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Organic Corrosion

B. S. BIGGS *Chemical Research*

The deterioration of rubbers, plastics, textiles, and surface coatings in service is a serious problem in industry, probably equal in dollar value to corrosion of metals. Particularly in the Bell System, where apparatus frequently is expected to last thirty or forty years, it is obviously essential that the causes and mechanisms of organic corrosion be understood. One or another aspect of such deterioration and methods of preventing or retarding it have been under study in the Laboratories for years. The result has been a constant general improvement in the life expectancy of organic compounds in systems applications.

In the search for materials that will give long, trouble-free life to apparatus, many designers, familiar with the easy rusting of some metals, turn to plastics or rubbers with the expectation that these organic compounds will be immune to corrosion. They discover that although such obvious chemical changes as rust on a "tin" can or the green film on copper cannot readily be detected as the early corrosion products of a plastic or a rubber, in their later stages of deterioration many plastics and rubbers are as irreparably damaged as some rusted metals.

One of the agents through which chemical deterioration of organic compounds is brought about is oxidation — reaction with the oxygen of the air. Because reaction with oxygen can be activated by both heat and light, the terms "thermal oxidation" and "photo-oxidation" are frequently used in describing it. Reactions indoors at room temperature are usually slow and ordinarily cause little trouble, but outdoor exposure is a severe condition, the ultraviolet component of sunlight being a very energetic initiator of chemical reaction — sunburn, for example.

The mechanism by which oxygen damages a plastic or rubber is still a research problem. Studies reveal that oxidation of organic substances is usually a free-radical chain reaction — a reaction of molecular fragments with oxygen in such a manner that new centers of attack are produced in chain-like fashion as decomposition progresses. Although many of the details are not yet known, the damage can be appraised in its general aspects.

Plastics, rubbers, and textiles are composed of large molecules, known as polymers or "many units," and their value as structural materials is dependent on this large size or high molecular weight. One of the principal effects of oxidation is to cut these large molecules into smaller pieces, thereby weakening the whole structure. Another effect may be to lower the value of a polymer as electrical insulation. A third may be to introduce more ties or "cross-links" than were originally present, thus impairing the flexibility and toughness afforded by a nice balance in the inter-molecular forces. Increasing greatly the number of cross-links tends to make the material glassier or more brittle, particularly when accompanied by a shortening of the average length of the molecules. Ultimately the material may

Fig. 1 — V. T. Wallder at an outdoor exposure plot examines part of the original sample of black polyethylene that has been exposed since 1941.

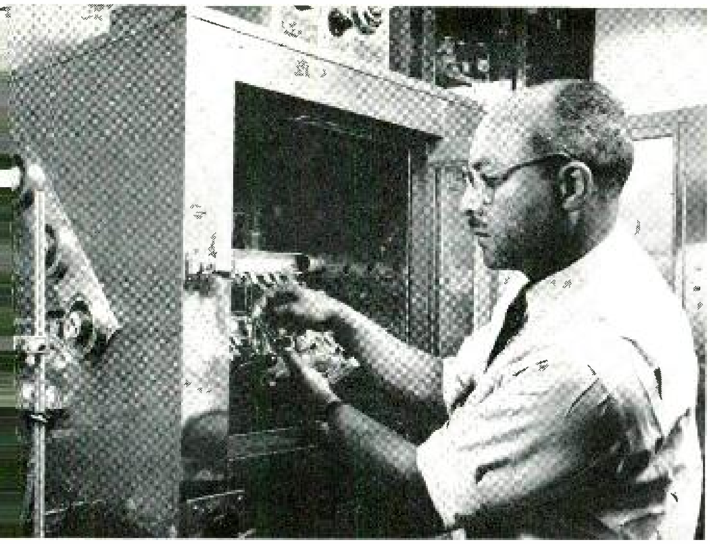
craze, or crack, and the surface may chalk away. Erosion of the surface of polymers outdoors occurs particularly in those materials which, at very low molecular weight, tend to be soluble in water — the cellulosics, for example.

