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Electrical
Measurements

MEASURING INTER-ELECTRODE CAPACITANCES

Since the very beginning of the communication art there has been a continuous trend toward the use of higher frequencies. As a result, a more detailed analysis of circuit elements has generally been necessary, and it often becomes desirable to measure extremely small values of capacitance. This has been particularly true in the development of high-frequency electron tubes during the war. The direct capacitance between the grid and plate of such a tube may be very important to the operation of the circuit, and yet it may be as small as two billionths of a microfarad. No standard capacitors of this order of magnitude are available with which the unknown could be compared in the ordinary type of bridge. Moreover, the residual capacitances in the bridge and the effects of the capacitances of the test leads make the techniques employed for larger capacitances entirely impracticable.

A further difficulty enters because the capacitance of importance is the "direct" capacitance, and the measurement must thus exclude capacitances from the two elements to other elements and ground. Suppose, for example, that it was desired to measure the direct capacitance between elements A and B in the structure shown at the left of Figure 1. By the earliest methods employed this would be done by first grounding A while leaving B ungrounded and then making a measurement between A and B. Following this, A would be left ungrounded and B would be grounded and

New bridge for measuring capacitance between grid and plate of VHF tubes

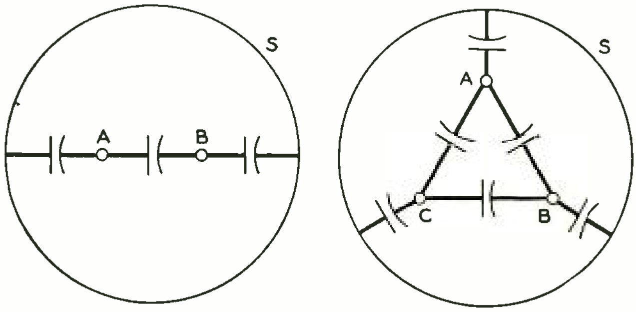


Fig. 1—With two conductors in a grounded enclosure, as at the left, there are three capacitances involved; while with three conductors, as at the right, there are six capacitances

a similar measurement made. A and B would then be connected together and a third measurement made to ground. From these three measurements, the direct capacitance between A and B could be determined. Where more than three elements are involved, as at the right of Figure 1, many more capacitances may be involved, but by grounding all elements but one it is always possible to determine a direct capacitance from three grounded measurements. The method employed in the Laboratories until recently, however, is based on the use of a bridge described by Dr. G. A. Campbell in 1904 and a suggestion from E. H. Colpitts dating from 1902. With this method, only two measurements are necessary, but the precision obtained is only about 0.05 $\mu\mu$f. Although it was satisfactory for the simpler forms of tubes, it is inadequate for modern tubes employing internal screening, which reduces the critical grid to plate capacitance to a few billionths of a microfarad. In addition, it requires two separate measurements in which most of the circuit capacitances enter into the balance relations, and these must remain constant to a degree that will not impair the accuracy of measurement. In many present-day applications these additional capacitances are so much greater than the direct capacitance being measured that dependable data can be secured only under the most carefully controlled laboratory conditions.

To provide a method of measuring these very small inter-electrode capacitances that would give dependable results directly and with good precision, a new bridge circuit has been invented. The main objectives are to measure very small direct capacitances by means of capacitances of larger sizes, and to eliminate the effects of the capacitances to ground and of the leads. Since any physical capacitance has a conductance closely associated with it, such as the leakage through the insulating material of a condenser, a capacitance is more correctly referred to as an admittance where precise measurements are concerned, and this new circuit is really an admittance bridge, but it measures the capacitance and conductance components separately. Omitting its power supply, detector, and shielding, this new bridge can be represented as shown in Figure 2.

The conventional form of bridge would have an adjustable admittance connected in the AD arm and the unknown admittance would be connected in the CD arm as shown in the left of Figure 3. A variant of this might have adjustable admittances in both the AD and CD arms arranged so that when

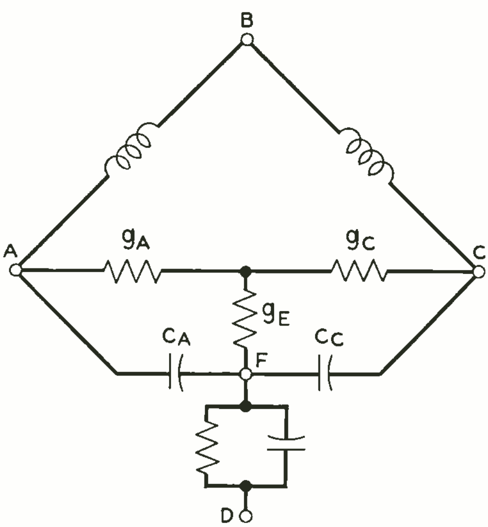


Fig. 2—Simplified schematic of the new bridge that has been developed for measuring inter-electrode capacitance

one of them was decreased, the other would be increased. The unknown admittance would then also be connected across the CD arm, and its value could be determined from the settings of the two adjustable admittances after balance had been secured. The circuit of Figure 2 is the equivalent of this latter arrangement, and at the same time secures certain other advantages.

Any three-terminal star network such as g_A, g_C, and g_E of Figure 2 can be replaced by an equivalent delta network. If this were done for the star conductance group of Figure 2, the circuit would become as shown in the center of Figure 3, where G_{AC}, G_A, and G_C are the delta equivalents of the star conductances of Figure 2. Since G_{AC} is connected across the diagonal of the bridge it has no effect on the measurement and may be disregarded. There thus remains a star connected network of admittances between points A, C, and D. This also could be replaced by an equivalent delta consisting of Y_{AC}, Y_{AD}, and Y_{CD} as shown at the right of Figure 3. Here, Y_{AC}, since it is across a diagonal of the bridge, has no effect and can be disregarded as is G_{AC}. This leaves Y_{AD} and Y_{CD}, and thus an unknown admittance connected across CD could be measured by adjusting Y_{AD} and Y_{CD} differentially—changing them simultaneously in opposite directions while keeping their sum constant. The unknown admittance Y_U would then be equal to $Y_{AD}-Y_{CD}$. The equivalent admittances Y_{AD} and Y_{CD} may be expressed in terms of g_A, g_C, C_A, and C_C of the original configuration, and proper adjustment of these elements would permit the unknown admittance to be evaluated.

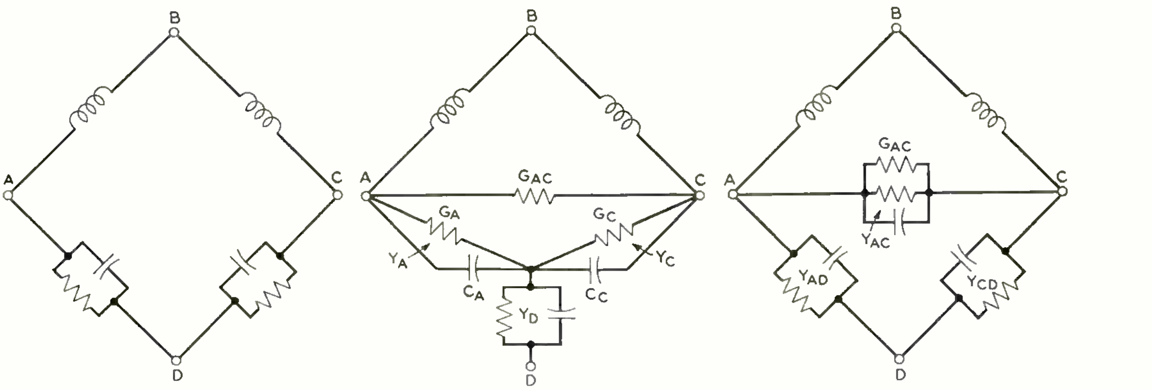


Fig. 3—By changing the star network of conductances of Figure 2 to a delta, the bridge would become as at center above. Then by changing the star mesh of admittances of this latter diagram to a delta, the circuit would become as shown at the right. This makes the bridge effectively the same as the conventional form shown at the left

If this were all that was brought about by the use of the double-star network of Figure 2, however, the bridge would have no advantage over that shown at the left of Figure 3. There is a very important advantage arising from the use of the double star, however, that is the major reason for its adoption. In adjusting the conductances and capacitances of the original configuration, the sum of g_A and g_C is always kept constant as is that of C_A and C_C. As a result, the sum of the two admittances Y_A and Y_C of the middle diagram of Figure 3 is also constant and has a constant phase angle. If the phase angle of Y_D is made equal to this constant phase angle, it can be shown that the unknown admittance is equal to a constant times (Y_A-Y_C), and that this constant will vary with the value of

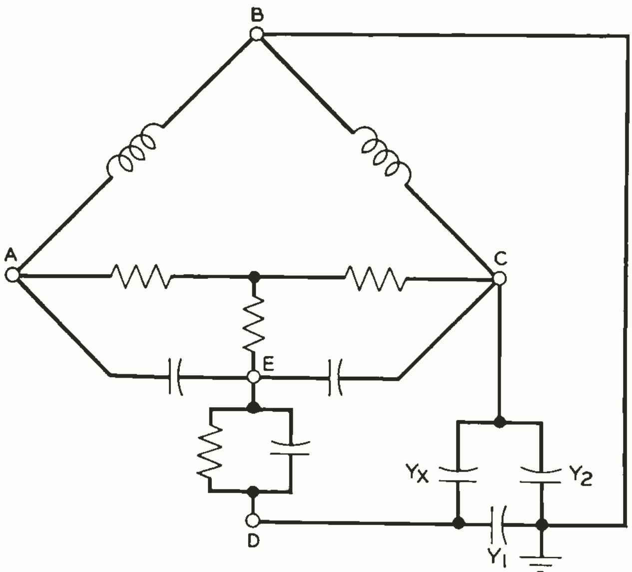


Fig. 4—The direct capacitance being measured is treated as a three-terminal network, and connected to the bridge as shown above

Y_D. It can also be shown that the capacitance component of the unknown is equal to this same constant times $(C_A - C_C)$, and that the conductance component of the unknown is equal to another constant times $(g_A - g_C)$. In both cases, the value of this constant is less than unity.

The double-star network of conductance and capacitance of Figure 2 thus not only enables the conductance and capacitance of components to be measured by differential adjustments of g_A and g_C and C_A and C_C, but provides an adjustable multiplying constant in the equation so that the actual values of the standards may be much larger than the corresponding components of the unknown.

In the actual bridge, the conductance and capacitance standards are adjusted so that five constants are available in consecutive decimal steps of 1, 0.1, 0.01, 0.001, and 0.0001 which for convenience are indicated as reciprocals which are used as divisors. The adjustable range of the quantity $(G_A - G_C)$ has a maximum value of 10 micromhos, readable to 0.5 μmho, and $(C_A - C_C)$ has a maximum value of 110 μμf adjustable to 0.1 μμf. Using the divisor of 10,000, therefore, the capacitance of the unknown can be read to a hundred-thousandth of a micro-microfarad, and the conductance to five hundred-thousandths of a micromho.

Since, as already pointed out, the direct capacitance to be measured will be associated with a number of capacitances to other elements or ground, means have to be provided for eliminating these latter capacitances from the measurement. This is accomplished by treating the unknown as a three-terminal network. In measuring plate to grid capacitance of a vacuum tube, for example, all the tube elements except the plate and grid are connected together and to ground, and the leads from the plate, the grid, and ground will be brought to the bridge. These three leads embrace three admittances: the direct admittance between grid and plate; the admittance from the grid to the other elements and ground; and the admittance from the plate to the other elements and ground. Since ground is one of the terminals for both of these latter admittances, the three admittances are actually arranged in a delta network, which is connected to the bridge as shown in Figure 4, where Y_X is the direct admittance between plate and grid, Y_1

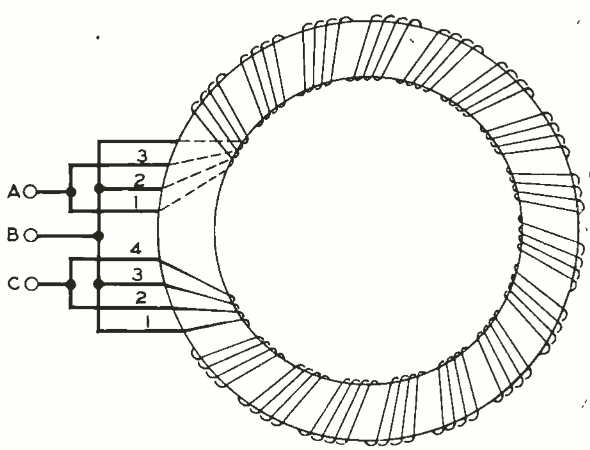


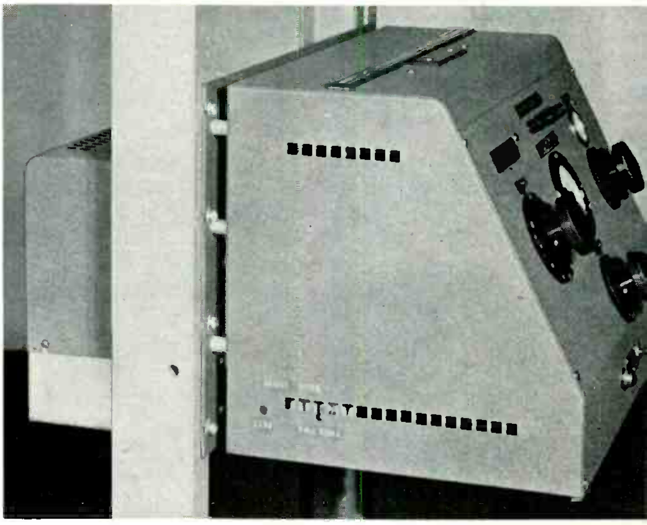
Fig. 5—Method of winding ratio arms for the new capacitance bridge

the admittance between grid and ground, and Y_2 that between plate and ground. The bridge is provided with two coaxial jacks, and the plate and grid would be connected to the inner conductors of the two coaxials while the ground leads to which all the other elements of the vacuum tube are connected would be connected to the two outer conductors of the coaxial.

With the connections so made, Y_X is across the CD corners of the bridge and is thus in the position for measurement. Y_1 is across the diagonal of the bridge and thus has no effect on the measurement, and is effectively eliminated from consideration. Y_2, however, is effectively in shunt with the BC arm of the bridge, and with the more usual type of bridge would definitely affect the bridge reading. In this new bridge, however, its effect is eliminated by the design of the ratio arms AB and BC.

These two arms, which are identical, consist of the secondary winding of a transformer, the primary of which is connected across the a-c power supply. These two ratio arms are formed by winding four parallel wires on a torroidal core and then connecting them as indicated in Figure 5. Alternate parallel wires are used for each half of the winding to reduce leakage inductance. Over this secondary with suitable electrostatic screening is then placed the primary winding. Because of the very close coupling between the wires of the secondary forming the two arms of the bridge, any voltage connected into one arm or any admittance connected across it would be directly reflected into the other as an equal voltage or admittance. The admittance Y_2 connected across BC is therefore reflected as an equal admittance across AB. It will thus have the same effect as an admittance connected across AC, and will not affect the reading of the bridge. Thus both Y_1 and Y_2 are made to have negligible effect on the reading of the bridge, and the measurement secured at balance is that of the direct admittance Y_X alone.

The circuit—shown complete but without shielding in Figure 7—comprises three basic units, an oscillator power source, a bridge, and a detector. These units are arranged on a 12¼ x 17-inch relay rack panel, as shown in Figure 6; the oscillator and the rectifier power supply are supported on the rear side of the mounting plate, and the bridge and detector units are contained in a sloping front housing supported from the front side of the mounting plate. The detector operates from the common power supply which is fed from the 60-cycle lighting circuit. A single switch serves to control the entire circuit. This composite arrangement of the circuit elements has proven very satisfactory, not only from the standpoint of convenience, but also because the



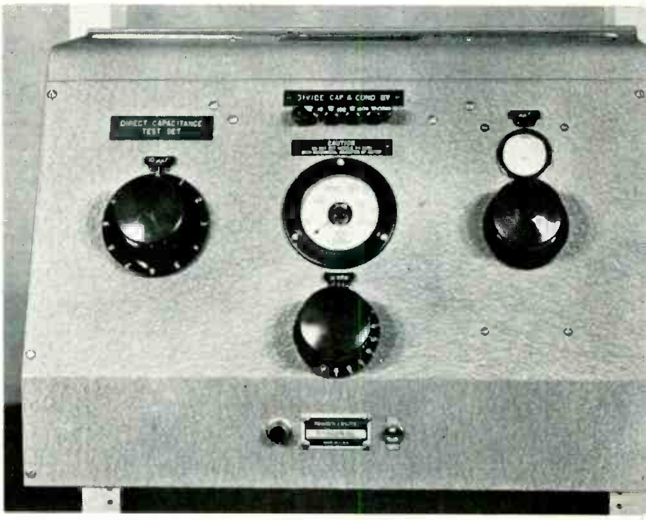


Fig. 6—Side and front view of new bridge showing the oscillator and rectifier power supply mounted behind the bridge and detector unit

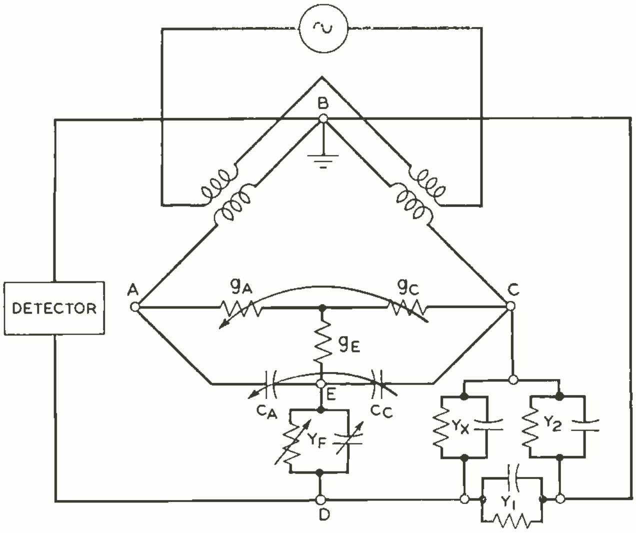


Fig. 7—The bridge circuit and the unknown, complete except for shielding

permanent nature of the connections and orientation of the components ensures reliability in performance and freedom from spurious coupling between elements which would seriously impair the accuracy of the capacitance bridge.

The oscillator is crystal controlled and operates at 465 kilocycles. This frequency was selected because it is high enough to provide ample sensitivity to permit a bridge balance down to a capacitance of only 0.00001 μf to be detected with the detector operating well above noise, and yet it is not so high that troublesome effects due to series inductance and resistance in the circuit and test leads are encountered. The supply potential delivered to the bridge is approximately 30 volts.

