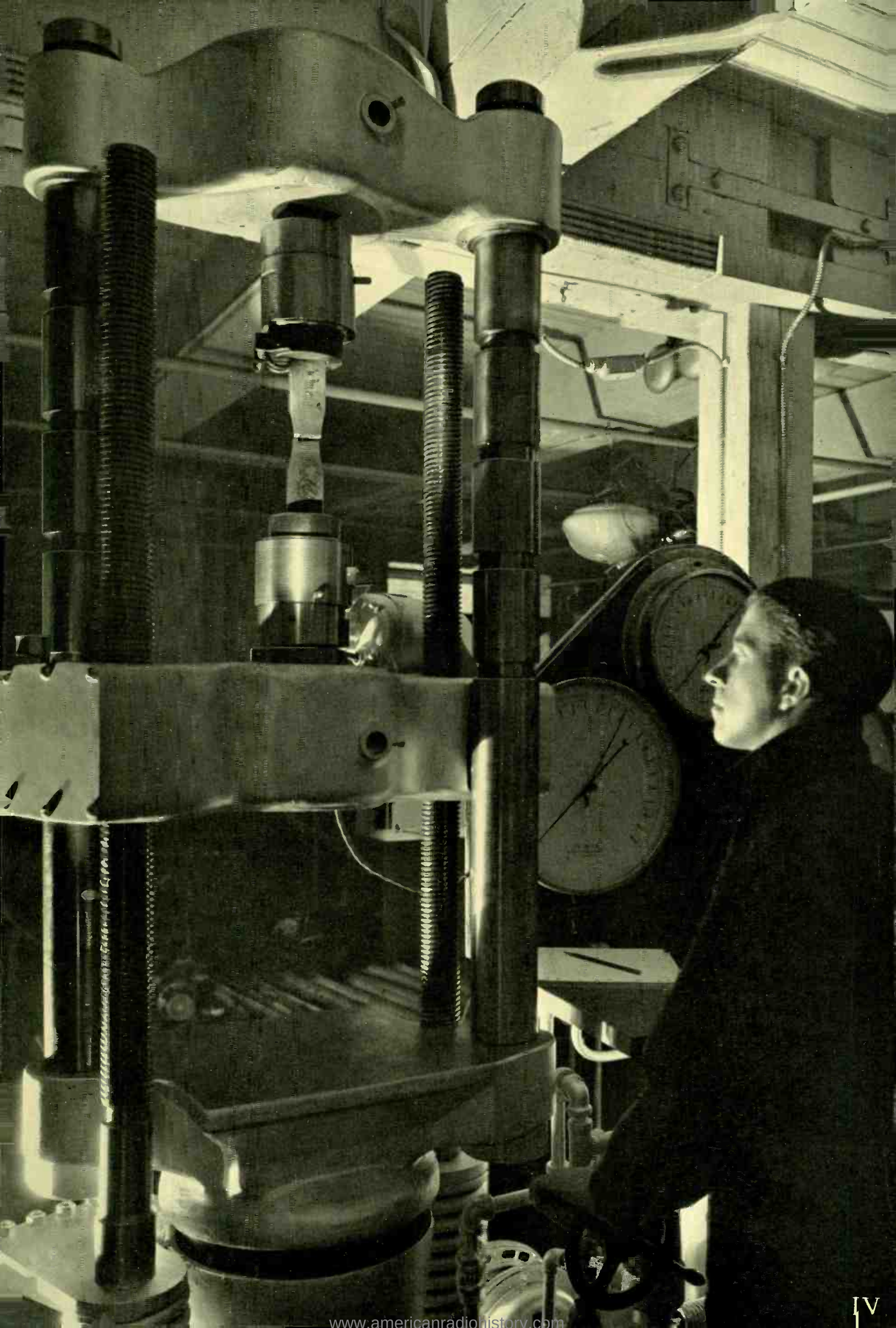
IV

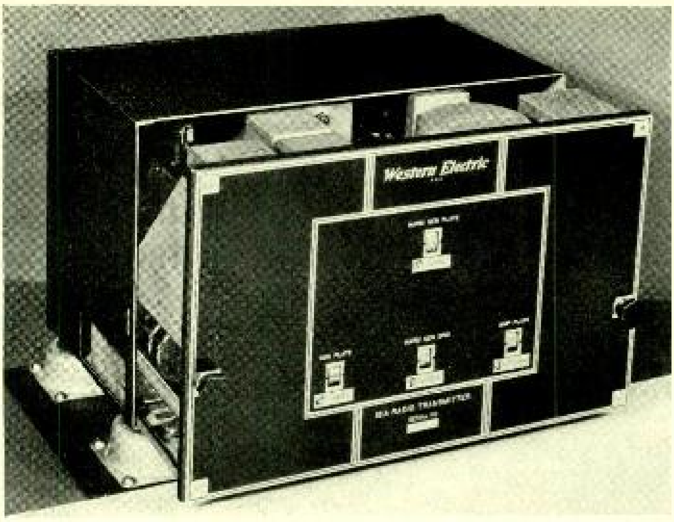
Testing a welded specimen in the Materials Laboratory.











A Mobile Transmitter for the Ultra-High Frequencies

By W. C. TINUS
Radio Development

THE assignment of certain ultra-high-frequency channels for police service has permitted many cities to take advantage of the desirable features of these very high frequencies. While some municipalities feel that one-way transmission is entirely adequate, others prefer two-way communication, which permits officers in patrol cars to talk to headquarters as well as receive announcements and instructions from them. For two-way communication ultra-high frequencies are particularly favorable because the transmitting antennas required are small and can, therefore, be conveniently erected on the patrol cars. To meet the demand for this two-way service, Bell Telephone Laboratories have developed a small radio transmitter for operation at any frequency in the range from 30 to 42 megacycles.

This new radio transmitter, known as the 18A, is designed to deliver 5 watts of high-frequency carrier power, which tests have shown to be adequate for the service intended. Its general appearance is shown in the illustration at the head of this article. The apparatus is mounted on a metal chassis which slides into a cabinet only eleven inches long, seven inches high, and six and one-half inches deep. The complete transmitter weighs under twenty pounds, and since it requires no attention in ordinary operation, it is usually mounted in the trunk or other compartment at the rear of the car. The only controls on the front of the transmitter are four tuning adjustments, which are turned to their proper settings with a screwdriver when the set is installed and require no further attention from the person operating the transmitter.