Since weather damage may render the polymer unfit for service, the biggest problem in materials engineering of organics is to develop compounds which will maintain adequate properties for the desired length of time under service conditions. The safest course has been to recognize that changes are going to occur and to try to determine whether the rate of change will be low enough to permit the apparatus to have the required service life.

The only sure way of learning how a material will age outdoors is to expose it outdoors and wait. This is an excellent procedure for screening out those materials which deteriorate rapidly (and unfortunately many polymers fall in this category), but it is obviously impractical to wait the required number of years for the evaluation of compounds which are usefully resistant to outdoor exposure. It is only when a new material becomes available in experimental quantities years before it reaches commercial production or before it is needed in systems apparatus that a reassuringly long history of outdoor exposure can be obtained in time to be useful, and even then this information must be reinforced with results from accelerated tests. The story of black polyethylene is a good illustration. Polyethylene became available in limited quantities just before the war, and many compounds of it, including one containing carbon black, were exposed outdoors by W. J. Clarke of the Chemical Research Department. All samples failed within a year or two except the black one. By 1947, when polyethylene was available in quantity and when a substitute was needed for lead cable sheathing, six years of favorable outdoor experience had been obtained on the black compound. This fact, coupled with equally encouraging information from accelerated tests, made possible the immediate launching of the plastic sheath program. The original sample has now undergone favorably almost fourteen years of outdoor exposure, and thus has come to have truly historical significance for plastics engineers.

The experience with polyethylene makes it evident that there is great value in the early outdoor exposure of every new polymer which comes to hand, and the Laboratories has for years maintained in several locations outdoor exposure plots like the one shown in Figure 1. It is also evident, however, that outdoor weathering is too slow to be used as the sole guide for an application which requires long life. Once it has been determined that a certain type of material is potentially suitable for years of outdoor service, the refinements of compounding must be pushed rapidly. In this work accelerated laboratory tests are invaluable.

Ovens operated at elevated temperatures and sun lamps or carbon arcs are devices commonly used in accelerated aging. One of the ways this is done is



—ig. 2 — *Apparatus for volumetric measurement of ab-rbed oxygen. W. L. Hawkins adjusts some samples being easured as he checks the level of the gas in the burettes.*

shown in the illustration at the head of this article. With such apparatus it is sometimes possible to produce in a week or two in the laboratory a state of deterioration reached outdoors after a year or more. Changes are detected by very careful measurement of physical and electrical properties.

Another accelerated method which can be used in a laboratory is volumetric measurement of the oxygen absorbed. If the sample is maintained at an elevated temperature in a closed system which includes a gas burette, and the system is filled with oxygen, the consumption of the gas can be measured by the change in level in the burette. Figure 2 shows some samples being measured with the apparatus. This method is particularly useful for detecting the time of onset of rapid reaction which marks the beginning of the end, and which usually comes after a period of very slow reaction known as the "induction period." It has been known for many years that certain chemicals added to the polymer are capable of prolonging the induction period. These substances, called anti-oxidants, are "getters" or traps for free-radicals, and in effect interrupt the chain reaction in an early stage. Each molecule of anti-oxidant, in its sacrificial reaction with a free-radical, may thus save as many molecules of the substance being oxidized as would otherwise have been attacked in the chain reaction started by that particular radical. This saving sometimes runs into hundreds of molecules for each free radical caught, which means that the rate of thermal oxidation in the presence of anti-oxidant may be less than 1/100 of that of the pure material. The volumetric oxygen absorption method is an excellent one for evaluating anti-oxidants and for determining relative susceptibility to oxidation. Obviously it cannot be applied to field samples.