Jacks for the two coaxial test leads are in the top of the cover, while on the sloping front are the controls and indicator. At the middle top of the sloping front shown in Figure 6 are five buttons used to select the multiplying factor. At the left is a capacitance decade with ten steps of 10 $\mu\mu$f each, and at the right is a continuously adjustable capacitance standard of 10.5 $\mu\mu$f that can be read to 0.1 $\mu\mu$f. The indicator is in the center, and has a range of approximately 90 db. Directly beneath the indicator is a continuously adjustable conductance dial with a maximum value of 10 μmhos, readable to 0.5 μmho.

Although designed primarily to serve the needs of these Laboratories and the Western Electric Company, this new bridge has met with a rather unexpected acceptance by manufacturers and research organizations in the electronic industry in spite of the fact that war conditions have prevented effective publicity.

THE AUTHOR: C. H. Young received the degree of B.S. in Electrical Engineering from the University of Michigan in 1927. He at once joined the Technical Staff of the Laboratories, where, with the electrical measurements group of the Apparatus Development Department, he has engaged in the development of precise impedance measuring equipment. Since 1941 Mr. Young has been associated with the electronic measurements group with which he had an active part in the development and manufacture of a number of defensive and offensive weapons for the Navy, including the magnetic airborne detector.

J. R. PIERCE
Physical
Research

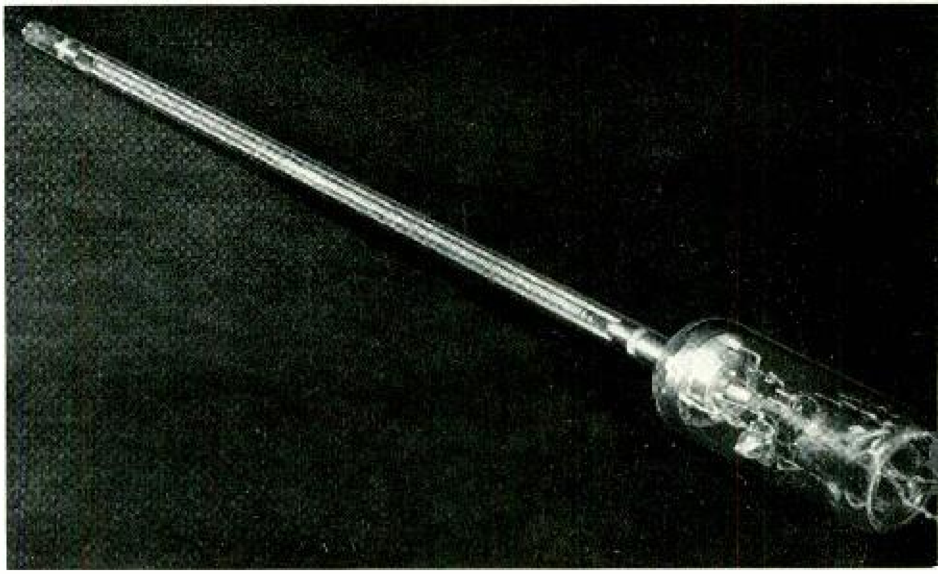
THE BEAM TRAVELING-WAVE TUBE

In developing broad-brand communication such as television and pulse modulation it has been difficult to obtain adequate amplifications over the wide frequency ranges required. With the amplifier tubes most suitable for microwave frequencies, such as disk-seal triodes and klystrons, high gain can be secured only by narrowing the band. If an amplifier with a band width of 10 megacycles were required, a gain of perhaps 10 db per stage could be obtained. Were such an amplifier readjusted to give a 20-megacycle band, the gain would fall from 10 db to 4 db, and for a 32-megacycle band the gain would be 0 db, and, as a result, the amplifier would be completely useless.

The recent development by Bell Telephone Laboratories of the beam traveling-wave tube promises to overcome this limitation. An experimental tube such as that shown in the photograph below has given a high gain with a band width about eighty times as great as has been practicable with other microwave tubes. Further, the nature of this new tube is such that the band can be broadened even more without sacrificing gain.

The beam traveling-wave amplifier has in common with other vacuum tubes an evacuated envelope and a stream of electrons, but it differs widely from more familiar types in appearance, construction, and operation. Electrons are accelerated from a hot cathode by a high-voltage electrode and shoot down the axis of the tube in a narrow beam, focused and guided by magnetic fields. No grids are employed, and the electrons striking the anode do not carry the amplified output, since the amplifying action has been completed before the electrons reach the anode.

One form of the beam traveling-wave tube



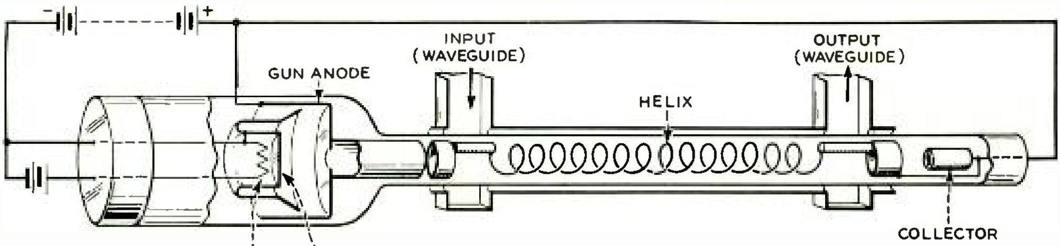


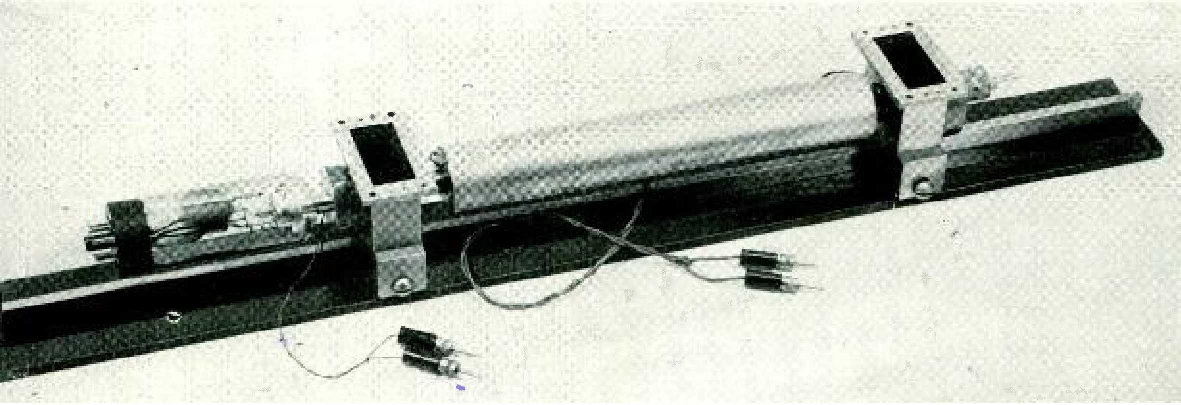
Fig. 1—Cross-section of beam traveling-wave tube showing the arrangements of the elements from the cathode at the left to the collector at the right

Surrounding the electron beam for nearly a foot of its length down the tube there is a closely wound helix of wire which carries the signal current. The signal current produces electric and magnetic fields, and indeed the signal progresses down the helix as an electromagnetic wave. This wave tends to go along the wire at about the speed of light, and as the wire itself is roughly thirteen times as long as the wound spiral, the wave travels down the helix about one-thirteenth as fast as light. The electron stream travels through the helix a little faster than the wave.

It is the interaction of the electrons with the electric field of the helix which produces the amplification; the greater the electron current or the longer the helix, the greater is the gain. No tuned circuit is used in any part of the path; the helix acts throughout as a smooth line capable of transmitting a broad band of frequencies, and thus band width limitations are almost absent. Were better means provided for getting the signal onto and off of the helix, bands of greater than 800 megacycles could probably be attained. As it is, the present 800-megacycle band far exceeds existing needs, and little effort has been directed toward broadening the band further.

In the present amplifier two wave guides, one carrying the weak input signal and the other the amplified output signal, are fitted around the tube near the ends of the helix. At each end the helix is fastened to a metal collar inside the tube, and short straight sections between the collars and the helix

Fig. 2—An experimental model of a beam traveling-wave tube showing the coil for guiding the electron beam placed over the tube between the two wave guide connections



act as antennas to couple the helix to the guides. At the input end, the receiving antenna picks up the electromagnetic radiation coming down the input guide and sends it along the helix; at the output end the transmitting antenna directs the power from the helix out into the output wave guide. This arrangement is indicated diagrammatically in Figure 1, while Figure 2 illustrates a complete beam traveling-wave amplifier.

Besides the tube and the two wave-guide connections, two coils which can be seen in Figure 2 are required in forming the electron flow into a narrow beam and in guiding it down the tube. The electrodes surrounding the cathode are so shaped as to send the electrons into the tube in nearly parallel paths. The narrow coil just to the left of the input wave guide in Figure 2 provides a final adjustment before the beam enters the helix, and the long coil covering the tube between the two wave guides keeps the beam from spreading in its passage through the helix.

The construction of the experimental tube can be seen more clearly in Figure 3, which shows enlarged views of the two ends. Four slender ceramic rods which run the length of the tube between the helix and the inner surface of the glass hold the helix accurately centered in the envelope. The ends of these rods are held in four slots placed ninety degrees apart in the metal collars to which the helix is connected. The connection of the helix to each collar is made at the end of a narrow projecting finger which acts as an antenna in coupling the helix to the wave guide. Thus, the ends of the helix are fastened to the high voltage ends of two antennas.

A mathematical analysis of the operation of the tube has been carried out. This agrees with measurements of the field along the helix in showing that near the input end, where the electron stream is shot in as a smooth unvarying flow, the signal level remains nearly constant for a short distance. In this region the signal acts on the electron stream, gradually producing fluctuations in velocity and density. Then, when these fluctuations become large enough, the electron stream begins to give up energy to the electric field, and finally there is a long region in which the signal increases the same number of db for each inch of travel.

The detailed behavior of the field and of the electrons in the region near the input end of the tube is quite complicated. It is found, however, that this complication can be resolved into a simple picture of three different waves, excited nearly equally by the input signal and traveling down the

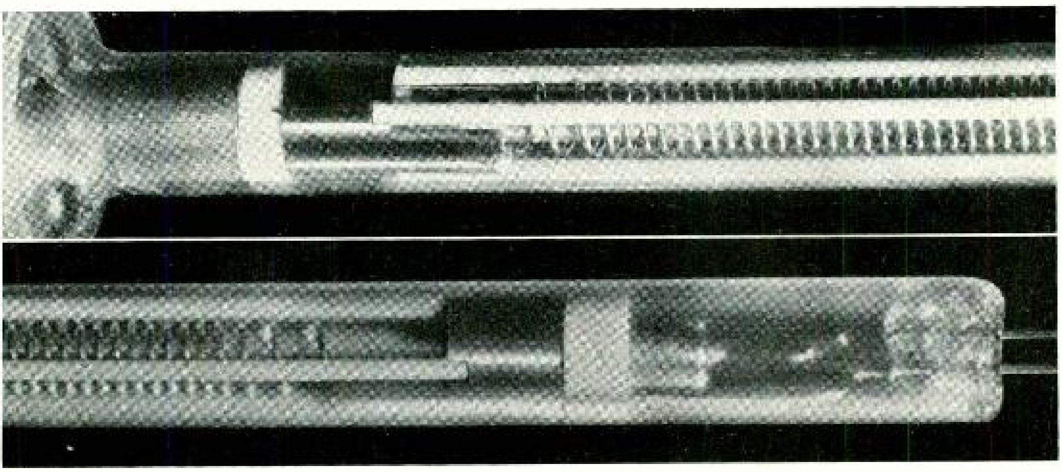


Fig. 3—At each end the helix is attached to a projection from a metal ring that acts as an antenna. Cathode end of the tube, above, and collector end, below

helix quite independently and without mutual interaction. In the absence of the electron stream there is only one sort of wave, of a unique speed and attenuation, which can travel on the helix; it can, of course, travel in either direction. When the electron stream is present, however, it is found that there are three different sorts of waves that can travel in the direction of electron motion. Two of these are attenuated with distance, and are present only near the input end of the tube, accounting for the complicated behavior in that region. The third wave has the unusual property of negative attenuation; that is, it grows stronger as it travels instead of weaker. It is this wave which, increasing with travel while the other two waves are attenuated and become negligible, accounts for the linear increase in the signal level with distance in the later part of the tube.

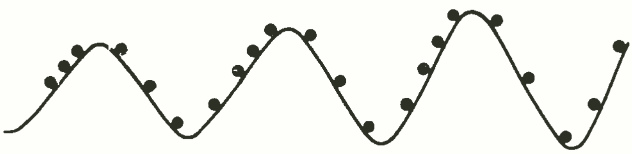


Fig. 4—The distribution of the electrons may be likened to the action of frictionless balls rolling up and down hills of increasing height

The mechanism leading to the increase of this negative attenuation wave can be likened roughly to the building up of water waves as a wind blows past them. In the beam traveling-wave tube, the electrons move faster than the increasing wave and form a sort of "electron wind" which gives energy to the wave as it moves along. A mechanical analogy of this action is illustrated in Figure 4, which shows a representation of the electric field as it would be seen by an observer moving along the helix with the speed of the wave. The electric field is represented as a series of hills and valleys, increasing slightly in height from left to right, the direction in which the wave is traveling, and the electrons are represented as frictionless balls rolling up and down over the hills. It can be shown that when the electrons move to the right past the wave, and when the hills grow higher with time (as they do for an observer moving with the growing wave), the electrons will go slower on the up slopes than on the down slopes. Hence, the electrons will crowd together in regions of retarding field, where they are going slowest, and where they are giving up energy to the wave.

In the past a number of studies have been made at these Laboratories and elsewhere of the interaction of electrons with traveling waves. During the war, R. Kompfner and others at the Clarendon Laboratory, Oxford, England, showed that amplification was possible with a device consisting of an electron stream and a helix. Work in these Laboratories by L. M. Field and F. H. Best in association with the author has been successful in producing amplifiers with the astonishingly high gain and broad band already mentioned, and further development should lead to tubes for various broad-band microwave communication systems.

THE AUTHOR: J. R. PIERCE received the B.S. degree from California Institute of Technology in 1933, and continuing his studies there, received his Ph.D. in 1936. He then joined the Technical Staff of Bell Telephone Laboratories, where he has been engaged in the development of electronic devices. During the war years his efforts were devoted almost exclusively to the development of electronic devices for the Armed Forces. Since then he has been carrying on developments, such as that of the beam traveling-wave amplifier, that hold promise of peacetime application.

R. J. PHAIR
Chemical
Laboratories

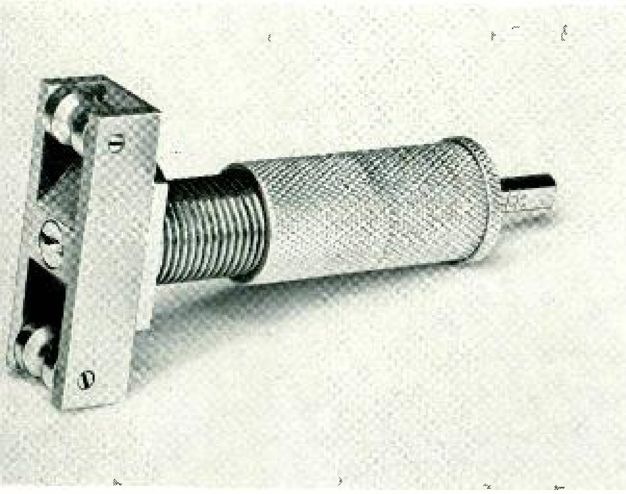
POCKET-TYPE ADHESION TESTER FOR ORGANIC COATINGS

Testing to determine optimum adhesional quality of a finish coating

When confronted with the question of the suitability of an organic coating for a particular usage, one of the first characteristics examined, other than appearance, is its adhesion to the base surface. Whatever the primary function, the finish must in most cases adhere tenaciously, if it is to protect the base and resist physical shock that may occur during production handling and service life.

Although the importance of adhesional evaluation is reflected in the many instruments designed to measure this property of coatings, the tools are in large measure restricted to laboratory use on specimen panels and it is common practice to estimate adhesion of paint films on parts, whether in production or the field, by the finger nail or knife. To fill the need for a quantitative method, which could be easily carried to the work and which would be adaptable to measurement of parts too large to handle in the laboratory, a pocket-type adhesion tester has been designed by Bell Telephone Laboratories.

The instrument is small enough to be held easily in the hand. It measures adhesion by determining the pressure that has to be applied to a scratching tool in the instrument to make it expose the base material under the finish. The scratching element is mounted at the end of a short cylindrical rod and is pressed by a spring against the surface tested. A threaded sleeve controls the pressure exerted by the spring by squeezing it between the end of the sleeve and a shoulder on the rod. Graduations on the outer end of the rod, which projects through the threaded sleeve, indicate the pressure applied. These parts are supported by a housing which has rollers on which the instrument rides over the surface of the finish. When both rollers are firmly pressed against a flat surface the



The adhesion of finishes is measured with this pocket tester by determining the pressure that has to be applied to its scratching tool to make it remove the finish and expose the base surface

spring pressure is transmitted directly through the scratching tool to the test film.

The more critical parts of the assembly are the spring and the scratching element. Springs suitable for use in the instrument are selected by comparing their stress-strain characteristics with a standard spring which was chosen to give the desired pressure differences over the range of compression permitted by the design. The spring and scratching tool are further checked after complete assembly of the device by comparing the adhesional levels obtained with them against a standard instrument* on representative coatings. The calibration markings are then scribed on the upper end of the inner rod. The scratching tool is a steel disk 0.256 in. outside diameter and 0.0625 in. thick. The periphery of the disk is smoothly rounded to a radius of 0.0312 in. and it is hardened, highly buffed and chromium plated.

In use the tool is set for minimum pressure, pressed firmly against the coating to be measured so that both rollers are in contact with it and then pushed with a slow, steady motion over the film. This process is repeated with increasing pressure, obtained by turning the threaded outer sleeve an arbitrary amount until the film fails. This occurs when the film is removed by the scratching disk and the base surface is exposed. The adhesional level is then read from the scale on the upper end of the graduated rod. Each division represents about a 500-gram increment and the scale covers a range of from 500 to 5,000 grams or from poor to excellent adhesion.

This instrument has been found very useful as an engineering aid in evaluating finishes applied by sub-contractors on parts furnished by them and also in ascertaining if standard coded finishes on equipment adhere satisfactorily. In addition, a number are now in use in the Western Electric Company for control testing, thereby furnishing information which may be used to check the finish materials purchased and to insure that the application procedures are such as to obtain optimum adhesional quality in finish coatings.

*RECORD, *August*, 1945, *page* 284.

THE AUTHOR: Entering the Laboratories in 1928, R. J. PHAIR, after holding various positions, became a draftsman. For eight years prior to 1943, when he was graduated from the Newark College of Engineering with the degree of B.S. in Chemical Engineering, Mr. Phair attended night school. In 1938 he joined the Chemical Laboratories to work on organic finishes. These studies have included the development and improving of instruments, methods for testing finishes, and investigations of organic materials which have led to the selection of a variety of insulating and protective coatings for metal and wood.