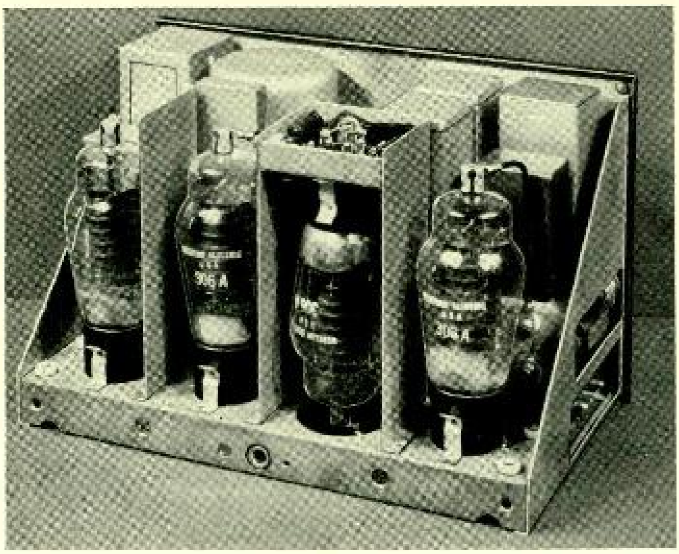


Fig. 1—*Rear view of the chassis of the* 18*A Radio Transmitter. The harmonic generator tube is inverted to shorten the leads*

When the transmitter is used on patrol cars all power is derived from the six-volt battery charged by the car generator. Tube filaments are supplied directly from the battery, while plate and grid potentials are obtained from a 300-volt dynamotor driven in turn by the battery.

The transmitter is crystal controlled and maintains its frequency well within .025% of the assigned value. Temperature control is provided, but the crystal is of a new type of cut and requires only that the temperature be kept above 0° C. All of the four tubes used in the transmitter are pentodes of the Western Electric 306A type. One is an oscillator, which feeds a harmonic generator, which in turn excites a modulating amplifier at output frequency. The fourth tube is an audio amplifier, the output voltage of which is superimposed on the plate and screen circuits of the modulating amplifier. The compact arrangement of the apparatus is indicated by Figure 1, which shows a rear view of the chassis removed from the cabinet.

A simplified schematic of the circuit is shown in Figure 3. As may be seen in this diagram four tuned circuits are employed; two of these are in the output circuit of the oscillator tube, and one each in the output circuits of the harmonic generator and modulating amplifier. At very high frequencies both the inductance and capacitance required for such tuned circuits become quite small. In fact, the stray capacity due to the wiring and the tube elements alone is more than ample for efficient circuits. Since these stray capacities are fixed, it is desirable to tune these circuits by adjusting the inductance of the coils rather than by adding more capacity to the transmitter in the form of a variable condenser.

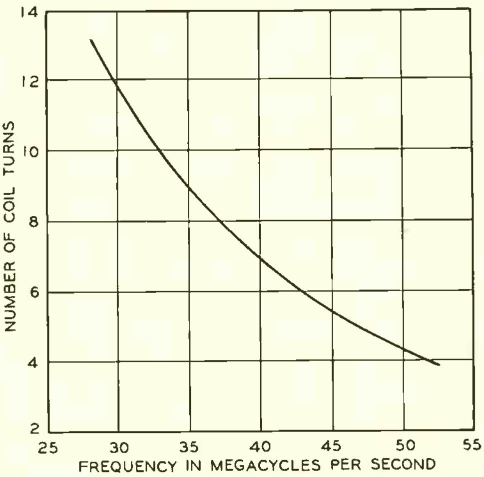


Fig. 2—*Tuning adjustment chart for the amplifier plate tuning coil*

To provide such tuning for the 18A Transmitter presented quite a problem because the usual methods of building continuously variable inductances become impractical when applied to coils of the small size required for ultra-high frequencies. To overcome these practical difficulties, the arrangement shown in Figure 4, which is a view of the under side of the chassis, has been developed. The bare wire forming the inductance is wound on an insulating cylinder which can be rotated by a screwdriver from the front of the panel. A connection to one end of the coil is made through one of the bearings, and the other connection is made through a small grooved wheel which rides on the turns of the coil. This small contact wheel is free to rotate on a shaft parallel to the coil, and rolls along the turns as the coil is rotated one way or the other. A light spring holds the contact wheel against the coil with even pressure, thus insuring a good and steady contact at all times.

Tuning is simplified by the provision of four charts showing the number of turns of each coil that should be in the circuit for any desired frequency. One of the charts is shown in Figure 2. A small dial immediately above each adjustment, evident in the illustration at the head of this article, indicates the number of turns in the circuit. The first coil in the plate circuit of the oscillator tube is set for the crystal frequency and causes the crystal to oscillate. The second coil is set for either twice or three times this frequency. The voltage developed across this second tuned circuit drives the harmonic generator grid at 2 or 3 times the crystal frequency. The coil in the plate circuit of the harmonic generator tube is normally set for twice the frequency applied to the harmonic generator grid. This is the final or carrier frequency, and the coil in the plate circuit of the modulating amplifier is also set for this frequency. Thus the carrier frequency is normally either four