A method which is now coming into use for measuring the extent to which oxygen has combined with organic material is that of direct analysis for oxygen content. Until recently oxygen was determined in organic substances by difference; that is, analyses were made for all other elements present and the difference between the total percentage of these and 100 per cent was assumed to be oxygen. In recent years, direct methods based on quantitative conversion to carbon monoxide have been perfected so that it is now possible to measure the oxygen content of deteriorated material without including the errors in the analyses of all the other components. Figure 3 shows the oxygen content of successive layers beneath the surface of polyethylene after irradiation with a carbon arc for 1000 hours. In one case the polyethylene contained no additive and in the other it contained 2 per cent of well-dispersed carbon black. The

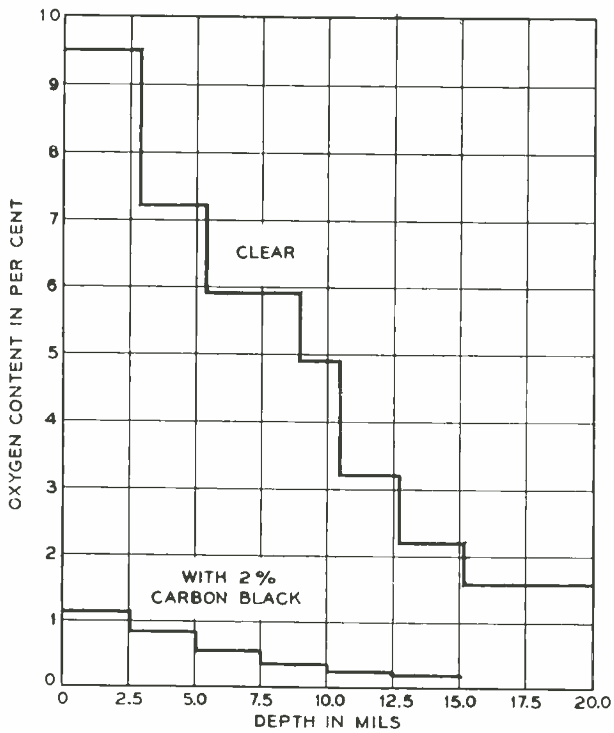


Fig. 3 — Oxygen content of polyethylene at varying depths after 1,000 hours under a carbon arc. Acknowledgment is made to the National Bureau of Standards for these analyses.

successive layers were sliced off with a microtome. The data in Figure 3 not only illustrate the usefulness of this method in detecting the extent of oxidation but re-emphasize the value of opaque substances in protecting organic materials from photo-oxidation. Anti-oxidants are of only small benefit here. The only effective method yet found for protecting organic polymers from sunshine for long periods of time is the incorporation of light-absorbing substances. Although in general the best protector is carbon black, several other pigments and a few organic light absorbers have been found helpful in special cases.

While oxygen is the most prevalent enemy of organic matter, there are other substances in the normal atmosphere which are sometimes important – ozone and water vapor. Several polymers in commercial use, notably natural rubber and the synthetics based on butadiene, contain a type of chemical grouping referred to as "unsaturation" in which one carbon atom is depicted by chemists as tied to another by two bonds instead of one. This is a reactive arrangement, particularly with ozone, and rubbers containing such groupings, when stretched in the presence of even the minute amounts of ozone found in the air, are apt to develop many cracks running transverse to the direction of stretch. Almost everyone has seen such cracks along folds in rubber gloves or old inner tubes, at bends in laboratory rubber tubing, or in garden hose. A discussion of this reaction has been published previously.*

The other most common degradative reaction, and again one which affects only certain types of chemical groups, is hydrolysis or reaction with water. Esters, amides and a few other chemical groups are subject to this reaction particularly in the presence of acid or alkali. The widely publicized sudden disintegration of nylon hosiery during certain smog conditions is an example; in this case acid vapor in the smog is responsible for the hydrolysis of the polyamide (nylon).

Not all the changes that occur in plastics and rubbers during service are chemical. Although they have not been reviewed here, such physical changes as the soaking up of oils and the loss of plasticizers by leaching or by evaporation are also of great engineering importance.