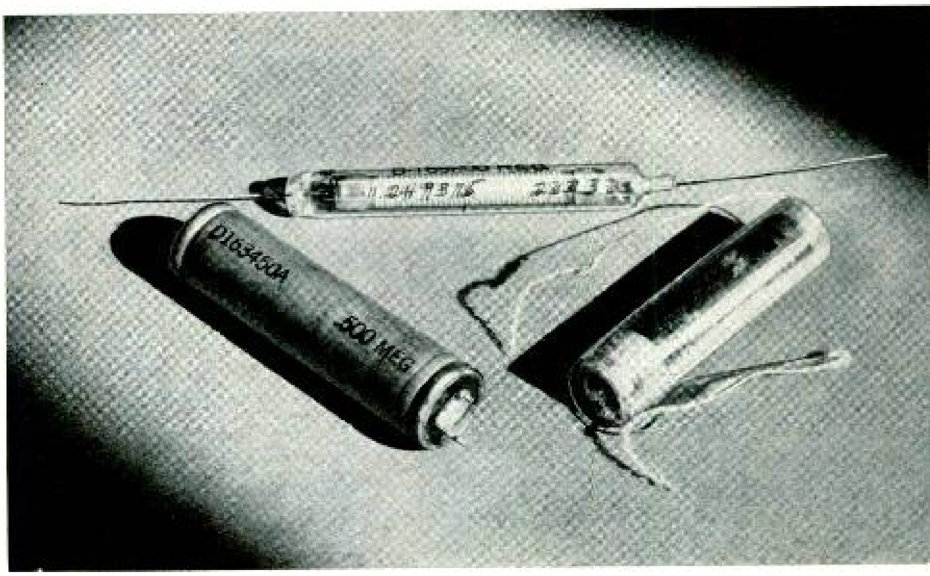
E. C. HAGEMANN
Transmission
Apparatus

PRECISION RESISTANCE NETWORKS FOR COMPUTER CIRCUITS

Electrical gun directors developed in the Laboratories during the early years of the war not only proved a decisive factor in defending Britain against the air blitz, but were equally decisive in many of our amphibious offenses such as Anzio, Normandy and the Pacific islands. Other computing devices, similar in general purpose, were developed for surface ships, submarines and aircraft. Their influence on the conduct of warfare was revolutionary, and their influence on techniques in the Laboratories and the Western Electric Company was almost as radical. Precision of fire control is the essence of the computer's purpose, and it was the necessary precision in the design and manufacture of its component parts that presented a challenge to the Laboratories. Among these precision components are the resistors associated in groups and used to derive the very precise voltages needed for the operation of the computers.

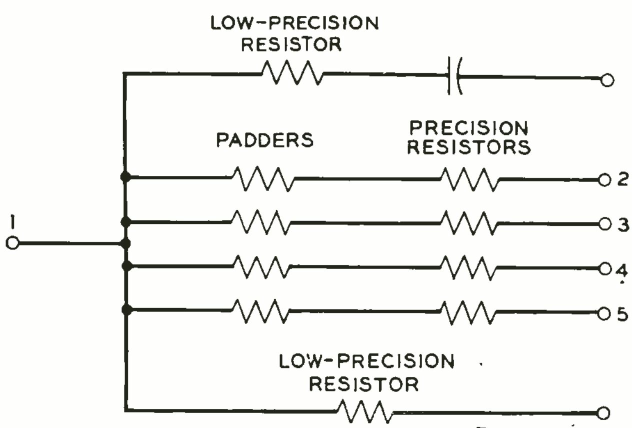
If the ratios of some of these resistors to each other depart as little as 0.03 of one per cent from their correct value, the projectile may miss its target by as much as ten yards at maximum range, even if all other factors are precisely at their correct values. A precision of this order in a resistor was formerly considered possible only in laboratory standards, and yet the success of these computers depended on hundreds of thousands of resistors of this order of precision. Moreover, the resistors must be capable of withstanding the wide range of temperature and humidity encountered in going from the tropics to the arctic, and from sea level up to altitudes of 50,000 feet. Even this does not represent the full magnitude of the problem, since the resistors had to withstand the vibration and shock of trucks, ships and planes under battle conditions, and they had to be designed for large-scale manufacture by

Typical resistors used in precision networks



personnel that was relatively inexperienced.

When the initial development of the M-9 director* was begun late in 1941, wire-wound resistors were the only available type that held promise of meeting the critical requirements. One of the first decisions that had to be made was the range of values of the resistances to use, considering both resistor and circuit design. In the computers, these resistors are mounted in groups as indicated below, and their function is to provide accurate voltage ratios at the right-hand terminals. It was not the absolute value of any one resistance that was of particular importance, but the relative values within a group. The order



Resistance networks took many forms, but that indicated above represents one of the more common types

of magnitude of the resistors could thus be selected within a reasonable range, but once a value had been established for one resistor of a group, the others had to have precise ratios to it.

If low values of resistance were selected, considerable power would have to be dissipated by each unit, since, for a given voltage, the dissipation is inversely proportional to the resistance. If very high values were selected, on the other hand, either a large resistor would result because of the very large amount of wire required, or the wire would have to be extremely small, and thus would be subject to breakage under severe conditions.

A still further limitation on the selection of resistance range was the paralleling effect of the insulation resistance between the resistor unit and its housing. If the paralleling resistance of the insulation of a ten-megohm resistor, for example, decreased from 100,000 to 3,000 megohms, which is still a very high value by any normal standard, the apparent resistance of the resistor would decrease by 290 parts in a million. In many cases the maximum permissible departure due to all effects, including variations in power input and temperature, is only 300 parts in a million. If, on the other hand, the maximum resistance value were only one megohm, the above parallel leakage would cause a reduction in resistance of only twenty-nine parts in a million. As a result of such considerations, it was decided to use resistors within the range from 0.1 to 2.0 megohms.

With this point settled, a study of various alloys was undertaken to determine the most desirable from the point of view of resistivity and temperature coefficient. A nickel-chromium alloy with a temperature coefficient of about eighty parts in a million per degree Centigrade was found to be quite suitable.

To eliminate the effect of wide variations in humidity on the insulation resistance, it was decided to enclose the resistors in sealed containers, and since it was the relative values of the various resistors that were important, it was also decided to mount all the resistors of a single set in the same container so that differences in temperature of the individual units would be held to a minimum. Each resistor is first enclosed in a small sealed metal tube. Besides protecting them from handling, such construction tends to stabilize the temperature and leakage and makes it possible to prevent the leakage of one unit from affecting another. The enclosing metal tubes are all connected together electrically and to the common ground of the network. In this way, all leakage currents flow to the same point and cannot return by way of another resistor and thus change its effective value.

After the individual units are wound and

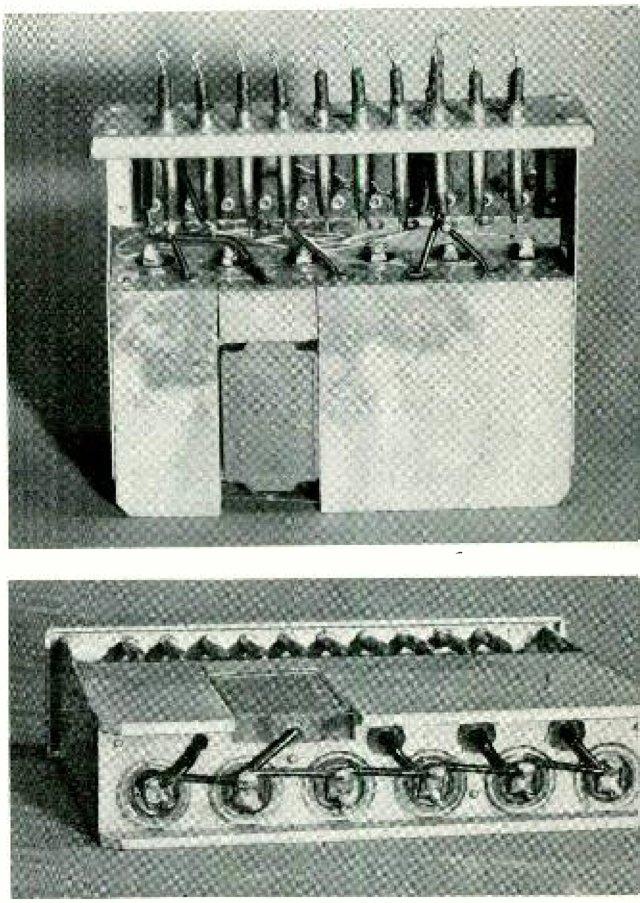
*Record, *January,* 1944, *page* 225.

sealed in their individual containers, each is carefully measured to determine its resistance and temperature coefficient, and these values are marked on the containers. Although the temperature coefficient is nearly the same for all the units, there will be some variations with different batches of alloy. If the coefficients of two units in the same group differed by even a comparatively small amount, there might be a relatively large variation in the ratio between the two resistors over the wide range of temperatures encountered. For this reason, the units employed for any one group are selected so that the temperature coefficient for all of them will be alike within limits narrow enough to avoid an objectionable change in ratio over the specified range of temperature.

After the units for a group have been thus selected, they are inserted in a rectangular wooden block slightly thicker than the diameter of the individual resistors, and the block is then attached to the cover of the can in which the assembly is to be housed. Such an assembly is shown at the right. This assembly is first thoroughly dried, and then impregnated with a moisture-proofing wax. After it returns to room temperature, the assembly is ready for the final adjustment of its resistors.

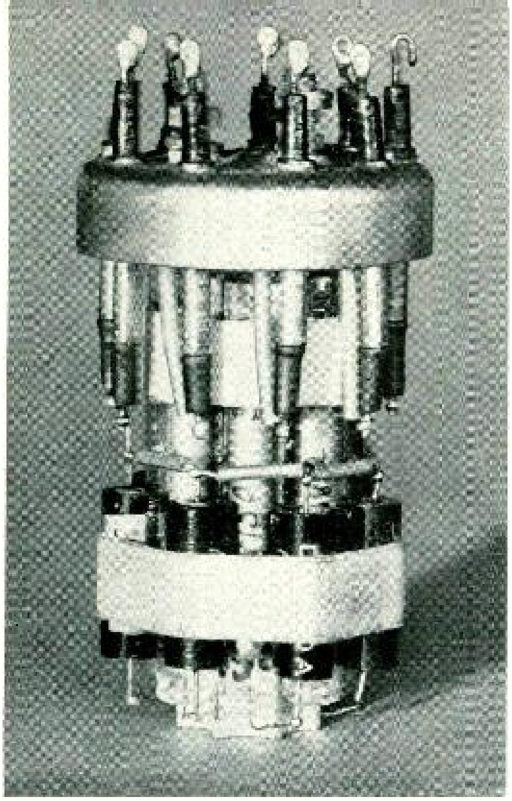
The unit resistors as thus assembled may not be quite the correct values to give the desired ratios, but they will be at least within two per cent of the correct values. Small wire-wound padder resistances are employed to build out the low-value units to the correct ratio values. These padders are attached to a bracket on the cover assembly and then wired to the units they build out. After careful measurements to insure all units are of the correct value, the assembly is put in its container, the cover is sealed in place, and a small hole in it is sealed closed. The entire assembly is then immersed in hot wax. This heats the air in the can, and the resulting pressure will force air out through any leaks. Air leakage is disclosed by a series of bubbles, and the can is then repaired and tested again. After the can is found to be tight, the sealing disk over the hole in the cover is removed, the can is immediately filled with hot wax and the sealing disk is again soldered in place. The assembly is then cleaned, lacquered and stamped with the proper designations. Frequently, one or two less critical resistors and sometimes a capacitor and resistor are to be associated with the precision resistors. In such cases, these elements are mounted in the same container. In the illustration below, a capacitor is evident near the left end.

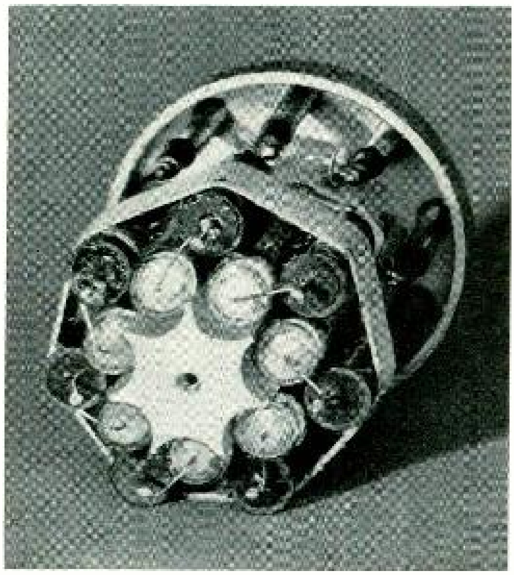
The wire employed for these resistors is 0.0015 inch in diameter, and by 1943, the



Side and bottom views of the resistance network inserted in its wooden container

Western Electric Company alone was manufacturing resistors using this wire at the rate of more than a hundred million feet a year. Even this amount would not meet the demands, which had grown to exceed the combined wire-drawing capacity for this wire of all the resistance wire manufactur-





Side and bottom views of network in the aluminum core mounting

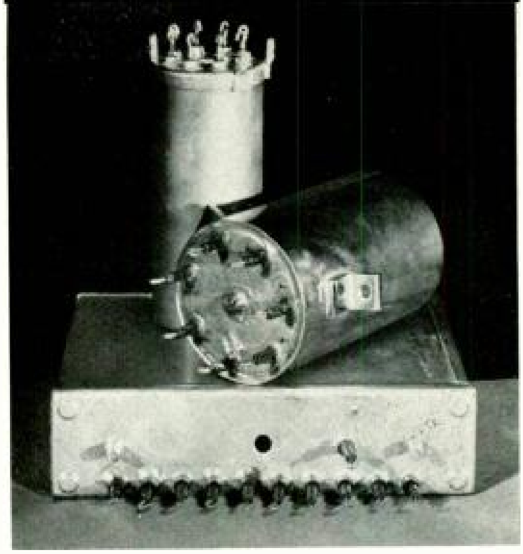
ing concerns in the United States. Fortunately, the Research Department had previously done considerable work on new glass-sealed, deposited carbon resistors which with certain possible improvements could be substituted for wire-wound resistors for many applications. Although glass-sealed resistors were already available on a laboratory basis, much further development was found necessary before sufficiently stable resistors could be obtained and introduced on an adequate commercial scale. This development was carried on jointly by the Research and Transmission Apparatus Departments. After exhaustive tests and several improvements, satisfactory resistors of this type were introduced into manufacture in time to avoid serious delays in producing precision resistances for the new M-8 gun data computers and aircraft radars urgently wanted by the Armed Forces. The use of this new type of resistor brought in new problems, however, because of their larger and more widely spread temperature coefficients and the necessity of considering the thermal properties of the glass envelope and the greater inherent weakness of the glass when subjected to vibration or shock. Among others, H. M. Thomson, D. R. Brobst and T. L. Tanner played an important rôle in the development of those networks.

The deposited carbon resistors have an average negative temperature coefficient of about 300 parts per million per degree Centigrade, while the wire-wound units had a positive coefficient of about eighty parts per million. This higher temperature coefficient and the higher resistance values (up to about eight megohms) made it necessary to develop an entirely new measuring technique to obtain the required sensitivity, speed and precision in calibrating the precision resistors.

Two resistors of the same temperature coefficient which had the correct resistance ratio when both were at the same temperature might be out 300 parts in a million when the temperature of one differed from that of the other by as little as one degree Centigrade, while the specified precision of initial matching for many computer circuits is as severe as 100 parts in a million. With the improved measuring apparatus and techniques that were developed, accuracies better than fifty parts in a million were obtained in resistance ratio measurements.

A completely new type of mounting was developed for these carbon-film resistors. Instead of the wooden block, a grooved core of aluminum was employed. The resistors are laid in the grooves and then held in place by a banding of a special adhesive tape, as shown on the opposite page. They are further secured to the mounting and to each other by a thermoplastic cement which, studies had shown, could be relied upon to secure the resistors firmly in place, and yet was sufficiently elastic to permit the glass envelope and the parts of the network assembly to expand and contract freely with temperature changes. The short padding-out resistors, of a less precise deposited carbon variety, are assembled on the outside of the glass-sealed resistors. Where condensers were required, a tubular paper condenser was used that would fit in the grooves of the core or in the space normally occupied by the padding-out resistors. With the above construction, satisfactory thermal conditions are obtained due to the thermal conductivity of the aluminum core and of the copper case which encloses the assembly.

Another form of unit was designed for the more recent computers used with aircraft radars, where greater compactness and lighter weight was required. A typical unit is shown upright in the next column. Because of somewhat reduced requirements on the resistance matching, building out resistors could often be omitted, and when they were needed, a very small carbon resistor of the composition type is employed. A new cover arrangement employ-



Two of the aluminum core networks resting on one of the wood container units. The upper unit is the lightweight structure for aircraft

ing glass-sealed terminals also helped in securing smaller size.

These designs of precision resistance networks for various computer circuits required the preparation of more than one hundred specifications and about four hundred drawings, not including a large amount of engineering sketches made to facilitate early completion of the models of the apparatus. Most of the assembly work, as well as all the testing and adjusting for most of the models—more than one thousand in number—was done by engineers and technical assistants in the Transmission Apparatus Development Department.

THE AUTHOR: E. C. Hagemann, after receiving the degree of B.S. in Electrical Engineering from Bucknell University in 1916, spent a year with the Crocker-Wheeler Company and then joined the A T & T, where he engaged in transmission testing in the toll cable plant, working at various repeater stations between New Haven and Washington. During World War I he served as an ensign in the Navy, and on returning to the Bell System joined the Physical Laboratory of the Laboratories. Here he was concerned with testing and development of condensers, capacitance standards and bridges, and the studies of materials and apparatus for use at radio frequencies. Since that time, with Transmission Apparatus Development, he has been chiefly engaged in developing loading and retardation coils. During World War II he was occupied for the most part with resistance networks for directors and radar computers.

NON-LINEAR COILS FOR PULSE GENERATORS

H. A. STONE, JR.
Transmission Apparatus Engineering

In electromagnetic apparatus, the term "non-linear" is usually applied to a coil with a core of high permeability that saturates at a relatively small current. Because the transition from the non-saturated to the saturated condition of such a coil is very abrupt—being accomplished by a very small change in applied field—such a coil may be treated as having two values of inductance: a high inductance at small currents and an extremely low inductance at large currents. The ratio of these inductances may be several thousand to one. Applications for such coils had been found prior to the war, notably as harmonic generators for carrier telephone and telegraph systems,* and as tone generators for dial and busy signals.† The non-linear coil made an early entry into the war as a phase modulator and harmonic generator for the SCR-508 and SCR-509 radio transmitters.‡

Another important contribution of the non-linear coil to the war was in its application as a pulse generator for radars. A requirement common to all radar transmitters is a source of high power in the form of short bursts, which may be of the order of one microsecond in duration and repeated at the rate of a few hundred to a few thousand times per second. Vacuum-tube circuits were used in some early radars to form these pulses, and in others the pulses were obtained from the successive discharges of a condenser through a rotary spark gap. Although both of these methods were used with considerable success, each entailed certain disadvantages. The early vacuum tubes required frequent replacement, and were limited in the power they could handle. Burning of the points in spark gap mechanisms introduced instability in the timing, and the moving parts were subject to wear. To avoid these difficulties, attention was turned to non-linear-coil circuits to obtain the required pulses. Practical circuits have been developed and are in wide use. Non-linear coil pulse generators are characterized by comparatively long life, good stability, and operation from a relatively low-voltage power source.