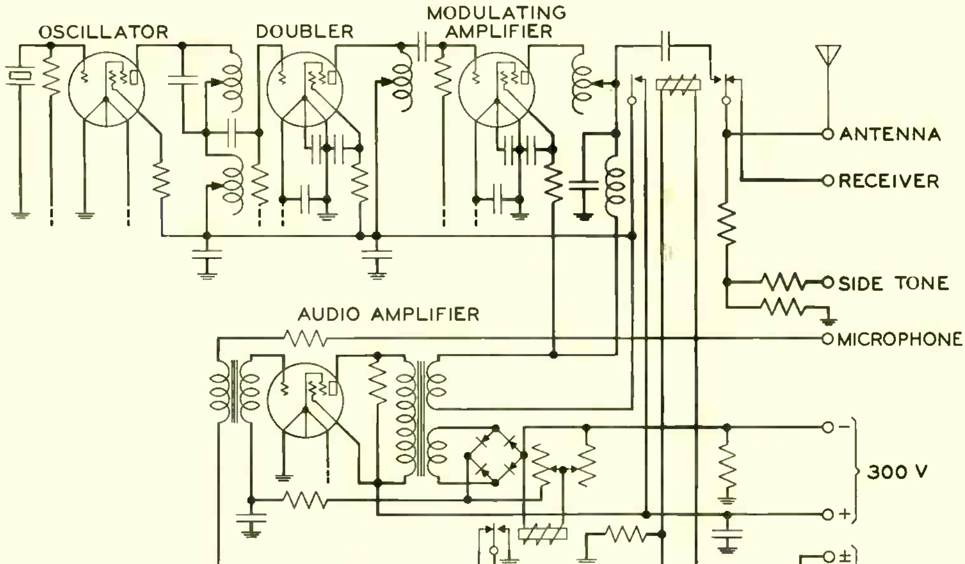


Fig. 3—Simplified schematic circuit of the 18A Radio Transmitter

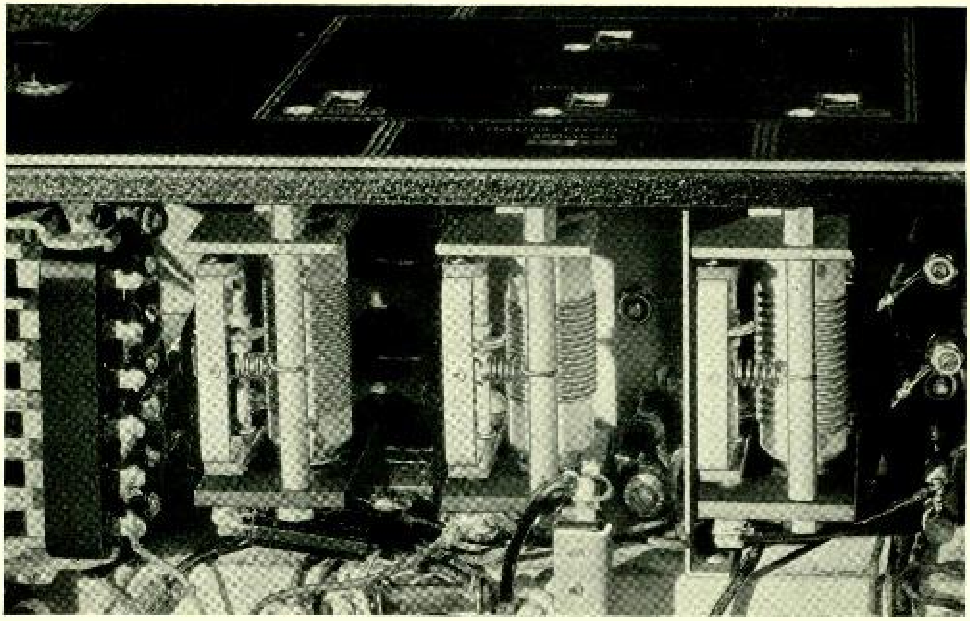
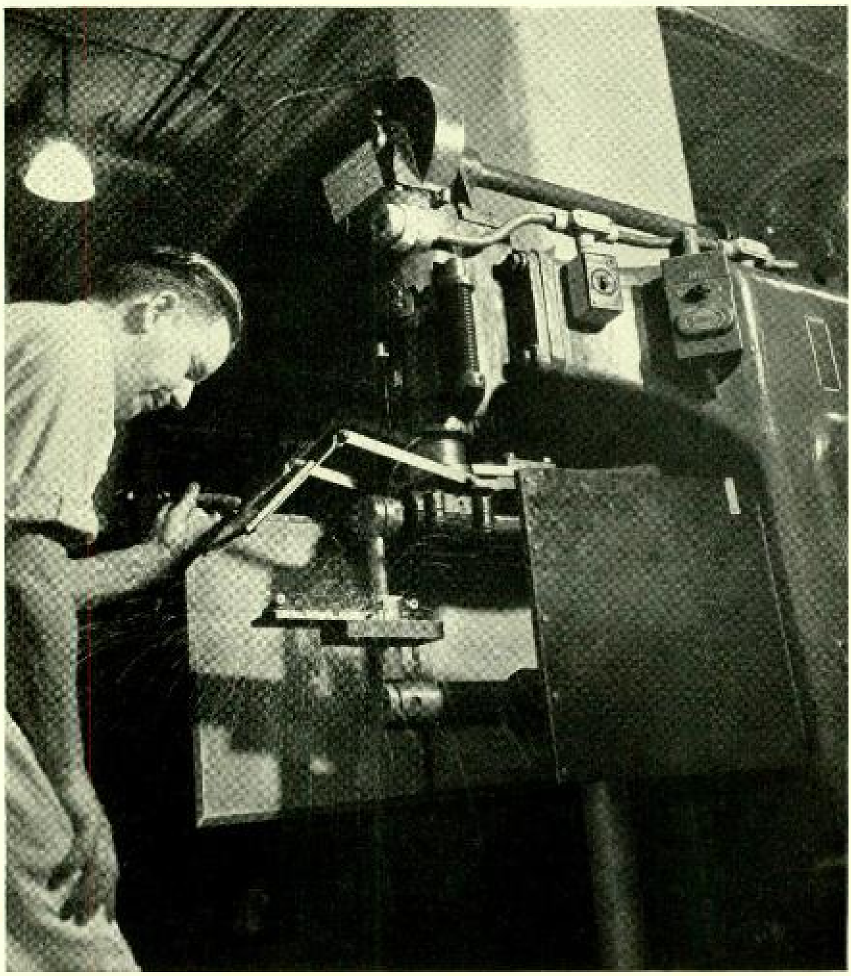


Fig. 4—View of under side of the 18A Transmitter showing three of the continuously adjustable coils

or six times the crystal frequency. With the help of the charts, the set can be approximately tuned before power is applied to the transmitter. A slight readjustment for maximum output is then made on the completed installation and no further attention is required.