Giving up the use of all such vulnerable materials is obviously no solution. Rubbers and plastics have engineering properties which frequently cannot be duplicated with other materials. In fact, they have achieved their present wide industrial use by uphill competition with older materials. When properly chosen, properly compounded, and properly used they can have characteristics which are invaluable. Continuing research at the Laboratories has as its purpose the proper choice, compounding, and application of these materials for the Bell System.

* Record, *March*, 1948, *page* 119.

THE AUTHOR

B. S. Biggs received his M.A. and Ph.D. degrees from the University of Texas in 1931 and 1933, and from 1933 to 1936 he was a member of staff of the Coal Research Laboratory at the Carnegie Institute of Technology. He joined Bell Telephone Laboratories in 1936. At the Laboratories he has worked on the composition of wood preservatives, on the synthesis of dielectric materials and polymers, and on other phases of organic chemistry. In recent years he has engaged principally in rubber and plastics engineering, dealing especially with deterioration problems. In March, 1954, Mr. Biggs was appointed assistant chemical director. He is a member of the American Chemical Society and of the Society of Chemical Industry.

One facet of modern American business is the use of dictation machines that permit dictation for later transcription, without requiring the presence of a stenographer. Greater efficiency is achieved when a pool of such machines is made available as needed to a large number of people, and this is further enhanced if access to the machines is through regular Bell System PBX extension telephones. A recorded telephone dictation circuit developed at the Laboratories permits users of dial PBX extensions to control a dictation machine by dialing special code digits.

Recorded Dictation Using PBX Extension Telephones

MISS JOAN H. COYNE *Special Systems Engineering*

From all appearances, this telephone user is merely carrying on a normal telephone conversation – discussing a business transaction, confirming an appointment, or chatting with a friend. He may be doing any of these things. Or, he may be dictating a letter to a dictation machine – over the telephone. This has recently been made possible for users of dial PBX extensions by the development at the Laboratories of a special switching circuit that automatically connects an extension telephone to a dictation machine through the dial PBX.

Over the years, there has been a constant search for more efficient ways of providing stenographic service. Requirements for such service vary greatly, depending upon individual needs or the type of business organization. Obviously, in some situations the volume of dictation is sufficient to warrant the employment of full-time secretaries. Sometimes, stenographic pools are a satisfactory solution to the problem. The development of dictation machines, on which dictated material is recorded for later transcription by a typist, has paved the way toward greater efficiency by permitting material to be dictated without a stenographer actually being present. However, the use of such machines has been limited to those persons or groups having a sufficient volume of dictation to justify the cost of individual machines.

Greater economies and better efficiency in the use of dictation machines are possible if each machine is available to a large number of people. Various manufacturers of dictation equipment have taken steps in this direction by offering remote-control systems that permit a centralized pool of dictation machines to be operated from a private network of telephone sets.

Still further savings can be realized if regular Bell System PBX extension telephones are used for such purposes in place of the privately-owned telephone sets. This eliminates both the special wiring arrangements and the extra telephones on each user's desk required for isolated systems. To permit Bell System PBX extensions to be connected with and send control signals to a customer's dictation machine, the Laboratories has developed a recorded telephone dictation circuit to be used in conjunction with a dial PBX. This new circuit has been designed to operate with dictation machines that are presently available for privately-owned remote-control systems. Furthermore, it is thought that new designs of dictation and recording equipment could be adapted readily to work with the special circuit.