Several different circuit arrangements have been used, but the simplified schematic on the opposite page will illustrate the principle employed. As shown here, the non-linear coil has two windings, one of

*RECORD, *July*, 1937, *page* 357. †RECORD, *February*, 1942, *page* 152. ‡RECORD, *March*, 1946, *page* 102.

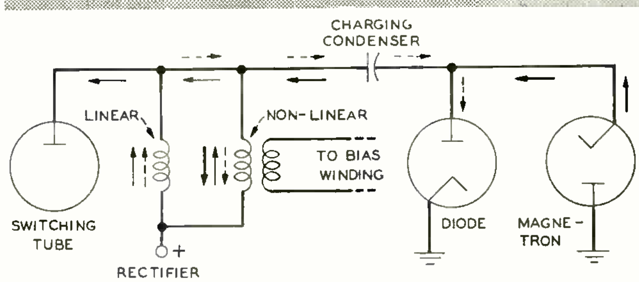
which is supplied from a d-c source, and serves to magnetize the core to saturation in one direction. In other circuits, a single winding performs the functions of both the windings of the coil illustrated.

At the beginning of a cycle, there is no charge on the condenser, and no currents are flowing except the d-c in the bias winding, and the core will be saturated in what may be called the positive direction. As the plate circuit of the switching tube, which is controlled by a square-wave generator, becomes conducting, current supplied by the rectifier builds up through both the linear and the non-linear coils as indicated by the light solid arrows. The direction of flow through the non-linear coil is opposite to that of the biasing current, and the current is great enough to carry the core through the unsaturated region and then to saturate it negatively.

When the switching tube cuts off, the energy stored in the field of the linear coil, which is much greater than that of the non-linear coil, develops a very high voltage across the coil. A rush of current flows to the condenser, charging it through the diode to ground, and a smaller amount flows through the non-linear coil in a reverse direction. Current flow at this time is indicated by the dashed arrows. This latter current again carries the core of the non-linear coil through the non-saturated region and saturates it positively. The condenser has become heavily charged by the time the non-linear coil becomes positively saturated, and as the saturation point is reached, the non-linear coil acts as a short circuit to ground, and the condenser discharges through it and the magnetron at the right, as indicated by the heavy solid arrows. A magnetron voltage of about 25 kv can be obtained in this manner from a 6,000-volt rectifier, and the peak power of the pulse may reach 1,000 kw.

Non-linear coils for pulse generators are, as might be expected from the magnitude of the power handled, much larger and quite different in design from the harmonic generators for radio and telephone use, although both operate on the same principle of saturation. For contrast, the non-linear coil in a typical radio-telephone transmitter contains two hundredths of a gram of core material, whereas the coil in the SV radar has a core weighing 13 kilograms; six hundred and fifty thousand times as much! More than two miles of molybdenum permalloy tape go into each SV core.

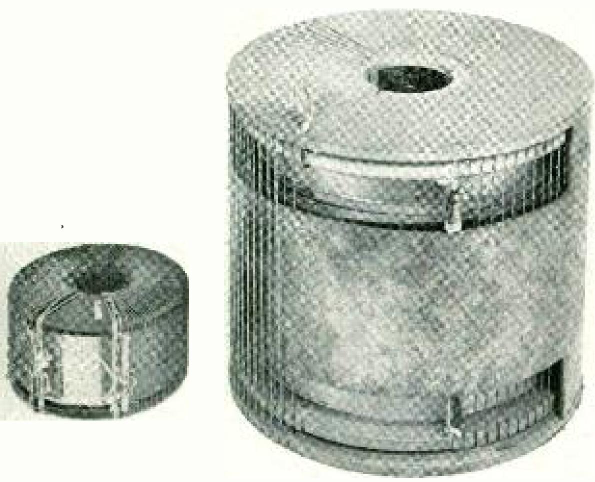
The design of practical coils of this type is complicated by numerous conflicting requirements. The core is built up of thin magnetic tape which is highly sensitive to strain. It must not be clamped too tightly,



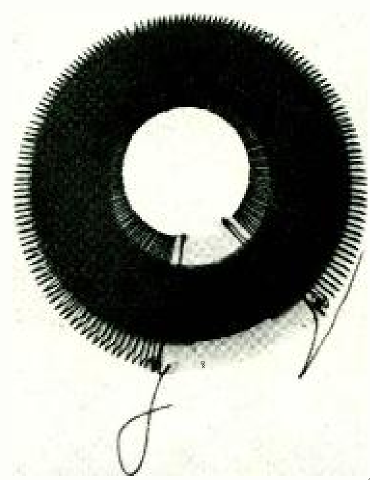
Simplified schematic of pulse generating circuit showing the position of the non-linear coil

and the edges of the tape must be protected from damage. Yet, in service it must be able to withstand severe shock and vibration without tearing loose from its support. Magnetic considerations dictate that the windings lie close to the core and to each other, while the high internal voltages demand generous separations to reduce the destructive effects of corona. Because of the power they handle, these coils are inherently large, yet since they are used in restricted places, severe limitations are placed on their over-all size. One example of the extent to which it has been necessary to go to realize small savings in space is illustrated by the coils that are shown on the next page and in the X-ray view. This non-linear coil was widely used in several radar systems. It will be noticed that the core and the coil are eccentric. This unusual construction was employed to provide the necessary spacing between the high potential winding ends and the core, and to reduce the spacing at the center of the winding where the voltage is negligible. The conventional concentric construction providing equal voltage protection would have resulted in an eighteen per cent increase in the coil volume. In most of the later coils, however, it was found possible to secure adequate separation without resorting to eccentric coils, and since the concentric types are easier to manufacture, the concentric coil is used wherever possible.

Molybdenum permalloy is used for the core material in all of the non-linear coils for radar pulse generators. Its high initial permeability, low hysteresis loss, and easy saturability at low fields make it by far the most suitable of the available magnetic materials. It is used in the form of tape one mil in thickness and ⅜ to ½ inch wide. The tape, insulated with a film of silicic acid, is wound into tight sections from 3 to 6 inches in diameter and weighing from 200 to 1,500 grams. From two to ten of these sections are stacked one above the other to form a core of the desired size, as shown on the opposite page. A slotted fiber tube inserted into the stack and sprung against the inner periphery prevents the core sections from moving out of alignment. The tube also provides support for the winding heads, as shown in the photograph.



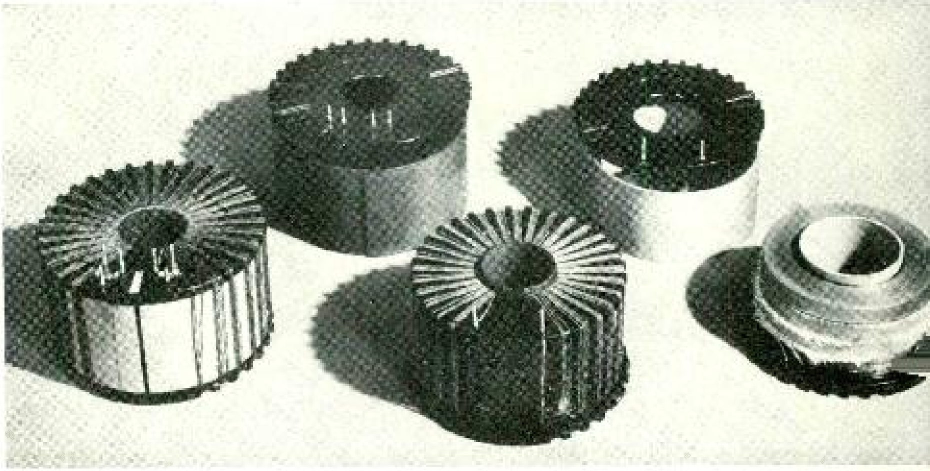
At left, a non-linear coil with an eccentric core; at right, a non-linear coil for the SV radar



X-ray photograph of non-linear coil that is shown at the extreme left

Glass cloth is used for cushioning between the core sections, and inner and outer cylindrical insulators of phenol fiber are placed around the core between the heads. After the two heads and the insulation are in place, the inner, or pulsing, winding is put on the core assembly and connected to terminals as shown second from the right in the illustration. After the inner winding is completed, a similar set of insulating heads and tubes is placed over it to support the outer, or biasing, winding. The cylindrical insulation around the inner winding extends over the inner heads, and only the outer heads and insulation are visible. Holes in the outer head permit the terminals from the inner head to project through them, while terminals for the outer winding are mounted on the outer head directly. Both inner and outer heads are provided with radial projections between which lie the turns of the windings. This permits the whole assembly to be firmly clamped without damage to the windings.

The coil that is illustrated has a 1,000-gram core, and a 20-kv pulse is generated across the inner winding. For larger coils, with operating voltages up to 40 kv and more, phenol plastic insulators are unsatisfactory. Although the entire assembly is immersed in oil, corona rapidly disintegrates this type of material, and most organic materials are affected to some extent.



Steps in assembling a non-linear coil shown from the stacked core at the right to the finished coil at the left

The coil for the SV radar operates at 42 kv across the inner winding. The winding heads are machined from glass-bonded mica, and the cylindrical insulators are a built-up material of mica flakes bonded with a small amount of resin. Since this material becomes soft at high temperatures, it cannot be used as a bearing member, and in this coil a brass tube through the center of the core stack is used for support of the winding heads.

To save the space that would be required for many separate components individually sealed and each provided with its own high-voltage terminals, the non-linear coils are wired into a common chassis with the other elements of the pulser network, including the charging condenser, linear coil, magnetron filament coil and several small coils and condensers whose function is to "shape" the generated pulses by providing resonances in the circuit. The entire assembly is immersed in oil in a welded steel can. Such a chassis with the non-linear coil is shown in the photograph at the head of this article on page 450.

Radars equipped with non-linear coil pulse generators are widely used for search and fire control on surface vessels and submarines. Nearly ten thousand non-linear coil pulse generators have been manufactured by Western Electric for the Navy.

THE AUTHOR: H. A. Stone, Jr., received a B.S. degree from Yale in 1933 and joined the technical staff of the Laboratories in 1936. From then until undertaking war work, he was with the Transmission Apparatus Development Department developing a variety of retardation coils and similar apparatus. During the war period he devoted his time to the development of coils and networks for use in military radio and telephone projects, and to the design of radar pulse generators such as those described in this issue of the Record. Since the close of the war he has been concerned with coil problems in vehicular radio, type-L carrier, and other communications projects, and with the development of new uses for non-linear coils.

BLOW HOT—BLOW COLD
The M-9 never failed

Everyone figured that the M-9 gun director would work, but under what extreme circumstances no one could say with absolute certainty. That was the reason for the mission to Panama, and the mission to Canada. When the returns came in, they were greeted by more than a few somewhat boastful "I-told-you-so's." Facts, unquestionably, are facts.

The M-9, just as the name implies, directs guns. It directs heavy anti-aircraft artillery, using information obtained either from its own optical sighting system or from radar equipment. This director solves the complex trigonometrical problems of gun-pointing, electrically. The answer comes out as fast as electricity will speed through its circuits. That's fast—even in these times. It not only figures out how the gun must be pointed to get the shell to the place where the airplane will be when the shell arrives, it actually points the gun. It also sets the fuse so that the shell will explode at the right time. All the gun crew has to do is load ammunition and watch the airplanes fall.

Chronologically, the mission to Canada comes first. Winter-testing is something that happens to almost every piece of equipment designed to fight a global war. They take it to a place like Shilo Camp, the Army ordnance proving ground, 120 miles northwest of Winnipeg in Manitoba, Canada, where the temperature drops as low as 50 or 60 degrees below zero and the wind blows free across the wide, frozen plains. They "soak" it in cold and windy weather until it breaks down, find out why it failed and recommend improvements. The M-9, however, did not stop functioning.

L. J. Kelly of Bell Telephone Laboratories, where the M-9 was designed, reached Shilo Camp on February 1, 1943, to work with the proof officer on cold weather tests. The first job was to try the M-9 indoors to make certain the one to be tested was operative under normal conditions. Then it was moved outside into the snow, and there it stayed for the duration of the tests.

IT ISN'T THE HEAT; *these M-9 trailers, exposed to tropical sunshine, functioned perfectly*

"The camp ran by the thermometer instead of the clock," Kelly says. "Whenever a storm was predicted, all leaves would be cancelled, and the boys would sit around waiting for the temperature to fall so they could go to work on various testing projects. I remember one night the weather office predicted an extreme low the next morning at about 8 a.m. They called us a couple of hours early so that we would be ready. Sure enough, at 8:30 the temperature hit minus 32."

That was the coldest at which they tested the M-9, although while he was there the temperature dropped to 47 below zero.

"We wanted to try the M-9 in wind, snow and varying cold," according to Kelly. "We'd pull the canvas hood off and let it soak from four to twelve hours. Then we would turn it on. We tried it at various temperature levels from zero to 32 below."

A few minor troubles developed. One motor in the altitude converter wouldn't operate at extreme low temperatures and had to be replaced. Lubrication was not a problem so long as the specific lubricants recommended for cold weather operation were used. A synthetic rubber cable sheathing became hard as steel. The liquid in the levelling tubes of the optical tracker contracted so much that the boundary of the bubble could not be seen.

But electrically the system never failed. There was never an occasion when it was inoperative due to the weather conditions.

IT'S THE HUMIDITY; *this M-9 trailer parked in jungle, soaked up moisture but still functioned*

"The temperature dropped once from 27 above to 31 below in 21 hours. That's 58 degrees in less than a day. But the system didn't fail. I've seen it with frost all over its insides, and it didn't fail then, either."

Just by way of comparison, the men who worked with it had nowhere near the resistance to cold that the M-9 had. Here's a list of the clothing that Kelly habitually wore: long woolen underwear, melton cloth ski trousers, heavy wool shirt, coveralls made of heavy duck lined with kersey, a wool, blanket-like material. On his feet he wore two or three pairs of wool socks and slippers or shoes, inside cloth-topped, rubber-footed galoshes, and on his head a knit wool cap that covered the entire face except the eyes and upper part of the cheekbones, plus a helmet lined with the same kersey and buttoned under the chin. He kept his hands warm with a three-layer arrangement of wool gloves, wool mittens and ski gloves, in that order. That was the camp's standard costume. When it was really cold, they added more.

"You couldn't touch metal with your bare hand," Kelly explains, "it would pull the skin off. No one was ever allowed to work alone. The air was so dry that it often seemed comfortable. No one would know they were being frostbitten unless someone else was watching them. One man's face turned white from frostbite in five minutes. Another man's ears were frozen in eleven minutes."

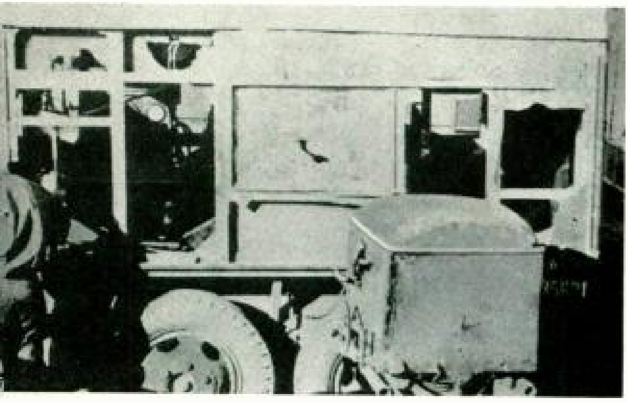
The M-9 subsequently underwent other cold weather tests, but they could hardly be called laboratory experiments. A number of equipments spent several years in Alaska and the Aleutians—Adak and Kiska and such places. There was also northern Europe, the defense of Antwerp and the Battle of the Bulge, during the winter sports season. People who look at newspaper pictures will remember the snow and ice. The M-9 didn't fail there, either.

There were actually two trips to Panama. C. E. Fordham arrived the first time in October, 1943, as a Bell Laboratories observer for the Ordnance Department. Among other things he visited M-9 emplacements to find out how the equipment was operating under tropical conditions. Upon his return to the States in January, 1944, he presented his conclusions in a gray folder titled "Report on Maintenance of Electrical Equipment at Panama," now on file in the Laboratories. The essence, he reports, was something like this:

"The M-9, if given proper protective maintenance, functions about the same in the tropics as it does in the States."

Fordham journeyed to Panama again in 1945 as a Laboratories representative with a formal tropical-testing mission conducted by the Army. The Pacific offensive had begun and the Ordnance Department was haunted by visions of equipment sitting on the beaches or in the jungles for weeks at a time without protection or maintenance until it was needed for use. Exhaustive controlled-exposure tests were planned.

One M-9 was set in the open where tropical sunshine and showers could batter it all day long. Daily temperatures averaged around eighty or eighty-five degrees, but inside the M-9 trailer, which had an oven-like effect, the thermometer usually soared to 125 or 130.



The most severe test of all couldn't stop this M-9. During the defense of Antwerp, a V-1 buzz-bomb exploded thirty feet away. Heat from the blast fused parts of the optical tracker. The M-9 computer inside the trailer continued to function perfectly without repair

The M-9 thrived on such treatment. "We left it there two months," Fordham explains, "and the conditions were actually beneficial. The heat kept it dry. The best way to use it in the tropics is to keep it in the sun."

Another M-9 was deposited in the jungle and left there for five months. On this, the Atlantic side of the Panamanian Isthmus, rainfall ranged from 150 to 180 inches a year, and the relative humidity averaged about 85 per cent. Under the heavy cover of the jungle it was always damp, always warm and always dark. Here the moisture collected and fungus grew on almost everything—including humans.

During the testing period, the M-9 received no protective maintenance. It was turned on 30 minutes a month so that they would know when it deteriorated so much as to become inoperative. But it never did.

"At no time," says Fordham, "did it cease to function beyond the ability of the field maintenance people to repair it, usually very quickly."

Fungus growth, he explains, was more a symptom than a disease in itself. "You should have seen it—all over the inside of the trailer and the equipment. But when everything had been thoroughly dried, the fungus was found not to have damaged the equipment nor to have interfered with its further performance."

Corrosion was not a serious problem, but there were some minor troubles connected with moisture itself. A few plastic and fiber parts of the equipment would soak up water and swell or warp. They found an easy answer for most of this, however, since the equipment dissipates some two kilowatts of heat during operation.