One of the interesting features of this transmitter is the provision for changing from "talk" to "receive," during a two-way conversation. The same antenna is usually employed for both the transmitter and the receiver and a relay is incorporated in the radio transmitter which switches the antenna back and forth between receiver and transmitter as required. Contacts are provided on this same relay which connect plate power to the transmitter and disconnect plate power from the receiver when the antenna is connected to the transmitter, and reverse this operation when the antenna is connected to the receiver. Two ways of operating this relay are provided, and at the time of installation the user may select the type he prefers. One method utilizes a "press-to-talk" switch in the handle of the telephone handset. When this switch is pressed the transmitter is operating, and when it is released the receiver is operating. The alternative method utilizes a voice-operated relay, furnished as a part of the transmitter, which closes the circuit to the main change-over relay. Audio-frequency currents generated by the speaker's voice are amplified and rectified so they may actuate this voice-operated relay. With this method of operation the radio system is changed from "receive" to "transmit" as soon as someone talks into the handset microphone. Consequently, this arrangement gives a very fast and simple operating procedure.

A toggle switch, mounted on the control unit that carries the handset, is used to apply power to the transmitter to make it ready for operation. The operation of this switch energizes the filament circuits and starts the dynamotor, so that the transmitter is ready for instant action. Normally the receiver is connected to the antenna, but as soon as the patrolman speaks into the handset microphone, the antenna is switched over to the transmitter, and plate power is applied. These relays are very fast operating so that usually only a small portion of the first syllable is lost. The antenna relay is of the slow release type and thus does not drop out between words, but as soon as the speaker pauses at the end of a phrase or sentence, the relays release and put the system in the "receive" position.



Electric spot welding in the Development Shop of Bell Telephone Laboratories. Asbestos shields normally enclose both sides of the welding head; here one has been turned back in order to show the operation

The Dielectric Behavior of Camphor

By W. A. YAGER
Chemical Laboratories

MORE than twenty years ago, Dr. P. Debye showed that "polar" molecules, by orienting themselves when an electric field is impressed, provide an explanation of the high dielectric constants of certain liquids. The classical concept of a solid does not permit an extension to them of this picture of molecules able to move about as in a liquid. Until recently dielectric measurements have universally borne out the dictate of this theory: that the dielectric constant of a polar solid must be lower than that of the liquid. Within the last few years, however, the application of the new quantum mechanics to these problems has shown that readjustment of orientation, and thus a high dielectric constant, is possible even in solids, under certain conditions and within limits. From investigations in these Laboratories, it seems that camphor may be such a solid.

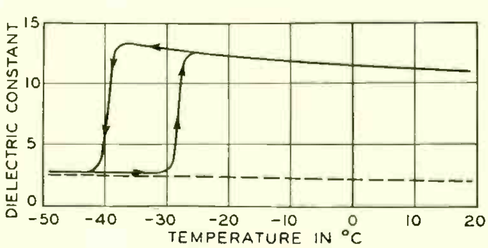


Fig. 1—The dielectric constant of d-camphor varies in a curious fashion with temperature. The broken line is the square of the refractive index

As was pointed out in a review of dielectric theory in the RECORD,* the concept of a "polar molecule" or "dipole," whose centers of positive and negative charge are permanently separated, is necessary to explain plausibly the high dielectric constant observed in many liquids. In a liquid system such a dipole is free to rotate so as to align itself in the external field and hence to increase the dielectric constant. By cooling the system until it becomes solid, this rotation is supposed to be restrained, either suddenly as with a crystal or gradually as with a glass. In the former case the dielectric constant drops sharply at the freezing point to a value equal roughly to the square of the refractive index of the material. In the latter case the corresponding drop of the dielectric constant is gradual, and the temperature at which the drop begins increases with increasing frequency. When observed at a constant temperature within a properly chosen frequency range, this latter effect appears of course as a decrease of the dielectric constant with increasing frequency.

This dependence of dielectric constant on frequency is due to internal friction (roughly equivalent to viscosity) large enough to impede but not to prevent molecular rotation. As the frequency increases, the molecules are progressively less able to follow the alternations of the applied field. Those molecules which do rotate lag

*RECORD, *June*, 1931, *p.* 463; *July*, 1931, *p.* 535.

behind the field, producing their maximum counter-emf after the applied voltage has begun to decline. The resulting phase displacement appears in dielectric measurements as a high conductivity which attains its

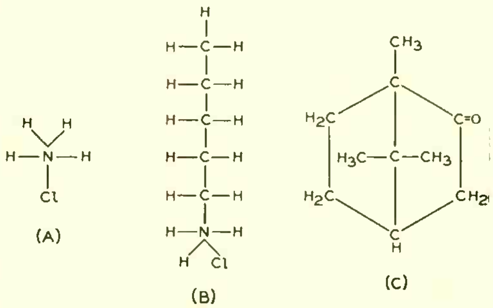


Fig. 2—Specific heat anomalies in ammonium chloride (A) and in normal amyl ammonium chloride (B) have led to the suggestion that, above certain temperatures characteristic of these materials, the NH_4 group in the former and the C_5H_{11} group or the $C_5H_{11}NH_3$ group in the latter may be capable of rotating within the molecule

maximum near the frequency where the dielectric constant is falling most rapidly.

Most organic materials thus far investigated fit into this picture in their dielectric behavior. A few are known which do not. As can be seen in Figure 1, the dielectric constant of solid d-camphor* at room temperature is several times as large as the square of its refractive index, as indicated by the broken line. As the camphor is cooled, its dielectric constant begins at −37 degrees Centigrade to drop to the value normally expected in solids. Neither increase of conductivity nor variation of dielectric constant with frequency accompanies this drop. When the temperature scale was retraced, a type of hysteresis appeared in the sample investigated. The dielectric constant did not begin to rise again until the material was warmed up to −31 degrees Centigrade. This behavior fails to fit into either side of the classical picture. As a result, some other explanation must be sought.

d-Camphor is not an isolated example of this strange effect. The corresponding transition has been observed in a sample of d-l camphor† between −50 and −75 degrees Centigrade. Except for the transition temperature, this camphor is dielectrically very similar to d-camphor. Similar changes of dielectric constant have been observed in a number of other materials which are chemically closely related to camphor.