"It usually dried itself out without any help," Fordham says. "All you do is just turn it on."

Fordham emphasizes the increased importance of "breathing" of equipment that takes place in the tropics.

"In the evening when the temperature goes down (to some 70 degrees), the air in all enclosed spaces contracts. As it does, the cabinets breathe, drawing moisture into their air spaces."

Fordham also has some less professional stories that no one listens to without smiling. There was the one, for example, about the ant that was big enough to smoke a cigarette.

"He didn't actually smoke one, but he picked up a burning cigarette and carried it off the ant hill."

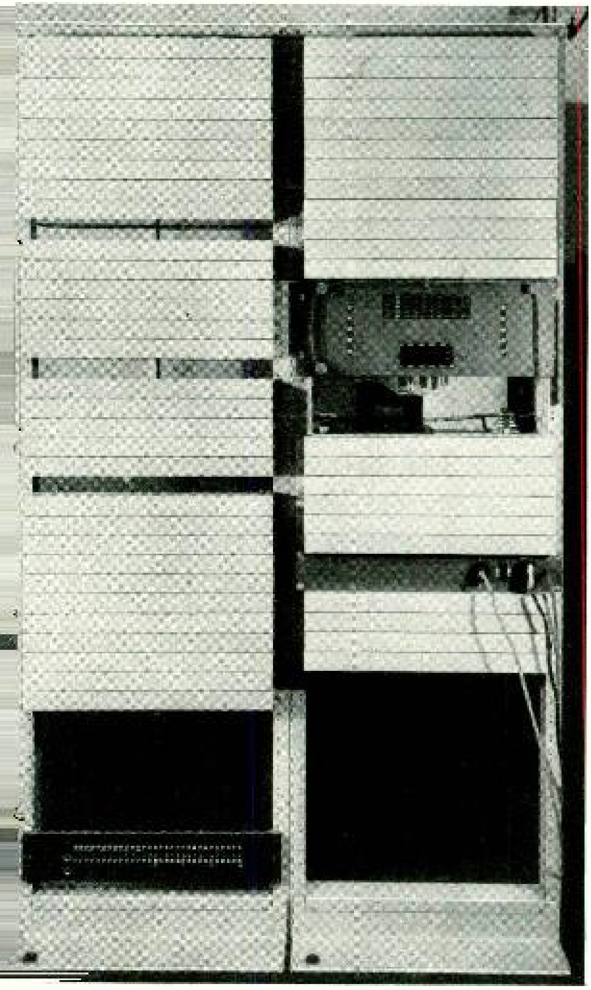
The conclusions that Fordham and Kelly reached were proved again and again during the course of the war. The M-9 was used all over the world—in the heat of North Africa and the beaches and jungles of the Pacific, in the dampness of the Dover Coast, where it defended London from the buzz-bomb, in the snows of the Aleutians, the Italian Alps and Belgium. At Antwerp, one blustering week in March, it helped set a record that other anti-aircraft computers have never equalled—but that's another story. In no case was the M-9 allergic to climate. Wet or dry, hot or cold, frost or fungus—the M-9 did not fail.

O. CESAREO
Switching Development

THE RELAY INTERPOLATOR

As a part of the development of the M-9 gun director, it was necessary to provide accurate test equipment which would move the input knobs of the director exactly as an operator would move them in tracking a hostile airplane, and then check whether the orders given by the director would keep the gun properly pointed. The design of this test equipment required an enormous number of computations—so many, in fact, that even if all the computing facilities of the Research Department had been continuously devoted to this one job, it would have taken nearly a year to carry them out. Since the equipment had to be built in less time than that, some way of speeding up these computations was required. G. R. Stibitz, who was then employed by the National Defense Research Committee, suggested that an all-relay digital computer might be designed to do the job. The Systems Department engineers looked into this suggestion and decided that a machine could be designed and built, and could carry out the necessary computations, all in less time than would be required by ordinary computing methods; and that the entire cost of building and operating it would be less than the labor cost by ordinary methods. The N.D.R.C. therefore requested the Laboratories to build the machine. The Systems Development Department undertook to develop the computer, which became known as the relay interpolator, since the principal part of the computing to be performed was interpolation, and the apparatus performing these calculations consisted mostly of relays.

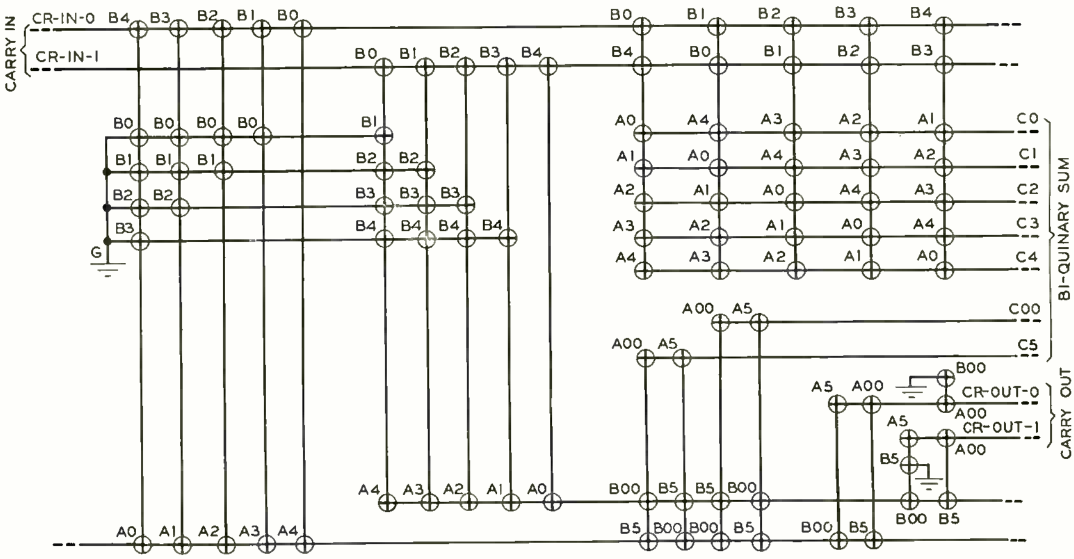
Two bays of relay racks carry the U-type relays of the interpolator



All computations are based on the use of a bi-quinary adder and a group of register circuits. In bi-quinary notation, a digit is always represented by two numbers: a quinary part consisting of one of the digits 0 to 4 inclusive, and a binary part consisting of either 00 or 5. The latter part tells whether or not the digit is less than 5, and the sum of the binary and quinary components gives the value of the digit. Thus the digit 7 would be represented by the binary 5 and the quinary 2, while the digit 3 would be represented by the binary 00 and the quinary 3. Compared to decimal notation, the bi-quinary notation has the advantage of requiring only seven units instead of ten to express any of the ten digits. In the bi-quinary notation two, and only two, numbers are required to express any digit. This means that for any digit, two relays, one in the binary group and one in the quinary group, and only two, will always be operated, which greatly simplifies checking by electrical means. Although it is possible to express a decimal digit with less than seven units, these other methods do not lend themselves to use in adder circuits and to ready checking, which is important with apparatus of this type.

Adding is accomplished by two sets of relays: an A set to carry one of the numbers to be added, and a B set to carry the other. The sum of the digits recorded on the A and B relays will be indicated by the appearance of a ground on two of seven C leads: two of the seven representing the binary part of the sum, and five the quinary. The interpolator is designed to handle five-digit numbers, and there will be a group of these C leads for each digit of the number. Each of the A and B relays closes a large number of contacts when it is operated, and it is ground on an input circuit carried over circuits connecting suitable combinations of these contacts that appears on the C leads to give the proper sum.

How this is brought about is indicated in the diagram below, which shows the contacts for the A and B relays for one digit. The various contacts are indicated by a circle around the intersection of two lines, and each such contact is marked with a letter and a number to indicate on which relay the contact appears. If the digits 6 and 2 are to be added, for example, where 6 is put on the A relay and 2 on the B, the A5 and the A1 relays will be operated to indicate the digit 6, and the B00 and the B2 to indicate the digit 2. Four relays will thus be operated, and as a result, ground would appear on the C5 and C3 leads to indicate a sum of 8.



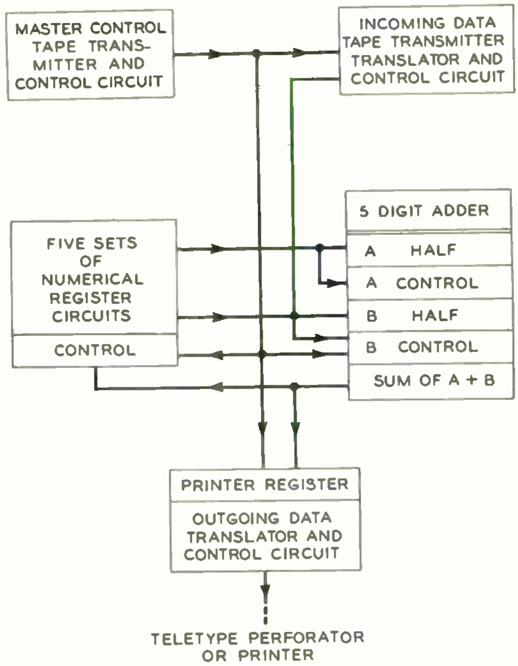
Inter-connection of contacts of the A and B relays used in adding

The bank of contacts at the middle right of the diagram performs the addition of the quinary component. For the addition in this case, the input ground will appear on the top lead marked CR-IN-O at the upper left. Following this along to the B2 contact—third from the upper right—and then down to the A1, it will be found that the ground will then appear on the C3 lead to indicate that the quinary part is 3.

Following from the ground marked G just below the CR-IN-1 lead at the upper left, up to the B2 contact, then horizontally to the adjacent B2 contact, then vertically down to the A1, then horizontally to the BOO lead fifth from the right, and then up to A5, it will be seen that ground will also appear on the C5 lead to give the correct sum for the binary component. These are the only C leads on which ground will appear with A5 and A1 and BOO and B2 operated when the input ground appears on the CR-IN-O lead. There will be a ground on the CR-OUT-O lead at the lower right, however, to indicate there is no carry-over to the next digit. This ground will follow along the same path as that for the C5 lead except that at the third BOO contact after leaving A1 at the lower left, it will pass up to the A5 contact and thus appear on the CR-OUT-O lead

The circuit shown represents the relays for only one digit. For the five-digit interpolator, there are four other similar sets of relays for the other digits, and the CR-IN and CR-OUT leads go to the relays for the previous and following digits respectively. If the 6 and 2 of the above example had been the second digits of a number of which the first or right-hand digits had been 7 and 5, a 1 would have been carried over to be added in with the 6 and 2, since 7 plus 5 is 12. The C2, COO, and CR-OUT-1 leads would have been grounded for the sum of the first digits 7 and 5, and thus for the summing of the digits 6 and 2, ground would appear on the CR-IN-1 lead at the upper left instead of on the CR-IN-O. This would have grounded C4, C5, and CR-OUT-O, showing that the second digit was 9 and that there was no carry-over, since the sum of 67 and 25 is 92.

All the calculations of the interpolator are carried out with these two sets of adding relays, but the over-all results instead of being addition may be multiplication, which is the successive addition of a number to itself the required number of times, or it may be subtraction. A number B may be subtracted from another number A by adding to A the complement of B—that is, the number that added to B would equal 100,000, or a 1 followed by as many zeros as the interpolator is designed to handle. Suppose, for example, that 63 were to be subtracted from 98. The complement of 63 is 99,937 since 63 plus 99,937 is 100,000. When 98 is added to 99,937 the result is 100,035, but since the interpolator handles only five digits, the initial 1 will be lost, and the result indicated will be 00035, which is equal to 98 minus 63. These complementary numbers are secured through a relay circuit that registers the complement of a number on the adder whenever that number is to be subtracted.



Block schematic of circuits of the interpolator

Five principal circuits comprise the interpolator. As indicated in the schematic, they include: five sets of registers on which numbers may be stored during the process of calculation; an adder, which includes two sets of adding relays, one for the A number and one for the B; a master control circuit that guides all the operations carried out by the interpolator; an input control circuit; and a printer control circuit. The known quantities to be used by the computer and the formula to be followed in the calculations are introduced in the form of teletype tapes, that for the formula being a continuous loop so that the same calculation may be carried out over and over again for different sets of input data. Results of the calculations are recorded either on a teletype page printer or in code on teletype tape. The latter form permits the results to be used directly with the dynamic tester employed for checking electrical gun directors.

In all these circuits every effort was made to provide checking operations at each step of the calculating process before proceeding to the next step. This goal was attained in about 98 per cent of the computer operations. Approximately two per cent of the computer operations could not be checked because of the limitations of the five-hole teletype code combinations—thirty-two possible combinations. All things considered, the over-all computed accuracy of the interpolator is very high. The probability of two troubles occurring simultaneously and mutually compensating each other was considered to be too remote to make it worth while to avoid it.

The master control circuit obtains its instructions from the signals received from a teletype transmitter actuated by the circular formula tape. Its procedure is to decode the first signal on the tape, give the necessary orders to the interpolator circuits for carrying out the operation, and then when the required operations have been performed, to release the signal from the master control tape and advance the tape to the next code. In carrying out the calculations it may transfer numbers from the input tape or the registers to the adder, place sums from the adder back into the register, transfer numbers from the registers or from the sum of the adder to the printer register, or perform other similar operations. In transferring numbers from the register it may shift the decimal point in either direction by relay circuits in the same general way it determines complements of numbers when a subtraction is to be performed.

Besides teletype apparatus and control and operating keys, the interpolator as finally designed consists primarily of 493 U-type relays. The original arrangement using 390 relays was arranged on two relay racks as shown on page 457. It was initially supposed that the interpolator would be used for this one purpose only and then junked. But before the first job was done, others were at hand, and as it turned out the interpolator was kept busy for several years. So well did it perform during this period that, when the war ended, the N.D.R.C. gave it to the Navy, and it is now in service at the Naval Research Laboratory at Washington, D. C.

THE AUTHOR: O. Cesareo joined the Western Electric Company at West Street in 1919 as a Junior Assistant. Upon completion of the Junior Assistants' Course in 1922 and subsequently the Technical Assistants' Course in 1925, he became Member of the Technical Staff, and with the Switching Development Department worked on relay application and design problems, particularly concerning the Y and U relays. In 1939 he transferred to the manual systems laboratories where he was engaged in development work such as utilizing thermistors as time delay relay devices. During the early war years he was engaged in writing radar instruction manuals and in the development of radar trainers. Since 1943 he has been associated with the development of relay computing devices such as the relay interpolator described in this issue of the Record, the ballistic computer, and the X-66744 computer system.

L. C. ROBERTS
Telegraph
Development

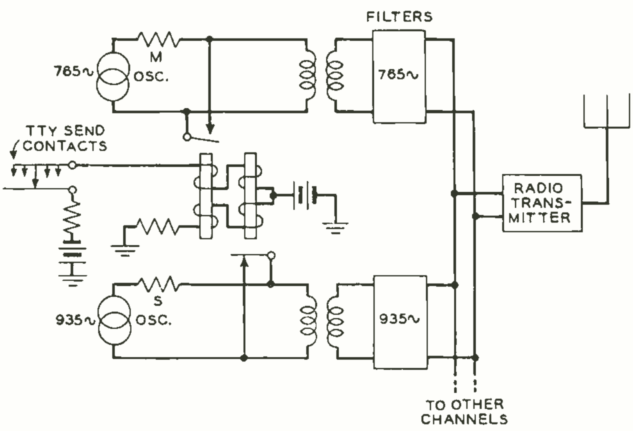
MULTI-CHANNEL TWO-TONE RADIO TELEGRAPHY

Shortly after Pearl Harbor, the Signal Corps was confronted with the need for increased telegraph communication between the United States and many distant parts of the world. At the same time, many of the radio-telephone terminals of the Bell System were not fully used either because the distant terminals were in enemy country or because of Government restrictions on overseas telephone conversations. Representatives of the American Telephone and Telegraph Company, aware of this situation and of the Signal Corps' need for additional facilities, pointed out to the Signal Corps that many additional telegraph circuits could probably be provided by applying voice-frequency carrier-telegraph systems to radio-telephone circuits. The Signal Corps requested that arrangements be made to investigate this possibility, and it was decided that coöperative tests would be made with engineers of the American Telephone and Telegraph Company and Bell Telephone Laboratories. The demand was urgent. There was no time to develop devices particularly suited to the purpose, and thus equipment already in production had to be adapted, if possible.

An obvious starting point for the tests was to try the operation of a standard VF telegraph system* on a channel of a twin single-sideband radio system.† It was surprising to no one, however, that a very brief trial indicated this was impracticable. The received tone of one channel of a VF telegraph system operating over such a radio channel fluctuates over a range of many db from instant to instant. At one moment it may be received at normal level, and a few seconds later the level may be 20 or 30 db lower. It might at first be thought that an automatic volume control could be made to compensate for such level fluctuations, and doubtless considerable improvement could be obtained. In the standard VF telegraph system, however, a single tone is used for each channel, the tone being connected to the circuit for dots and dashes (commonly called marks), and removed for spaces. If a volume control were made fast enough to follow the very rapid fading that is sometimes experienced, the noise during spaces would be amplified to the same level as the signals, and thus no intelligence could be received. This sets a limit on the possibility of improvement by such means.

These considerations led to abandoning the attempt to use single-tone transmission, and it was decided to adopt two-tone transmission instead. This latter method of transmission was developed by the Laboratories and, beginning in 1928, was used for passing information by teletypewriter to assist in handling telephone traffic over the radio-telephone circuits between London and New York. For two-tone transmission, one channel of the standard system is used for marks and an adjacent channel, employing a tone 170 cycles higher in frequency, is used for spaces. With such an arrangement, the amplitude of the transmitted signal is substantially constant, and a fast-acting gain-control device may be used without danger of raising the noise to the level of the signal. This two-tone transmission, however, has the disadvantage of requiring two channels for each message, and

*Record, *February*, 1929, *page* 241. †Record, *March*, 1941, *page* 202.

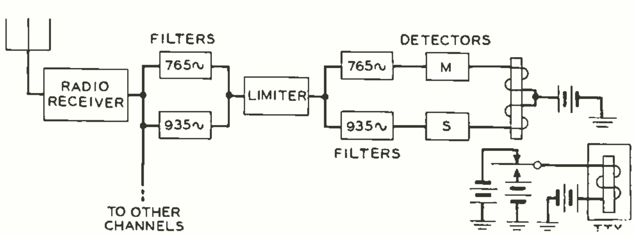


Circuit arrangement of transmitter terminal that supplies six two-tone radio-telegraph channels

thus provides only six telegraph circuits for a twelve-channel system.

The results obtained with this two-tone system were much better, but they were still not considered satisfactory to meet present-day requirements. What was needed was a limiter, a fast-acting device that delivers a constant output for wide variations in the input signal level. No limiter was in production, but one had been built at the Laboratories for some experimental work, and this was borrowed for the tests.

With the limiter, there was a marked improvement. The circuits were now good enough for automatic transmission of International Morse code, in which the received dots and dashes are recorded on a paper tape, but considerable further improvement was desired for teletypewriter transmission, because even with the limiter, deep selective fading would at times reduce the signals below the noise level. With the former methods of transmission, the receiving operator can use judgment in interpreting the message, but a teletypewriter cannot use judgment, and better transmission is consequently required.



Circuit arrangement of receiving terminal for two-tone radio-telegraph transmission

It is a well-known characteristic of selective fading that when a signal received at one frequency has faded so that it cannot be detected because its intensity is less than that of the noise or static, a signal at a frequency only a few hundred cycles away is usually being received at a much higher level; and by the time this second frequency has faded, the first will generally have returned to a usable value. It seemed reasonable, therefore, that if the signal were sent simultaneously on two frequencies, one or the other frequency could be received most of the time.

This "frequency-diversity" system was tried and the improvement was outstanding. The sending relays of two channels carrying frequencies that differed by about 1,000 cycles were connected at the sending end so that the same two-tone signals were sent out simultaneously on two pairs of frequencies. The detectors at the receiving end were connected to a single receiving relay. Now the circuit was satisfactory for multichannel teletype operation and made possible the provision of much-needed facilities for the Signal Corps.

Standard voice-frequency carrier-telegraph equipment was modified quickly by the Western Electric Company for two-tone operation, limiters were built, the equipment was assembled in cabinets and delivered to the Signal Corps for shipment to overseas points where it was most urgently needed. Single-sideband transmitters and receivers were supplied also for locations where they were not already available. The Long Lines Department made the necessary arrangements for the home terminals of these systems.

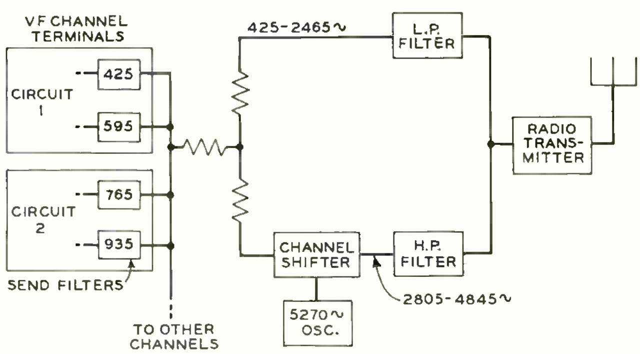
The circuit arrangement for one channel of this system is indicated in the first two illustrations. On a marking pulse, the transmitting relay short-circuits the 935-cycle supply and allows the 765-cycle supply to pass to the radio transmitter, while for a spacing pulse the reverse action takes place. At the receiving end, band-pass filters select the two frequencies for this channel and pass them to the limiter. At the output of the limiter, similar band-pass filters select the two frequencies and pass them to separate detectors, the outputs of which operate the receiving relay.

From each such system, the Signal Corps could obtain six two-tone circuits using the International Morse code with Boehme recorders for receiving. To obtain teletypewriter circuits, however, two of these two-tone circuits had to be used for each message, and then there were only three channels per system. The advantages of teletypewriters in furnishing immediate typewritten copy and not requiring skilled operators were appreciated by the Army, but the attendant reduction in the number of circuits per system to three was unsatisfactory on some routes. Some means were therefore sought to increase the number of telegraph messages that could be transmitted over a single radio channel.

A voice-frequency telegraph system suitable for providing six two-tone circuits occupies a frequency band less than 2,000 cycles wide, while each channel of the single-sideband system can transmit a band about 5,000 cycles wide. On one radio channel there was thus space for two voice-frequency telegraph systems, but no channel filters for frequencies above 3,145 cycles were available. To design and build them would have required too much time. There was a channel shifter, however, that was used on radio circuits to move the voice transmission from the lower frequencies to the upper frequencies of one channel of a single-sideband circuit. By using such a shifter, a method was designed for transmitting six channels of the frequency-diversity telegraph system—twenty-four tones—over a single radio channel without requiring much additional equipment.

The arrangement of the transmitter is shown at the right. Outputs of six two-tone telegraph circuits, and a single-tone circuit used as an order wire, are connected together and then passed through a resistance network to a two-branch circuit—all frequencies flowing equally into each branch. Along the upper branch they pass directly to the radio transmitter through a low-pass filter that passes all frequencies below about 2,600 cycles. Along the lower path, they enter the shifter circuit, where they are modulated with the current from a 5,270-cycle oscillator. A balanced copper-oxide modulator is employed that eliminates the carrier, and the upper sidebands are eliminated by a low-pass filter in the shifter. The lower sideband frequencies, which are higher than those in the upper branch, are then passed through a high-pass filter to the radio transmitter.

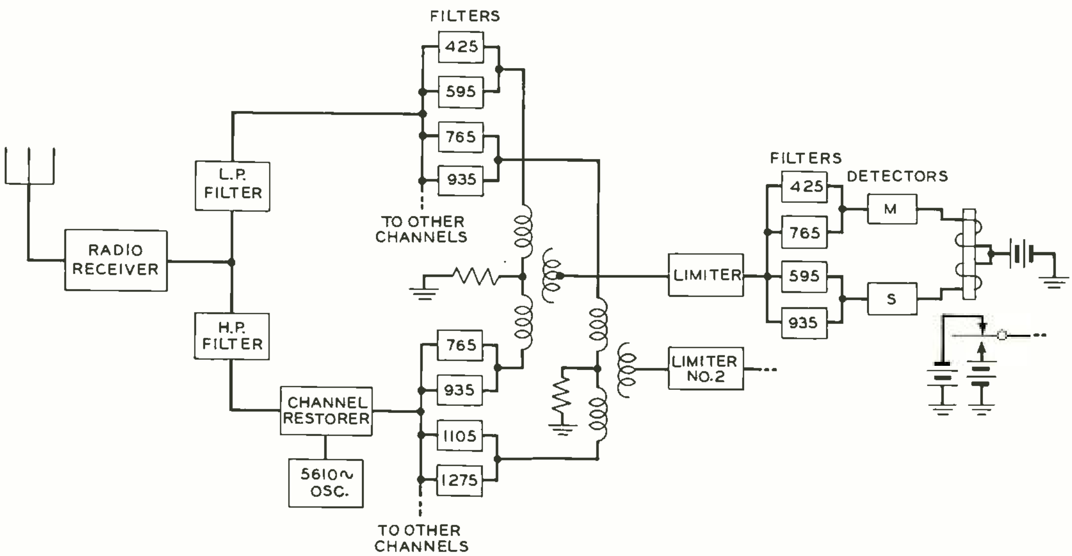
The twelve frequencies from the six two-tone telegraph channels are spaced 170 cycles apart from 425 to 2,295, inclusive, and the order-wire frequency is 2,465. The lower sideband frequencies resulting from the modulation of these frequencies in the shifter with 5,270 cycles are spaced 170



Transmitter terminal for multi-channel two-tone radio teletypewriter transmission

cycles apart from 4,845 to 2,805. The radio transmitter thus transmits thirteen frequencies spaced 170 cycles apart from 425 to 2,465 cycles and a corresponding set of thirteen frequencies from 2,805 to 4,845. Each teletype signal pulse is represented in this group by two frequencies. Thus, a marking signal for the No. 1 teletypewriter circuit is represented by frequencies of 425 and 4,845 (5,270-425), while a spacing signal for the same channel is represented by 595 and 4,675 (5,270-595) cycles, and so on for the other five channels. If selective fading over the radio path should drop out the radio frequency corresponding to 425 cycles, the same information would nearly always be carried on to the receiver by the radio frequency corresponding to 4,845 cycles, which is about 4,000 cycles higher.

which is changed by the shifter of the transmitter to 4,845 cycles, is restored at the receiver not to 425 but to 765 cycles. The corresponding spacing signal of 595 cycles would be restored to 935 cycles. At the receiver, therefore, the two pairs of frequencies for this particular channel would be 425 and 595, 765 and 935 cycles. These tones are combined in a hy-



Receiving terminal for multi-channel two-tone radio teletypewriter transmission

Variations in the radio path cause large changes not only in signal strength but also in the phases of the alternating currents received. At the receiving end, therefore, if the 4,845-cycle current were restored to 425 cycles and combined with the 425-cycle current transmitted directly without being shifted in frequency, the two currents would reinforce each other at times, but at other times they would tend to cancel each other. To avoid this cancellation, the frequencies that were shifted to higher values at the transmitter are restored to frequencies differing from their original values by modulating with an oscillator frequency of 5,610 cycles instead of 5,270. Thus, an original frequency of 425 cycles,

brid coil, and amplified in a common limiter. At the output of the limiter, they are once more selected by band-pass filters and rectified in marking and spacing detectors. This arrangement thus provides a six-channel frequency-diversity system without the duplication of detectors or the development of new filters.

At the receiving end, therefore, the circuit is arranged as indicated schematically above. At the output of the radio receiver, low-pass and high-pass filters separate the frequencies below about 2,600 cycles from those above it. The output from this low-pass filter is connected to the input of thirteen band-pass filters for the frequencies 425 to 2,465 cycles, inclusive, while that from the high-pass filter passes to a channel restorer, where the frequencies are modulated with the current from a 5,610-cycle oscillator. Channel filters in this branch then separate the various frequencies, and the pairs of frequencies from each branch corresponding to a single channel are combined in a hybrid coil and then amplified in a limiter. At the output of the limiter are four channel filters. Two of them select the two frequencies corresponding to marking signals and pass them to the marking detector, and the other two select the frequencies for the space signaling and pass them to the spacing detector. Although one frequency of a pair may have been eliminated by fading, the other will usually be present to operate the receiving relay.

This multi-channel two-tone system is capable of handling a large amount of traffic over a single radio-frequency assignment with comparatively low power per channel. Unlike other systems of large traffic capacity, it furnishes independent start-stop teletypewriter circuits which have maximum flexibility in that they can be readily terminated in teletypewriters of types in heavy production and general use, or extended over land lines to such machines at different locations by simple connections which permit use of standard forms of start-stop regenerative repeaters where these are necessary. Operation with narrow frequency bands for the individual channels was made possible by the inherent frequency stability of the single-sideband circuit. The system was designed and made available quickly, utilizing for the most part standard components already in production.

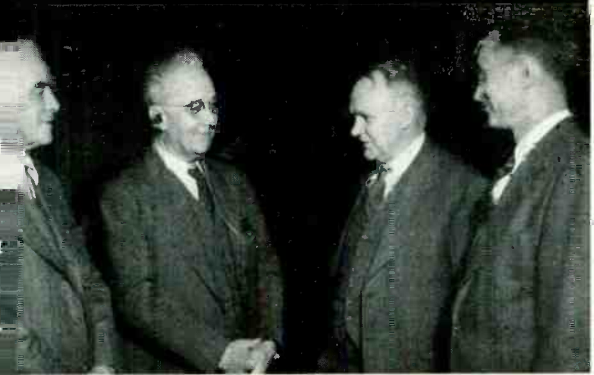
Multi-channel two-tone circuits have been used to connect headquarters at Washington with the Armed Forces in distant parts of the globe. The Bell System owned and operated one terminal of systems extending to England, the continent of Europe, Hawaii, Australia, and two locations in Africa. It is understood that their use was very satisfactory and of great value in the prosecution of the war.

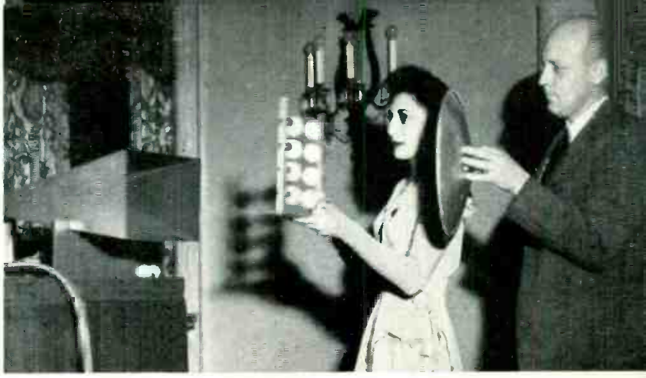
THE AUTHOR: L. C. ROBERTS received the A.B. degree from Harvard in 1916 and spent the following year at M.I.T. receiving the B.S. in E.E. degree. He immediately joined the D & R and came to the Laboratories in the 1934 consolidation. His work has been mainly on the transmission development of telephone and telegraph repeaters. He has been associatd with d-c telegraph work with its related problems of prevention of interference with the operation of telephone circuits on the same wires and the prevention of interferences from signaling and power currents to telegraph; with a-c operated telephone repeaters for railways and with voice-frequency telegraph, particularly on problems connected with its applications to types J and K telephone systems. During the war period, Mr. Roberts devoted his entire time to developing telegraph facilities for the Armed Forces.

TELEPHONE PIONEERS OF AMERICA

The annual winter party of the Frank B. Jewett Chapter of the Telephone Pioneers of America, attended by over 850 members and guests, including 65 life members, was held in the Hotel Commodore on November 1. Following an informal reception and the dinner, D. A. Quarles, president of the Chapter, welcomed those attending, and then introduced the program of entertainment, featuring Bob Cronin and his NBC Orchestra. Dancing concluded the evening's festivities.

Arrangements for the dinner and entertainment were made by a Pioneers committee under the chairmanship of P. W. Spence. During the reception there were demonstrations of several Laboratories developments, including airborne radar, the mirrophone, and high-power microwave transmission.

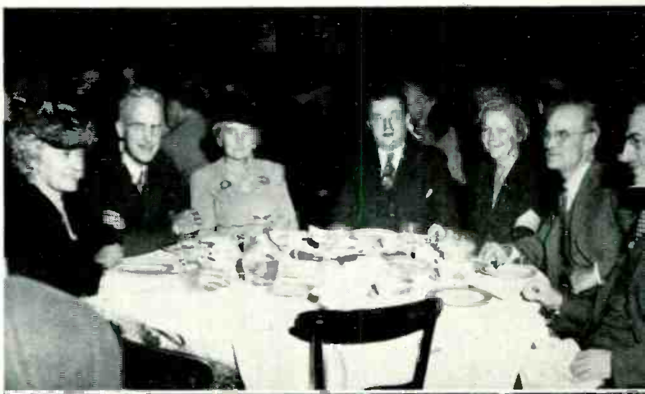




PIONEERS DINNER highlights

NEWS AND PICTURES

OF THE MONTH



TBA Medal received by O. E. Buckley

TELEVISION BROADCASTERS' CONVENTION

Recognition for outstanding contributions to the field of television was given to Oliver E. Buckley, president of the Laboratories, by the Television Broadcasters' Association on October 10 at a banquet climaxing the Association's annual convention. The citation to Dr. Buckley reads: "For his supervision of the application of television to military uses during the recent war and his work in the application of his broad communication knowledge of the transmisssion of television programs."

Similar recognition was given to Keith S. McHugh, vice president of A T & T: "For his constant work in furthering a program of facilities to transmit nation-wide television on a commercial basis."

Accepting the medal, Dr. Buckley said:

"I am deeply appreciative of this award by the Television Broadcasters' Association, which comes to me as representative of Bell Telephone Laboratories. We look on it, not only as a tribute to our work in the past, but as an expression of confidence in our future efforts."

Dr. Buckley then proceeded to describe the fundamental problems of television transmission as essentially like those of telephony. There are three media of transmission—wire, pipes or tubes and radio. Any pair of wires that carries a telephone conversation can carry television, but because of the high frequencies involved, the losses are high and an amplifier must be used about every mile. By the use of pairs specially shielded, more television circuits can be used in the same cable and fewer amplifiers are needed. More economical is the coaxial conductor—a copper tube with a wire down the middle. Said Dr. Buckley:

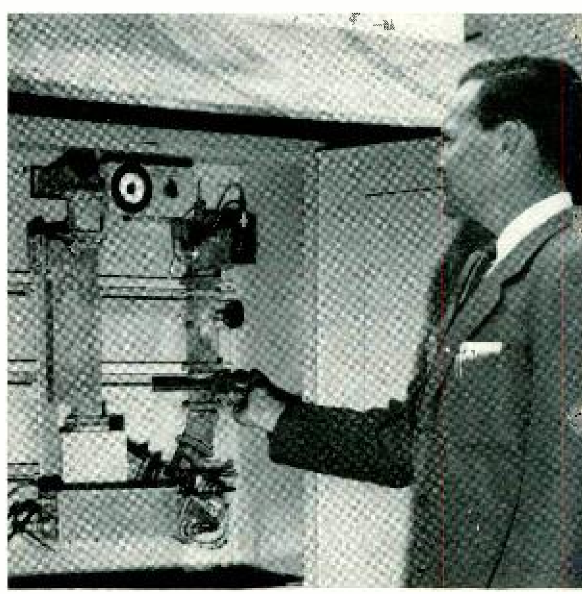
"As presently equipped for telephony, the coaxial cable handles television quite successfully and with little loss of detail. We recognize, however, that it does not go high enough in frequency at present to give the detail that will be demanded for television of the future. To meet that situation, we are hard at work pushing up the limit of frequency of the coaxial system. Now, a nice thing about the coaxial cable is that you don't have to change the cable to raise the limit of frequency, but only to replace the amplifiers by new ones more closely spaced and capable of working at higher frequency. We now transmit up to about 3 megacycles and expect with new amplifiers to advance that limit to 7 megacycles or more. But there is no basic reason for stopping there if ultimate demands go higher."

Passing to the third form of transmission—radio—Dr. Buckley said that the means now under development for radio would meet the needs of television; such a system between the Laboratories buildings at West Street and Murray Hill was included in a television path which terminated at the Convention.

Concluding, Dr. Buckley showed his audience specimens of two electron tubes designed in the Laboratories—the velocity-modulated tube and the traveling-wave tube.

Accepting his award on behalf of the American Telephone and Telegraph Company, Mr. McHugh recalled the Bell System's pioneer work in television, and told of the coaxial cable program, which will put twelve to thirteen thousand miles into service by 1950. Next year it is expected that the New York-Boston radio relay link will be ready for trial and comparison with coaxial cable as to quality of transmission, flexibility, reliability and costs. Work is also being done on short links for local pick-ups, using both radio and wire facilities. After noting that in the development of this new art, technical and financial risks must be taken by

On the roof of the Waldorf-Astoria, G. W. Atkins adjusts the TE-1 radio receiver



broadcasters, motion picture people, and set makers, Mr. McHugh concluded:

"Our own risks in the comprehensive program to obtain split-second projection of television signals from one part of the country to another are not inconsequential. There are hazards of technical quality; there are hazards of production; hazards concerning frequency assignments; there are the usual hazards of intense competition in a new art which may be changed suddenly and violently over night by some unexpected invention or development; and, of course, there are the hazards of the loss of large sums of money.

"And what faith prompts the challenging and the risking of these hazards? That faith is simple. Its roots are deep in the belief that the American people will be as eager to have education, information and entertainment brought to their homes to see as they were keen to hear.