A promising line of attack on this problem is provided by the work of Linus Pauling, which has been widely accepted as proof that molecular rotation is possible in certain crystalline solids. At the expense of strict accuracy, Pauling's argument can readily be put in simple language.

*The melting point of this camphor is 179 degrees Centigrade.

†Camphor is found in three forms, chemically almost identical but differing in optical behavior. d-Camphor rotates the plane of polarization of polarized light to the right; l-camphor, to the left. d-l Camphor is optically inactive, and can be obtained by mixing the optically active forms in equal parts.

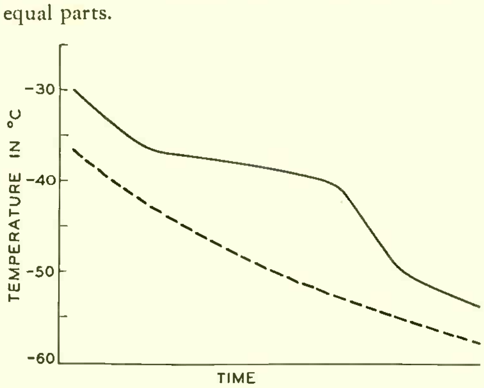


Fig. 3—In the cooling curve above and the heating curve in Figure 4 for camphor, the solid line represents the temperature of the camphor, and the broken line that of the bath

Application of heat energy tends to cause molecules to rotate regardless of their state of aggregation. In solids, strong inter-molecular or "crystal" forces as well as the moment of inertia of the molecule tend to inhibit this rotation. If sufficient heat energy be imparted to any given molecule it will overcome these restraining forces

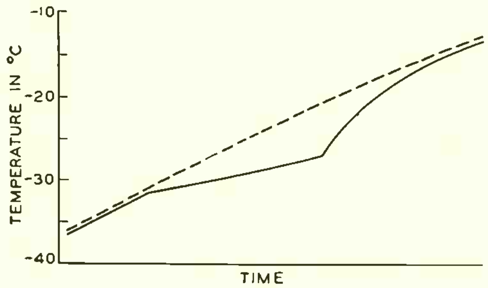


Fig. 4—The heating curve above and the cooling curve in Figure 3 for camphor show maxima of specific heat at approximately the same temperatures as the abrupt changes in dielectric constant shown in Figure 1

and rotate end for end instead of oscillating about a fixed position. This need not mean that molecular rotation can occur in all crystalline materials, however; the amount of heat energy required to overcome the restraining forces may be more than enough to melt the crystal. Pauling was able to show mathematically that such simple molecules, with low moments of inertia, as hydrogen and hydrogen chloride should rotate in the solid state. This rotation should cease, however, below a transition temperature determined by the magnitude of the restraining forces. The same calculations show that this transition temperature is far higher than the melting point in such materials as iodine, whose molecular moment of inertia is large. Thus the iodine molecule does not rotate in the crystal.

Pauling states that, when a crystal is heated sufficiently for a number of molecules to begin to rotate, the repulsive forces between molecules are thereby increased and the crystal lattice tends to spread. This amounts to a reduction of the attractive forces which restrain the rotation of other molecules in the crystal. More molecules are hence permitted to rotate, and the effect builds up to give a transition which is usually completed within a temperature range of a few degrees.

It is evident that if dipoles are free to rotate within a crystal, the dielectric constant should be high, just as in polar liquids. Hence, Pauling suggested dielectric measurements on solid hydrogen chloride,* whose molecules are known to be polar, as a convenient method of checking his conclusion that the molecules of this crystal would rotate above a transi-

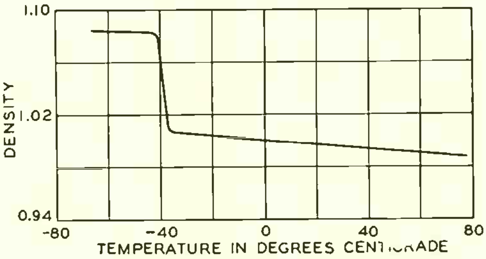


Fig. 5—An abrupt change in density accompanies the other changes which occur in camphor at a critical temperature

tion temperature. Following this suggestion, various investigators found that the dielectric constant, as predicted, is as high as or higher than in the liquid down to −175 degrees, where it drops rapidly to a value equal to the square of the optical refractive index. At the same temperature there is an evolution of heat such as would be expected to accompany a contraction of the crystal lattice and the

*Melting point—111 degrees Centigrade.

specific heat drops to a different level.

The existence of other examples of specific heat anomalies similar to that observed in hydrogen chloride led Pauling to suggest that in large molecules a group of atoms of low total moment of inertia may rotate as a unit within the molecule. The ammonium ion in salts, and aliphatic chains in alkyl ammonium halides (Figure 2) are possible examples of this effect. Some such effect as this is suspected as responsible for the unusual dielectric behavior of camphor.

The camphor molecule contains twenty-seven atoms, probably arranged in the structure shown in Figure 2C. Specific heat and infra-red absorption data for the determination of its moment of inertia are not available. It would be expected in a molecule containing so many atoms, however, that the moment of inertia would be large. It seems likely, therefore, that if dipole rotation is responsible for the high dielectric constant of camphor, the intermolecular forces are usually weak.

In the absence of specific heat data it was found possible to investigate camphor for an evolution of heat, such as that found in hydrogen chloride, by means of a cooling curve. Such a curve is obtained by slowly cooling the material kept in a bath the temperature of which is slightly lower than that of the material at the start and declines steadily, and plotting the temperatures of the bath and of the material against time. A heating curve is similarly obtained when the temperature of the bath is raised. Melting points and transition points are indicated on such curves where the rate of change of temperature of the material deviates from that of the bath while that of the bath is varying.

As can be seen in Figures 3 and 4, respectively, the heat capacity of camphor begins to rise at about -37 degrees on the cooling curve and at about -31 degrees on the heating curve. These temperatures correspond with those where the dielectric constant begins to change rapidly as shown in Figure 1. They also confirm the existence of a hysteresis effect associated with the transition point in this sample of camphor.