"Nowhere but in America could a project of this magnitude be undertaken with the zest and zeal and push essential to its early and successful completion. Just as our form of government has permitted free men to span this continent by rail and by air, to perfect a communications system which permits connection with the wide world, so too America encourages free men to risk their capital and their reputations in projecting sight to distant places. A great building, a bridge, a tremendous dam are magnificent works; but they are built best and lift the spirit highest when they represent the fruit of free men's dreams and of their vision and courage in making these dreams come true. We are proud and grateful that we have this heritage, and that our countrymen have the good sense to fight to preserve this right to take a chance.

"We in the Bell System thank you again for this high honor you have bestowed upon us tonight. We want to continue to work closely with you, and to fit our plans into your plans. We have faith in the work you are doing and in the goal you have set for yourselves."

To demonstrate the present and proposed forms of television transmission, an elaborate series of circuits was terminated at the exhibit held at the Waldorf-Astoria. Programs originated at the NBC studios, the Dumont studios, the convention itself, or the Balaban and Katz portable equipment in Washington were brought together at the Long Lines building. Thence any one of them was applied to a TE-1 radio link and transmitted to a receiver on the Waldorf-Astoria roof, where it was demodulated and transmitted to a number of television receivers in the A T & T exhibit. In charge of the radio transmission was J. F. Wentz, with K. D. Smith, G. R. Frantz, J. B. Maggio, G. W. Strodt, W. A. Blicken and W. E. Norris as engineers and operators.

In another demonstration, the television signal was sent by video coaxial from Long Lines to our West Street building, whence it was transmitted four times over the New York-Murray Hill radio link. The signal then returned by coaxial to Long Lines and thence by TE-1 radio to the Waldorf. G. N. Thayer was in charge of this project, and he was assisted by A. A. Roetken, F. E. Radcliffe, F. F. Merriam, R. L. Kaylor, W. W. Tuthill and J. H. Durett.

At the Television Broadcasters' Convention, J. F. Wentz, Ralph Bown, A. B. Clark and J. R. Wilson inspect a coaxial cable repeater

WEAF Becomes WNBC

Change of the call letters of the National Broadcasting Company's New York key station to WNBC brings up memories to many of the old-timers at West Street, for the former call letters, WEAF, were originally issued to a station on our roof-top here. To start at the beginning, an experimental station was licensed here in October, 1919, with call letters 2XB. Its "studio" was in Room 1109 and its 100-watt transmitter was in Room 1108. Later the transmitter was changed to a 500-watt outfit. In June, 1922, this station received a broadcasting license with call letters WEAF. About the same time A T & T erected a station atop its Long Lines building and began broadcasting from it in July under the call letters WBAY. Coverage of the area, however, was unsatisfactory and in August the broadcasting was shifted to WEAF at West Street. When the Laboratories developed the 5,000-watt transmitter it was set up in Room 1107.

In 1926, A T & T sold the station to the National Broadcasting Company which operated the West Street transmitter until the completion of a new station at Bellmore, N. Y.

WEAF served as a valuable proving ground for the telephone company's study of radio techniques. And it was the telephone company, through its operation of WEAF, which pioneered the American method of supporting the expense of broadcasting service by selling time on the air to advertisers.

Twenty years have passed since the A T & T ended its own experiments in radio broadcasting, but its services to the broadcasting industry have grown steadily. Not only do telephone lines connect studios with transmitters, but 135,000 miles of them also link stations with other stations, thus making radio networks possible; and Western Electric studio and transmitter equipment, developed by Bell Telephone Laboratories, is used in some of the country's best stations.

Harvey Fletcher (right) receives, on behalf of the Laboratories, from D. E. Hyndman, President of the S. M. P. E., its Scroll of Achievement

Laboratories Honored for Work on Sound Pictures

At the recent convention of the Society of Motion Picture Engineers in Hollywood, the Laboratories was presented with its Scroll of Achievement for the part played in providing motion picture sound equipment. In the presentation to Harvey Fletcher, who represented the Laboratories, President D. E. Hyndman of the Society read from the Scroll as follows:

Society of Motion Picture Engineers' Scroll of Achievement presented to Bell Telephone Laboratories, Inc., in recognition of

Their fundamental research in the art of communication, from which came the development of sound recording and reproducing equipment;

Their development of methods of high quality recording on both disk and film;

Their design of equipment that made possible the first commercially successful sound pictures.

This Scroll of Achievement is presented by the Society of Motion Picture Engineers in this Twentieth Year of the successful introduction of sound motion pictures.

E. B. Craft on Honor Roll of S. M. P. E.

At the Sixty-First Convention of the Society of Motion Picture Engineers, held at Hollywood in October, it was announced that the names of Theodore M. Case, Edward B. Craft and Samuel L. Warner had been placed on the Honor Roll of the Society. This action was taken in recognition of the part these men had played in the work which led up to the production of a practical system of talking motion pictures.

During most of the period when this work was going on, Mr. Craft was Chief Engineer of the Western Electric Company and under his leadership a program of development was carried out which produced the public address system, radio broadcasting, and the electrical recording which resulted in the revival of the phonograph industry and the successful presentation of talkies. When the talking picture system was offered to the motion picture industry as an accomplished fact in 1925, Bell Laboratories were in being with Mr. Craft as Executive Vice President.

The electrical recording development was very much of a personal achievement for him and its success was due in large measure to his enthusiasm and tireless effort. When he died in 1928 the future of electrical recording in the motion picture industry was assured.

William Shockley Awarded Medal for Merit

The Medal for Merit, highest civilian award, has been conferred on William Shockley, of Physical Research. Presentation was made in Washington on October 17 by Secretary of War Patterson. The citation, signed by President Truman, follows:

To Dr. William Shockley, for exceptionally meritorious conduct in the performance of outstanding services to the United States since January 1, 1944. Dr. Shockley, as expert consultant in the Office of the Secretary of War, displayed great initiative, foresight, and ability of the highest order in advising the Army Air Forces on training and operational techniques in the Very Heavy Bombardment program in the China, Burma and India Theater of Operations, and in developing training facilities and methods for the improvement of radar bombardment. He served with distinction, exhibiting great tact and vision in initiating and perfecting operational policies and techniques which greatly improved the effectiveness of the Twentieth Air Force. Through his unusual analytical facility and wide scientific experience, he made an outstanding contribution in the field of specialized operational research and analysis of broad military problems. By his tireless efforts, initiative and skillful application of scientific techniques to the problems confronting the Army Air Forces, he made an exceptional contribution to the war effort.

Mobile Telephones Help Meet Emergency in Pennsylvania Fire

The marvel of telephoning from a moving vehicle is expected to become a boon to American business. And while it is intended primarily for everyday use, it is flexible enough to serve in an emergency. This was demonstrated at the recent fire at the Sun Oil Company's Marcus Hook plant near Philadelphia.

An explosion which rocked the huge fractionating tower at that company's newest aviation gasoline cracking plant claimed the lives of nine persons and seriously burned 200 others. Searing flame from the burning structure was splashed over workmen and volunteer firemen who were fighting the blaze.

William Kelman, a Bell of Pennsylvania PBX repairman from the Chester office, hurried to the scene in a telephone-equipped company truck to be ready to clear any trouble which might affect telephone lines or equipment and to do everything possible to provide telephone service in the emergency.

Upon arrival he found local telephone service disrupted. He immediately made the mobile telephone available to Sun officials for emergency calls to hospitals and physicians, to summon additional aid and to direct rescue operations. Later, another car arrived and the two were stationed at the main gate.

William Shockley (right), awarded the Medal for Merit, is congratulated by Secretary of War Patterson

While Theodore Hartman, splicer, and his helper, George Rieder, made hurried repairs to a damaged cable, firemen, doctors, police and Red Cross representatives were given access to the mobile telephones for any emergency calls they wished to place.

E. C. Molina on Newark College Faculty

E. C. Molina, who retired from the Laboratories in 1942 after 42 years of service, has been named special lecturer in the mathematics department of Newark College of Engineering. In announcing the special services of Mr. Molina, College President Dr. A. R. Cullimore acknowledged the college's gratitude "to this distinguished gentleman of science for coming out of retirement to assist us in the task of training technicians who are so vitally needed by the nation's industry."

George K. Thompson Dies

George K. Thompson, who retired in 1930 from the former Department of Development and Research of the American Telephone and Telegraph Company after 48 years of service, died on September 22. In 1882, Mr. Thompson started to work with the Bell System in an attic room adjoining the one at 109 Court Street, Boston, in which Professor Bell and Dr. Watson carried out their first successful experiment in June 1875. While in Boston he was in charge, for a time, of the Section of the American Telephone and Telegraph Company's Engineering Department devoted to the development of instruments and station equipment. In 1907 he was transferred to New York City with the Engineering Department, and in 1919 became a member of the Department of Development and Research. In both of these assignments he continued in charge of work on instruments and stations.

Microwave relay station on Crows Nest Mountain at West Point used in the first two-link radio television system operated commercially by the Bell System. Three of Army's home games were televised by the NBC and broadcast from New York City

In addition to his more strictly engineering work, Mr. Thompson supervised many of the telephone company's World's Fair and other exhibits. He also set up a permanent communications exhibit at the New York Museum of Science and Industry in 1929 and 1930. After his retirement he continued to be associated with the Museum in the capacity of Acting Director and supervised the Museum's moving from 42nd Street to Rockefeller Center.

Graybar Sales Conference

During the convention of the Graybar Managers of Broadcasting Equipment Sales held in New York from October 15 to 17, members of the sales conference visited the Murray Hill and Whippany laboratories. A demonstration of the newly developed loud-speaker system for auditoriums was given at Arnold Auditorium, at which time W. C. Jones spoke on *Highlights of Acoustical Instrument Development* and L. Vieth discussed and demonstrated *High-Power Loud-Speakers for Auditorium and Outdoor Use.* The group took a short trip through the Murray Hill building, which included a visit to the loud-speaker testing area, where H. F. Hopkins spoke on *Loud-Speakers for Moderate Power Applications,* and a visit to the telephone transmitter laboratory, where W. L. Tuffnell spoke on *Some Interesting Aspects of Telephone Instrument Development.*

Following luncheon, the group inspected at Whippany the clover-leaf antenna for FM broadcasting with J. F. Morrison, who later spoke on *FM Antennas.* They also heard J. B. Bishop speak on *FM Broadcast* and W. H. Doherty on *AM Transmitters.*

Civic Responsibilities

Laboratories personnel have habitually taken an active, and many times a leading, part in the civic affairs of the community in which they live. This spirit is presently typified by the many Laboratories men who are participating in the work of the Boy Scouts of America. Among those who are serving in the Summit district in different capacities are:

C. F. Benner, Vice-Chairman of District; R. L. Hanson, District Commissioner; C. J. Frosch, District Chairman Leadership and Training; A. H. Hearn, Neighborhood Commissioner; P. J. Reiling, Neighborhood Commissioner; L. W. Stengel, Neighborhood Commissioner; P. J. Kreider, Scoutmaster, Troop 62; E. T. Sheldon, Scoutmaster, Troop 63; and S. O. Morgan, Vice-Chairman, District Advancement Committee. Also serving in other capacities are G. Bittrich, W. E. Campbell, J. S. Edwards, N. J. Eick, C. G. Erb, R. R.

R. L. Jones presents the Pioneer Certificate to George Rupp at a testimonial retirement dinner held in his honor at the King Arthur Grille Room of London Terrace

Kreisel, W. C. Kleinfelder, G. G. Lovery, V. L. Lunhahl, H. E. Mendenhall, G. E. Sawyer, J. H. Scaff, G. A. Teal and L. A. Wooten.

Organization Changes in General Accounting

George B. Small, formerly auditor of disbursements in the General Accounting Department, is now assistant comptroller reporting to A. O. Jehle, comptroller. Mr. Small's staff comprises A. T. McNeill, statistical accountant, and W. E. Marousek, chief auditor.

A. J. Daly is chief accountant, reporting to Mr. Jehle. His staff comprises L. S. Armstrong, cost accountant; H. M. Gessner, plant accountant; J. W. Stoner, tabulating accountant; M. A. Basedow, corporate accountant.

C. W. F. Hahner, formerly contract settlements manager, is now auditor of disbursements. His staff comprises F. W. Seibel, payroll accountant; T. J. Murtha, voucher accountant.

Doll and Toy Committees

Three separate Doll and Toy Committees functioned at the Laboratories to prepare Christmas gifts for sick and needy children in their respective localities. Ida Wiberg headed the New York group, arranging to have displays set up on November 19 and 20 in the West Street Auditorium, and in the Graybar and Davis buildings. Among those who worked on the committee at West Street were Ruth Leonard, Parnel Bray, Molly Radtke, Mildred Ralph, Mary Pavlic and Gloria Yurman.

At Murray Hill, Grace Murphy as chairman of the committee was assisted by Lois Burford, secretary. Joan Thomas was chairman at Whippany, Elizabeth Jentzen, treasurer, and Helen Benz, secretary.

Murray Hill Carolling

The Murray Hill Chorus of the Bell Laboratories Club, which presented a short musical program for the Summit United Fund Campaign Rally at the Summit High School on October 18, is now rehearsing a program of the traditional and contemporary Christmas music of many lands. The program and carol singing with audience participation will be held in the Arnold Auditorium as in previous years, during the noon hour on December 23.

News Notes

Chester I. Barnard, president of the New Jersey Bell Telephone Company, addressed the Executives' Conference of the Laboratories on November 14. He told of the work on the report on the control of atomic energy developed by the Lilienthal Committee of which he was a member. A sound film showing the atomic bomb tests at Bikini was shown by J. H. Waddell.

M. J. Kelly, Chairman of the Research Committee of the Navy Industrial Association, visited Bethesda Naval Medical Research Institute on October 4. Dr. Kelly addressed the quarterly Navy Industrial Association luncheon group on October 24 at the Army-Navy Club in Washington. He spoke on *Contributions of Industrial Research to the Military Research Program in the Post-War Period.*

D. A. Quarles attended a meeting of the Committee on Electronics of the Joint Research and Development Board in Washington.

T. E. Shea, a former member of the Laboratories, is now Assistant Engineer of Manufacture of Western Electric at 195 Broadway.

H. A. Etheridge is giving a course in Electronic Systems at Brooklyn Polytechnic Institute.

At the retirement luncheon given in his honor, Martin White offers a toast which G. B. Thomas, William Fondiller and S. H. Willard enjoy

J. E. RANGES

F. T. DEPUTY

American Legion Post Installs Officers

Western Electric Post 497, American Legion, composed almost entirely of Bell System employees in the metropolitan New York area, installed its new officers at a dinner held on October 22 at the George Washington Hotel. Twenty-two of its twenty-six past commanders swelled the attendance of Legionnaires to more than 125.

New York County Commander Daniel P. Dunn was introduced by Commander J. E. Ranges and installed the following new officers: F. T. Deputy, Commander, H. Bongard, First Vice-Commander, and R. V. Fingerhut, Second Vice-Commander, all from Western Electric; E. C. Hagemann, Third Vice-Commander, L. B. Eames, Finance Officer, N. C. Brower, Assistant Adjutant, J. N. Marko, Sergeant-at-Arms, all from Bell Laboratories; and R. C. Kenney, Adjutant, E. N. Emmons, Service Officer, J. J. Morrow, Chaplain, Western Electric. Following the installation ceremonies, Commander Deputy introduced Morton Sultzer as the toastmaster for the evening's entertainment program. County Commander Dunn spoke briefly on the purpose and aims of the American Legion. Past National Commander of the 40 and 8, George Dobson, spoke on his impression of the recent national American Legion Convention at San Francisco. Past Commander Fred Given presented the past commander's medal to the retiring commander, J. E. Ranges. George F. Haas narrated his experiences in a German prison camp and told of his several unsuccessful attempts at escape before he finally broke loose. Captain Michael J. Brennan spoke on the American Plan for Veterans. Interspersed with the talks were popular musical numbers presented by the Red Jackets Trio and Marion Carter, soloist.

News Notes

J. B. HAYS and T. C. HENNEBERGER investigated problems in New Castle, Pa., concerned with the restoration of telephone service after toll-cable failure in that vicinity.

J. B. DIXON, with representatives of the Western Electric Company, discussed supplies of wire products and line wire with the National Telephone Supply Company at Cleveland, Ohio, and the Wheeling Steel Company at Portsmouth, Ohio.

D. T. SHARPE visited Fredonia, N. Y., in connection with the installation of lightning protection at splice points in the Buffalo-Erie coaxial cable route.

AS THE LABORATORIES' representative on the Wire Inspection Committee of the A.S.T.M., A. P. JAHN inspected galvanized wire specimens undergoing atmospheric corrosion tests at test plots in Bridgeport, Sandy Hook, Altoona and State College.

R. M. C. GREENIDGE and H. D. BREINER have returned from Texas and New Mexico where they were engaged in testing the lightning protection features of the coaxial cable being installed on the southern Transcontinental Route.

K. BULLINGTON spoke on *The Effect of the Earth on Radio Waves* on October 29 before the Brooklyn Institute of Arts and Sciences.

Cover Girl

Cover girl of this issue of the RECORD is Nellie Schofield, who has worked on the Laboratories Doll and Toy Committee since its inception seven years ago to help provide toys and dolls for underprivileged and sick children at Christmas time. Now secretary to J. R. Wilson, Miss Schofield came up through the ranks from the Transcription Department after graduating from Packard Business School. She had also been a stenographer in Research and a secretary in Building T.

C. H. Amadon has established permanent quarters at Denver to facilitate the Laboratories' investigations on the production and preservative treatment of western pole and crossarm timbers for telephone use.

A. H. Hearn recently conducted experimental treatments at Orrville, Ohio, of Douglas fir poles, aimed at the control of bleeding.

R. H. Colley continued development of non-pressure and pressure treatment processes for miscellaneous pole timbers at Minneapolis, and made arrangements for initial treatment by both processes of western hemlock crossarms. He also coöperated with the Forest Products Laboratory at Madison, Wisconsin, on working plans for comparative laboratory tests of modern wood preservatives.

R. G. Koontz, W. A. Bischoff and C. R. McIver discussed drafting standards at the Hawthorne plant of Western Electric.

R. G. Koontz, A. D. Knowlton, A. A. Oswald and N. F. Schlaack visited Winston-Salem on radio and power-line carrier equipment matters.

W. L. Heard has been appointed to serve as Technical Observer to the United States National Committee of the International Electrotechnical Commission.

W. H. Bendernagel supervised the installation at Altoona, Pa., of new filters for the K2 carrier system between New York and St. Louis.

E. T. Ball and J. E. Greene were at Jamestown, N. Y., to discuss framework problems with the Dahlstrom Metal Company.

F. W. Treptow visited the Teletype Corporation in Chicago, Ill., regarding new printer equipment.

H. H. Spencer witnessed stability tests at Dallas on the Dallas-Fort Worth "L" carrier.

V. T. Callahan discussed mobile radio sets at the Kohler Company in Sheboygan, Wisconsin; post-war diesel engine sets at the General Motors Corporation, Detroit; and "L" carrier automatic engine sets at the Duplex Truck Company, Lansing, Michigan.