Pauling's statement that the crystal lattice tends to spread at the temperature where molecular rotation begins is interpreted to mean that an expansion of the substance and a reduction in its density may be expected to accompany such a transition. Experiment shows a seven or eight per cent change in the density of d-camphor at the temperatures where the dielectric constant of the camphor drops as it is cooled. The possible existence of a hysteresis is not clearly indicated by the density measurements.

Thus changes of specific heat and density accompany the large change of dielectric constant in camphor at a critical temperature. Together these changes constitute necessary but not yet sufficient evidence that the rotation of molecules or parts of molecules is the cause of the high dielectric constant of crystalline camphor at ordinary temperatures.

Heat Treatment in Magnetic Fields

By G. A. KELSALL
Magnetics Research

IN the use of magnetic materials heat treatment is of prime importance because the attainment of the desired magnetic properties for a particular purpose depends on the proper heat treatment. It is of interest not only to know the magnetic properties before and after heat treatment but also how these properties vary during the heat treatment or in general with temperature changes. The information thus obtained is often of theoretical interest in suggesting new heat treatments.

During the development of the permalloys such measurements were first made for small a-c magnetizing forces. Later these measurements were extended to larger magnetizing forces. In one experiment, with 78.5 permalloy, measurements were made with a constant d-c magnetizing force which was much larger than the magnetizing forces used for the a-c measurements. On returning to room temperature the maximum permeability was much higher than would have resulted from the heating cycle alone. The only differences in conditions compared to the previous tests were the presence of a much larger field and the fact that in this experiment the field was a direct one instead of alternating. In both cases the field was left on between readings. It was natural, therefore, to conclude that the presence of this large d-c field during the heating cycle was the cause of the higher permeability.

This interesting result led us to undertake a number of tests on permalloy and other magnetic materials. The results varied with the material, but those obtained from 78.5 permalloy and one of the perminvars—an alloy consisting of 45% nickel, 30% iron, and 25% cobalt—are typical of the alloys whose permeability was increased by this method of heat treatment. Permalloy of the 78.5 composition is normally given a double heat treatment. The first is an anneal in the temperature range from 900° to 1100° C, and the second a rapid cooling from a temperature of 600° C, which is above the Curie point (580° C). This rapid cooling from 600° results in a large increase in maximum permeability. If in the second heat treatment the specimen is cooled slowly from 600° at the same rate of cooling it had

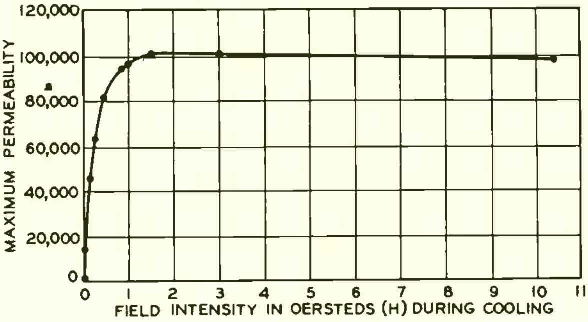


Fig. 1—Maximum permeabilities of permalloy when slowly cooled in a magnetic field

during the anneal, the maximum permeability will be about the same as after annealing. If a magnetizing force is applied during the slow cooling period of the second heat treatment, the maximum permeability obtained is comparable with that produced by the regular double treatment in which the cooling is rapid.

If a specimen which has a high permeability, due either to heat-treatment in a magnetic field or the normal double treatment, is subsequently raised to a temperature above the Curie point and is cooled therefrom at the same rate, as during the original annealing, the specimen will again have magnetic properties very closely approximating those after the original annealing.

In heat treating with a magnetic field, the permalloy is given the initial anneal as in the usual treatment, but from the temperature of 600°, to which it is then raised for the second part of the treatment, it is cooled slowly and in the presence of a magnetizing force. The resulting maximum permeability for this permalloy is about the same as obtained by rapid cooling, but for some alloys is considerably higher. In general it was found that those alloys which show a marked increase in permeability as a result of rapid cooling, also show an increase when the specimen is cooled slowly in a magnetic field.

The value of the field maintained during the cooling was found to have considerable effect on the final permeability. For 78.5 permalloy the relationship is as shown in Figure 1. For all the data plotted, the sample was the same for all the trials and was cooled at the same rate. For the greatest effect a field of 1.5 oersteds or greater is required. With the same heat treatment, but without application of the magnetic field, the maximum permeability would have been about 14,000 instead of the 100,000 obtained. A somewhat modified procedure, in which the permalloy was heated to the non-magnetic temperature, the magnetic field applied, the sample then cooled to slightly below the non-magnetic temperature and held there for some time, followed by cooling to 300° or lower before removing the field, was found to produce maximum permeabilities of over 140,000.

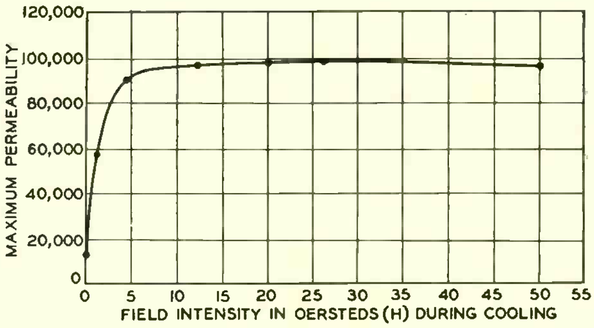
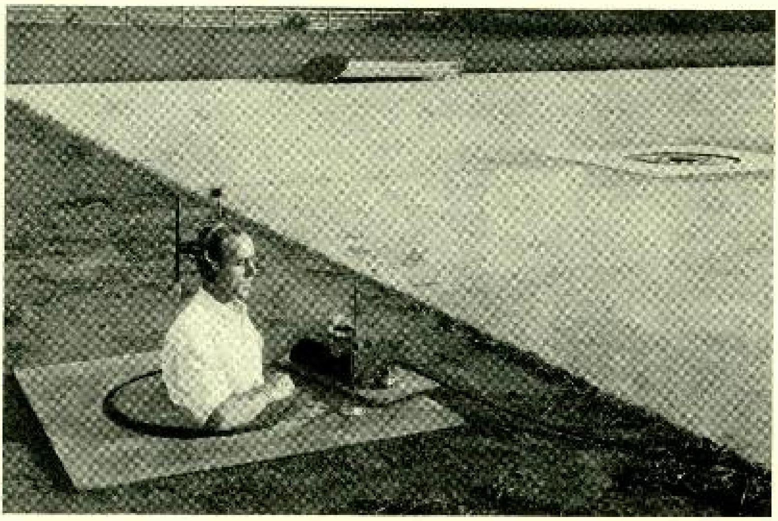


Fig. 2—To obtain high values of maximum permeability, perminvar requires higher values of applied field than does permalloy

Perminvar, of the composition already mentioned, behaves in a very similar manner, but the magnetic fields required to produce high permeability are larger as indicated in Figure 2. In the experiments with perminvar, the temperature was carried up to 725° C (Curie point about 715° C) instead of to 600° as was done with permalloy.

When obtaining high permeabilities by the usual heat treatment without the application of a magnetic field, the material is found to be isotropic in respect to its permeability. Along any direction in the specimen, the permeability will have substantially the same value. When the high permeability is obtained by slow cooling in a magnetic field, however, this is not the case. The highest permeability is found along the direction of the field applied during cooling; at right angles to this direction the permeability is less than it would have been after a simple anneal. In one sample of permalloy, the maximum permeability in the direction of the applied field was over fourteen times that at right angles to that direction. With perminvar this ratio was nearly seventy. It is of interest that an alternating field was found to be as effective as a direct field equal to its r.m.s. value, and that the permeability obtained is independent of frequency, at least up to 1000 cycles, the highest frequency tried.

This method of securing high permeability has definite advantages with certain forms of specimens. The rapid cooling required for the usual heat treatment is frequently difficult to obtain without causing undesirable stresses at certain sections, and these stresses make it impossible to get high permeability. This is particularly true of specimens with large cross-sections. For such specimens, the slow cooling in a magnetic field is very helpful, because the slow cooling avoids the formation of undue stresses, and the magnetic field provides the required high permeability. A permalloy cylinder, for example, intended for a magnetic shield, which was twelve inches long with inside and outside diameters of one and one-half and two inches, respectively, developed a maximum permeability of only 9000 when double heat treated. The same specimen when slowly cooled in a magnetic field, however, showed a maximum permeability of 111,000.



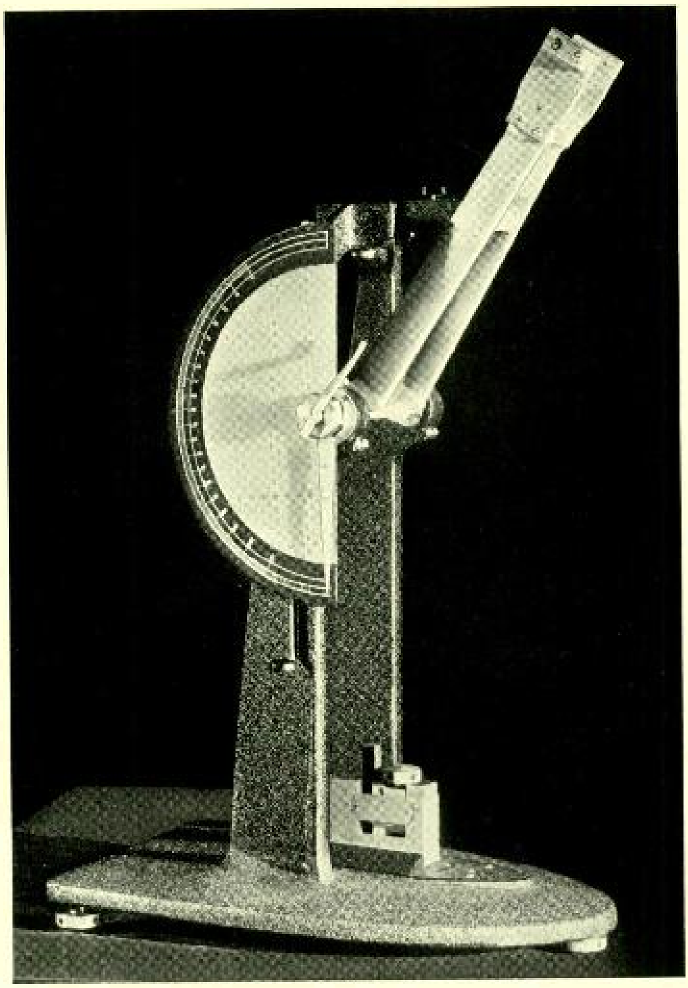
Making outdoor measurements of the directional characteristics of monaural hearing in a progressive plane sound wave

Impact Tester for Moulded Insulating Materials

By I. L. HOPKINS
Telephone Apparatus Development

ALL of the 17,000,000 telephones in daily use in the Bell System are made in part of moulded insulating materials. The importance of such materials to the telephone is evident when but one of their many uses is considered—namely, the casing of the handset and the mouthpiece and receiver of the desk type telephone. Some breakage of such parts is inevitable but losses have been greatly reduced by the use of compounds offering high resistance to fracture. The toughness of these products is therefore a very important characteristic and in studying them it has been found necessary to devise apparatus not only to determine the resistance to impact of the finished parts but also that of the material itself.

Investigations carried out years ago by others to develop methods of testing impact strength of materials have shown that the work required to break a test specimen is a reliable quantitative measure of the resistance to service fracture and that



the use of a swinging pendulum to cause the fracture is a simple and effective means of making the measurement. In practice the specimen is held in the path of the pendulum at its lowest point and broken by a single blow when the pendulum falls from a known height as it is released from a catch which holds it in an elevated position. The energy used to break the specimen is computed by measuring the difference between the height from which the pendulum starts and the height to which it swings after the break, with suitable correction for windage and friction losses.