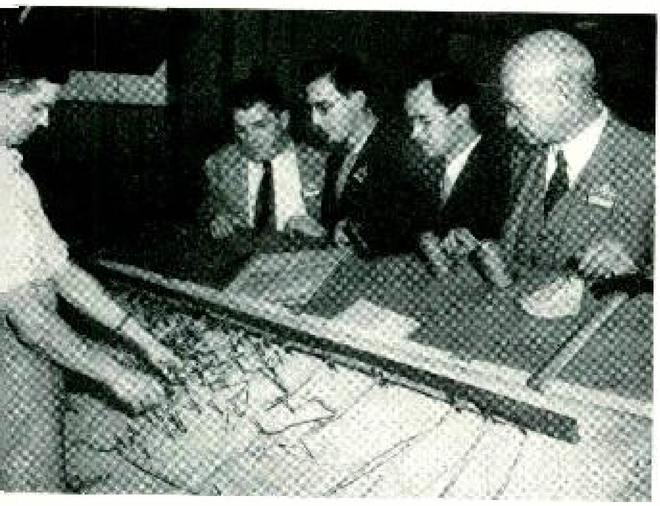
F. F. Siebert witnessed the operation of charging motor-generator sets at the Hertner Electric Company in Cleveland.

C. A. Smith conferred on MI carrier problems with engineers of the Western Electric Company at Winston-Salem.

Harvey Fletcher demonstrated the Tone Synthesizer and spoke before The Franklin Institute in Philadelphia on *The Pitch Loudness and Quality of Musical Tones.* At Hollywood he attended a stereophonic demonstration at the studios of 20th Century-Fox, jointly sponsored by the Motion Picture and the E.R.P.I. divisions of the Western Electric Company.

R. W. Hull, C. Herring and J. A. Burton attended the Luminescence Conference at Cornell University, sponsored by the Division of Electron and Ion Optics of the American Physical Society.

W. A. Yager attended the meeting of the Electrochemical Society in Toronto where a symposium on *Dielectrics* was held.



Members of the Bell System Editors' Conference on an inspection trip to the Kearny plant of the Western Electrip Company. Watching the forming of a local telephone cable are, left to right, J. W. Curtis, Ohio Bell; H. P. Forman, New York Telephone; D. F. J. Jones, A T & T; and P. B. Findley of the Laboratories.

On October 29 the conference visited Murray Hill, where they were welcomed by R. K. Honaman.

C. H. TOWNES presented a paper on *Microwave Absorption in Gases* before the New England Section meeting of the American Physical Society at New Haven.

J. R. HAYNES presented a paper on *The Motion of Electrons in Silver Halide Crystals* before a Conference on Luminescence at Cornell.

J. W. EMLING visited Aiken, South Carolina, in connection with one of the early field applications of the rural power line carrier system.

R. M. BURNS, U. B. THOMAS, JR., M. SPARKS and K. G. COMPTON attended the fall meetings of the Electrochemical Society held in Toronto.

R. A. CHEGWIDDEN discussed problems at Hawthorne related to the heat treatment of magnetic materials.

D. H. WENNY visited Hawthorne for discussion of metallurgical problems.

A. R. KEMP, F. S. MALM and V. T. WALLDER conferred on polyethylene for coaxial cable at the National Plastics Products Company and at Western Electric, Point Breeze. Mr. Wallder also witnessed tests of nylon-jacketed duct wire at the duPont Plastics Department.

J. B. DE COSTE prepared experimental polyethylene cables at Kearny.

H. PETERS discussed problems dealing with sponge rubber ear pieces at the H. H. Buggie plant in Toledo, Ohio, and hard rubber problems with engineers at Hawthorne. While in Chicago, he also attended the American Chemical Society meeting.

R. D. HEIDENREICH spoke on *Electron Microscope and Diffraction Investigation of Metallic Surfaces* at the New York meeting of the Microscopical Society.

E. K. JAYCOX presented a paper entitled *Spectro-chemical Analysis of Nickel Alloys* before the Optical Society of America meeting which was held in New York.

C. L. LUKE presented a paper *Photometric Chemical Analysis* before the Society for Applied Spectroscopy at a meeting held in New York City.

U. B. THOMAS, JR., and M. SPARKS visited the research laboratories of the National Battery Company at Depew, N. Y.

V. J. ALBANO presented a paper *Protective Coatings on Bell System Underground Cables* before the Northeast Regional Division of the National Association of Corrosion Engineers.

K. G. COMPTON has been elected chairman of the 1947 Corrosion Conferences sponsored by the American Association for the Advancement of Sciences. As chairman he has the responsibility of arranging programs and he is now arranging for the 1947 Corrosion Conference.

W. O. BAKER spoke on *Cohesion, Adhesion and Structure of Polymers* before Committee D-14 and others at the American Society for Testing Materials meeting in Atlantic City.

RECENT speakers at Deal-Holmdel Colloquiums were W. H. DOHERTY who selected for his topic *Some Recent Developments in FM* and R. A. Heising whose topic was *Patents.*

C. A. Lovell and P. S. Darnell discussed techniques employed in producing printed electronic circuits at the National Bureau of Standards in Washington.

M. C. Woolley witnessed the commercial trial of the 439A condenser at Hawthorne.

J. M. Barstow presented a paper on *Rural Power Line Carrier Telephony* before the Virginia Independent Telephone Association in Richmond, Va.

G. J. F. Tyne was at Winston-Salem in connection with the manufacture of coils for the rural power-line carrier system.

Engagements

Edward O. Grant—*Dorothy Philhower
*John Leighton—*Anne Gwozdz
Maurice J. Shanahan—*Justine Kelly
Earl M. Snellings—*Edna Gerber
Alex Zelkovsky—Madeleine Ryfkogel

Weddings

Edward Breitbach, Jr.—*Helen Murphy
Walter Chambers—*Virginia Davis
Robert Cully, U.S.C.G.—*Edna Fyhr
Albert H. Ferraris—*Marie Piano
Seymour Neuman—*Evelyn Zamichow
Edward Schou—*Lillian McNeill

*Members of the Laboratories. Notices of engagements and weddings should be given to Mrs. Helen McLoughlin, Room 803C, 14th St., Extension 296.

J. A. Ashworth and A. B. Haines attended a conference at Haverhill on magnetic materials and other matters in connection with the manufacture of transformers.

E. A. Potter attended a meeting in Chicago of the R.M.A. sub-committee on transformers and reactors for radio transformers.

A. R. D'Heedene, W. E. Kahl, S. Bobis and S. G. Hale conferred at Winston-Salem on the new carrier telephone system used in power-line circuits.

G. H. Lovell witnessed trial installation at Indianapolis and Dayton of filters using synthetic crystal units.

J. P. Messana and W. F. Janssen discussed ceramic terminals with the Stupakoff Ceramic and Manufacturing Company in Latrobe, Pa.

B. S. Woodmansee, F. R. Bies and W. J. Carroll conferred with engineers of the Air Matériel Command at Wright Field on the development for the Air Forces of low-frequency crystal units and associated test oscillators.

D. R. Brobst discussed switchboard cable coverings at Hawthorne, and distributing-frame wire problems at Point Breeze and at the United States Rubber Company, Bristol, R. I.

J. H. Bower attended a meeting of the Electrochemical Society in Toronto and, with C. A. Webber, conferred on special battery problems at the National Battery Company, Depew, N. Y.

C. A. Webber and H. H. Staebner studied cord manufacturing problems at Point Breeze.

W. L. Casper, R. A. Sykes and G. M. Thurston discussed crystal units at the Franklin Street Shop of Western Electric at Allentown. Mr. Thurston was also in Allentown with J. F. Barry and D. M. Ruggles to advise on the manufacture of crystals.

R. A. Sykes and F. B. Monell attended the National Electronics Conference in Chicago.

D. H. Gleason and V. F. Bohman visited the Western Electric Hawthorne and Lincoln plants regarding step-by-step apparatus.

H. B. Brown discussed selectors and other panel dial apparatus at Hawthorne.

F. W. Clayden inspected the trial of No. 1 metal-tipped wipers at the Albany step-by-step office of the New York Telephone Company.

W. J. Leveridge checked special pumping equipment made for the Laboratories at the Distillation Products Company in Rochester.

Fifty associates honored John (Jack) Bane on his retirement in an unusual luncheon party held in the firing line of the boiler plant at West Street, where Mr. Bane had been a prominent figure for 34 years

Virginia McCollum checks the sights on K. L. Warthman's camera while he discusses picture problems with Nancy Cristoluolo and Jane Conlon of the Laboratories and a visitor to the Camera Club's photographic field day held on October 12 *at Murray Hill and the nearby Watchung Reservation*

J. H. WADDELL spoke on *The Photography of the Atom Bomb* and showed the A-Bomb motion picture, the Fastax and the A-Bomb, and series of cloud stills, all in color, at the West Street Auditorium and in the Arnold Auditorium in Murray Hill.

R. H. NICHOLS, JR., presented a paper on *The Modern Hearing Aid* at the Eastern Zone Conference of the American Hearing Society which was held at Providence.

F. F. ROMANOW and H. F. HOPKINS attended a meeting in Atlantic City of the coördinating committee of the Sound Equipment Section of the Radio Manufacturers' Association to review sound system enginering problems.

M. S. HAWLEY assisted in the assembly of condenser transmitters at Burlington.

H. F. HOPKINS, H. W. HOLMLIN and H. L. LUNDBERG were responsible for setting up the equipment for the demonstration at the convention of Graybar Managers of Broadcasting Equipment Sales in New York.

M. H. COOK, R. E. POOLE, E. L. NELSON and W. H. DOHERTY attended the Graybar-Western Electric conference in New York.

O. M. GLUNT and R. A. DELLER represented the Laboratories at the Navy Industrial Forum in New York.

J. F. MORRISON attended the National Electronic Conference in Chicago.

LABORATORIES MEN who attended the Television Broadcasters' Association convention in New York included M. H. COOK, R. E. POOLE, W. H. DOHERTY, J. F. MORRISON, W. L. COWPERTHWAIT, D. R. FRANTZ, T. C. ONG, B. H. KLYCE and C. A. WARREN.

E. D. PRESCOTT inspected broadcasting equipment during a trip to the Dahlstrom Metallic Company, Jamestown, N. Y.

W. E. REICHLE, Chairman of the R.M.A. Subcommittee on Selective Calling Standards, attended a meeting of the Committee on October 29 in New York.

W. C. HUNTER attended a demonstration before Provisional International Civil Aviation Organization at Indianapolis.

A. E. HARRISON went to Winston-Salem regarding the design of fixed station radio transmitters for the A T & T mobile telephone system.

H. VADERSEN, at Winston-Salem, discussed indicators for a Navy project.

December Service Anniversaries of Members of the Laboratories

45 *years*
E. F. Hill

40 *years*
J. A. Hall
J. F. Lewis

35 *years*
Fred Haese
G. J. Seltzer

30 *years*
A. C. Goebel
Matilda Goertz
A. H. Heitmann
M. C. Kastner
J. B. Shiel

25 *years*
H. H. Felder
P. P. Kashtelian
W. G. Laskey
Veronica Salis

20 *years*
L. E. Cheesman
M. T. Dow
C. E. Fisher
A. L. Jones
L. G. Kersta
Florence McGuire
W. R. O'Neill
E. A. Potter
W. G. Smith
W. B. Vollmer

10 *years*
D. S. Barlow
V. G. Chirba
J. F. Clifford
J. M. Hanley
Joseph Hill
A. A. Houlihan
H. K. Meyer
J. J. Sabin
G. O. Voigt

D. K. MARTIN of the Laboratories and F. C. McMullen of the Western Electric Company have returned from England where they were industrial observers to the demonstration that was sponsored by the British Government of the Provisional International Civil Aviation Organization. They witnessed demonstrations of radio facilities at the Telecommunications Research Establishment at Great Malvern, at the RAF Transport Command Headquarters at Basingborne and at the Royal Aircraft Establishment at Farnborough, which might have application on international airways and terminal airports. Upon returning to this country, they observed a similar P.I.C.A.O. demonstration at Indianapolis under the auspices of the Civil Aeronautics Administration. Following the demonstration, delegates to P.I.C.A.O. from the forty nations represented met in Montreal to consider the choice of facilities to be recommended for use on international airways.

E. F. KROMMER visited the DeLuxe Metal Furniture Company in Warren, Pa.

W. L. FILMER conferred in Burlington on the design of fixed station radio receivers for the A T & T mobile radio-telephone system.

A. C. PEYMAN conferred recently at Burlington with Western Electric engineers.

N. C. OLMSTEAD visited the Amertran Company to follow their orders on the Laboratories.

P. H. SMITH and B. O. BROWNE inspected equipment being manufactured at the Blaw-Knox Company, Pittsburgh.

W. H. DOHERTY, J. F. MORRISON, J. B. BISHOP, A. K. BOHREN and P. H. SMITH were in Chicago for the National Association of Broadcasters' convention.

J. D. SARROS and T. E. LENIGAN witnessed test runs of Laboratories equipment at Norfolk.

"The Telephone Hour"

NBC, Monday Nights, 9:00 p.m.

December 9	*Jeanne Rosenblum, Anahid Ajemian and Leonid Hambro*
December 16	*Fritz Kreisler*
December 23	*Helen Traubel, Appollo Boys' Choir and Male Chorus*
December 30	*Lily Pons*
January 6	*Marian Anderson*

Restyling the Record

When the RECORD was first published in September, 1925, it appeared with a cover symbolic of telephone transmission, designed by Thomas M. Cleland. The cover was changed in September, 1937, to show a wave-motion motif, designed by Gustav Jensen, in which vertical lines represented a compressional wave train. Since August, 1943, a photographic cover has been used. During this twenty-year period there had been no radical change in the make-up of the interior of the magazine except the adoption of the photographic "bleed" technic in May, 1945.

The November 1946 issue, however, is the result of a restyling of the entire magazine by Frank Vitullo, Art Director of Bertell, Inc., who will continue to be responsible for the magazine's physical appearance. Mr. Vitullo is a graduate of the art school of Pratt Institute. For four years before joining Bertell last spring, he had been Assistant Director of Publications and Exhibitions at the Museum of Modern Art in New York City.

Safety in the Home

Based on an analysis of 1,000 home safety questionnaires brought in by school pupils in Queens and the Bronx, the Greater New York Safety Council calls attention to some common "booby traps" in homes. In one Queens neighborhood, for example, the hazard of falling associated with bathing facilities was the most frequently reported. In about one-fourth of the homes the tub and shower were not provided with secure hand holds and with non-skid mats. In a Bronx neighborhood, on the other hand, carrying loads so big that persons bearing them could not see where they were going was the most common unsafe situation recognized. Members of one-fourth of the families who returned questionnaires to one Bronx school reported that they had subjected themselves to this particular hazard.

Walking about the home was fraught with danger in a particularly large number of Queens homes because small rugs were not tacked down or skid-proof, and stair carpeting was not secured. A large proportion of the parents whose children attended a Queens school did not carefully wrap and label used razor blades, broken glass, china, etc., before discarding them.

One of the leading hazards in the Bronx school area included in the sampling was smoking in bed. In both the Bronx and Queens homes, the use and storage of naphtha, benzene, gasoline and other flammables was a relatively common, though dangerous, practice.

W. C. TINUS, W. H. C. HIGGINS and S. J. STOCKFLETH conferred with Warner-Swasey engineers in Cleveland.

R. A. CUSHMAN, H. T. BUDENBOM and L. H. KELLOGG visited the Army Proving Ground at White Sands, New Mexico.

S. B. KENT was at the Patent Office in Washington during October relative to patent matters.

MEMBERS OF THE Laboratories serving as officers or committee members of the American Institute of Electrical Engineers for the year 1946-1947 include: O. E. BUCKLEY, *Vice-President;* D. A. QUARLES, *Board of Directors;* O. E. BUCKLEY, *Executive Committee;* H. M. TRUEBLOOD, *Board of Examiners;* R. L. JONES, *Constitution and By-Laws;* O. E. BUCKLEY and D. A. QUARLES, *Edison Medal;* D. A. QUARLES, Chairman, and O. E. BUCKLEY, *Finance;* D. A. QUARLES, *Headquarters;* E. H. COLPITTS (retired), *Members-for-Life Fund;* E. G. D. PATTERSON, *Membership;* R. L. JONES, D. A. QUARLES, *Planning and Coördination;* R. K. HONAMAN, *Publication;* R. K. HONAMAN, Chairman, *Institute Publicity;* R. L. JONES, Chairman, *Standards;* O. E. BUCKLEY, *Technical Program;* J. D. TEBO, Chairman, and O. E. BUCKLEY, *Basic Science;* H. A. AFFEL, and R. G. MCCURDY, *Communications;* G. B. THOMAS, *Education;* S. B. INGRAM and D. A. QUARLES, *Electronics;* E. I. GREEN, *Instruments and Measurements;* O. E. BUCKLEY, Chairman, *New York City Geographical District Executive Committee;* H. A. AFFEL, *Radio Technical Planning Board;* and H. M. TRUEBLOOD, *Power Transmission Distribution.*

A. J. CHRISTOPHER and J. A. KATER are authors of *Mica Capacitors for Carrier Telephone Systems* published in the October issue of *Electrical Engineering.*

IF YOU REMEMBER the front cover of the RECORD for last month you will recognize at once the "Bell Laboratories chemist" on the facing page. Just in case you didn't look for his name last month, he's W. G. GULDNER, and his "plumbing" is in 1012 at West Street.

R. I. WILKINSON'S *Short Survey of Japanese Radar—II,* appeared in the October *Electrical Engineering.*

R. H. WILSON is the author of an article entitled *Self-Service Stockrooms Reduce Operating Costs,* which appeared in *Barrons Weekly.*

Obituaries

WILLIAM H. MATTHIES, October 20

For many years, as Director of Switching Development, Mr. Matthies was responsible for Bell System circuit development. His many contributions in this field were recounted in the RECORD for May, 1943.

JOHN H. WHITE, October 30

Mr. White was in charge of the Metallurgical laboratory at Murray Hill until his retirement—RECORD, July, 1943—and was concerned with the development and production of magnetic materials and of other metals and alloys for a variety of purposes.

ADOLPH R. SWOBODA, October 20

During his many years of service, Mr. Swoboda was concerned with the development of coin collectors, coils and testing apparatus, and varistors and thermistors as described in the RECORD for September, 1945.

JAMES J. KAHN, November 8

Mr. Kahn, Seaman 2/c, on military leave of absence since last June, was killed in a traffic accident at the Patuxent River Naval Base in Maryland. He joined the Laboratories in July, 1945, where he was a messenger in the General Service Department.

W. H. MATTHIES
1879-1946

J. H. WHITE
1880-1946

A. R. SWOBODA
1880-1946

J. J. KAHN
1929-1946