Machines constructed on this principle have been used for many years in testing metals and their adaptation to the study of moulded insulating materials therefore suggested itself when an investigation of the impact strength of such products was undertaken some years ago by the Laboratories. As this method of test is to a certain extent arbitrary, the problem of applying it to insulating materials was merely one of determining a specimen suitable for these materials and developing a machine of the sensitivity required. The essential problem which had to be solved for the new machine was to make a pendulum of the requisite length sufficiently light and rigid to deliver a blow of hundreds of pounds and yet measure accurately the impact value of specimens requiring only a fraction of a foot pound to break them. The difficulty was met by making the shaft of the pendulum of thin aluminum lattice work reënforced with crossbracing. The capacity of this machine, 2.26 foot pounds, was the smallest obtainable at the time.

The fundamental work of classifying materials according to their impact strength was done with this machine and requirements were written by the Laboratories for materials in which impact strength is a critical quality. The machine is well suited for the general testing of materials of the types listed below which have strengths lying in the following ranges:

Hard rubber	.12 to .35 ft. lbs.
Wood flour filled phenol plastic	.1 to .15 ft. lbs.
Cotton flock filled phenol plastic	.2 to .3 ft. lbs.
Phenol fibre—edgewise	.2 to .3 ft. lbs.
Phenol fibre—flatwise	1.0 to 1.2 ft. lbs.
Phenol fabric	1.2 to 1.9 ft. lbs.

Experience showed that some changes in construction, particularly to increase the permanence and rigidity of the pendulum and of other parts in order to insure accurate coaxiality of the pendulum axis, scale and pointer, were needed. A new model shown in the illustration was therefore built which incorporated these and other mechanical changes and yet gave the same results as the old one, thus preserving the continuity of the test data and making it conform to the requirements of the A.S.T.M. which were based on the older machine and similar ones built by others.

The most important change was the redesign of the pendulum which is made of streamlined duralumin tubing welded in the Laboratories experimental shops to form a rigid one-piece arm. The duralumin head is fastened to the arm by machine screws and final balancing is done by the adjustment of brass weights which are attached to the bottom of the head. These weights are also streamlined which not only keeps down the windage losses but distributes the weight

Table I

Constants of Impact Machine

Length of Pendulum	13.000″
Initial Elevation of Pendulum	24.000″
Effective Weight of Pendulum	1.000 lbs.
Capacity of the Machine	2.000 ft. lbs.
Distance—Axis to Center of Percussion	13.010″
Accuracy	about .001 ft. lbs.

correctly to balance the arm. The base and frame are made of cast iron in one piece and built-in sensitive levels are provided. The scale is chromium plated which not only protects it against the atmosphere but gives a highly reflecting surface which aids in avoiding parallax errors. To assure coaxiality the bearing, scale and pointer are supported on a one-piece holder. An improved release mechanism was also provided.

Contributors to This Issue

G. A. Kelsall graduated from Rose Polytechnic Institute in 1906 with the degree of B.S. in Electrical Engineering. The following three years he spent with the General Electric Company at Schenectady and with the Indiana Steel Company at Gary, and in 1909 went to Michigan State College as Instructor in Electrical Engineering. Since 1912 he has been with Bell Telephone Laboratories. For five years he worked on loading coils in the physical laboratory, during which time he developed the permeameter and permeameter furnace. From 1917 to the present time he has been with the Research Department engaged in the investigation of magnetic materials.

While a student at Union College, W. A. Yager spent one summer as an assistant in the research laboratory of the General Electric Company in Schenectady working on the development of carboloy. On receiving the B.S. degree in chemistry in 1928, he joined the Chemical Laboratories. Here he has since been engaged in dielectric and surface-leakage studies, and has most recently been investigating the dielectric properties of various materials under controlled conditions of frequency, temperature and humidity.

I. L. Hopkins received the degree of B.S. in mechanical engineering at M. I. T. in 1927 and immediately joined the Materials Department of the Laboratories. He was engaged at first in investigations relating to insulating materials including the development of testing methods and apparatus and the preparation of raw material specifications. For the past year he has spent most of his time on various problems connected with hard and soft rubber and the testing of phenol plastics.

W. C. Tinus began his radio career with an amateur radio station immediately after the war. He was later with several of the early broadcasting stations

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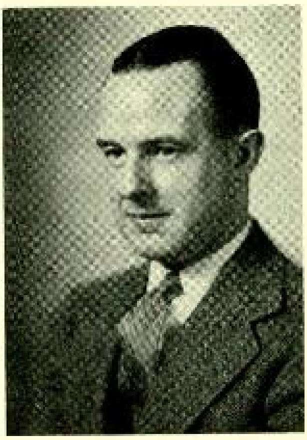

A. B. Bailey

A. H. White

in the southwest and also served at sea as a radio operator. He received the B.S. degree in Electrical Engineering from Texas Agricultural and Mechanical College in 1928 and then joined the Technical Staff of these Laboratories. Since that time he has been concerned with the development of airplane radio equipment and with its application to the rapidly growing commercial airlines throughout the United States.

Arnold B. Bailey received a B.S. degree in Engineering Administration from Massachusetts Institute of Technology in 1925 and then became a member of the instructing staff of the Department of Economics of the Institute. In 1926 he joined the Radio Development Department of the Laboratories and specialized in the design and installation of radio-telephone and broadcast transmitters. He aided in the development of a universal radio beacon for aircraft and later made a series of technical studies on the location and selection of radio sites for broadcast stations, including Stations WABC, WSB and WHN. For the last two years Mr. Bailey has been engaged in the design and development of two-way mobile systems for radio communication service.

Following his graduation from Occidental College in 1930, A. H. White entered the Laboratories as a member of the Chemical Department. Since then he has been occupied with research in the field of dielectrics, being particularly concerned with the relationship between the electrical properties and the molecular structure of dielectric materials.

J. T. Butterfield received the B.S. degree from Worcester Polytechnic Institute in 1907 and the E.E. degree from Purdue University in 1910. Coming at once to these Laboratories, he has been associated with the old Physical Laboratory and its successor, the General Apparatus Development Department, ever since. Among the advances to which he has contributed are improved insulators for open-wire lines, magnetic structure of the 54 type retardation coil, iron-dust cores for loading coils, switchboard lamps, vacuum thermocouples and fuses, electrolytic condensers, and to the study of bearings and lubrication. His present work consists of the development of improved methods of maintenance for base metal contacts used in the panel office system.

J. T. Butterfield