The present recorded telephone dictation circuit can be used with dial PBX's only; no provision is made for direct connection to Bell System telephone facilities other than the dial PBX with which it is associated. Central-office trunks cannot be connected to the circuit and any attempt by the PBX

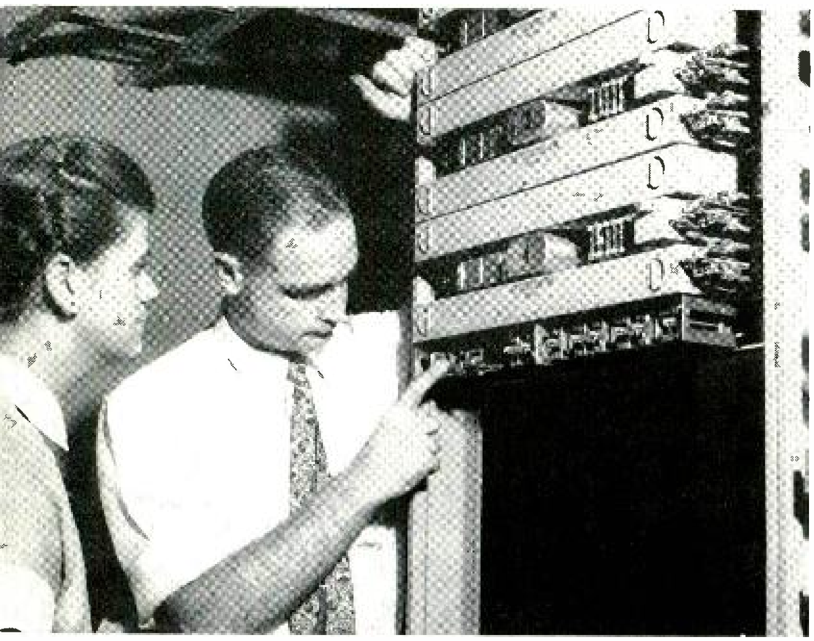


Fig. 1 — R. D. Williams discusses a feature of the circuit with the author. Equipment for four circuits is shown.

operator to monitor a line will automatically stop the dictation machine being used. All connections between the special circuit and customer-owned dictation equipment are made at a terminal box provided by the local Bell System company.

In a typical installation, Figure 2, any telephone user connected to the dial PBX can take advantage of recorded telephone dictation by using his regular extension telephone. A one- or two-digit code is assigned to the service so that dialing of the code connects the user with the appropriate level on the first or second selector switch of the PBX.* Each dictation machine in the pool connects to one terminal of this switch level through its own individual recorded telephone dictation circuit. The PBX equipment will therefore choose the first idle machine as it "hunts" across the switch level assigned to the service. If all machines are in use, the regular "busy" tone will be heard. When the circuit is connected to an idle machine, a distinctive "ready" tone is sent back to the person wishing to dictate.

Once a telephone user has been connected to a dictation machine, he has exclusive use and control of that machine until he releases it by replacing his handset in the cradle. All functions of the machine are controlled by the telephone user; he simply dials any one of five single-digit codes. To start dictating, he dials 1 and begins to talk. If he wishes to dictate more than one letter or message, and the dictation machine is one of those arranged to indicate an "end-of-message," he dials 4 after dictating the first message. This tells the machine to indicate that one message is finished and another is beginning. The various machines use different methods, such as marking an associated indicator strip or leaving a blank space on the recording medium, for making this indication. To stop the recording machine temporarily and still retain control of it, the telephone user again dials 1 as for starting a message. Thus, 1 is a combination start-stop signal. The "ready" tone is present whenever the circuit is in the stop condition.

Should a correction be necessary during a recorded message, the telephone user dials 2. This tells the dictation machine to indicate to the typist that a correction is to be made but does not stop the machine. As with an "end-of-message" signal, the method of indication depends upon the arrangement provided by the customer's machine. When play-back is desired, the telephone user dials 3 to hear a play-back of at least part of his recorded message. The amount played back again depends on the particular machine.

If for any reason, such as to request that the material be typed immediately, the telephone user wishes to speak to the machine attendant or typist, he dials 0. Since the digits 1 through 4 are used for other control purposes, it might seem more logical to use 5 for this function. The reason why 0 is used,

* The type of connection between the telephone user and the special recorded telephone dictation circuit depends upon the switching arrangement employed in the PBX. In this discussion, step-by-step PBX equipment is assumed.

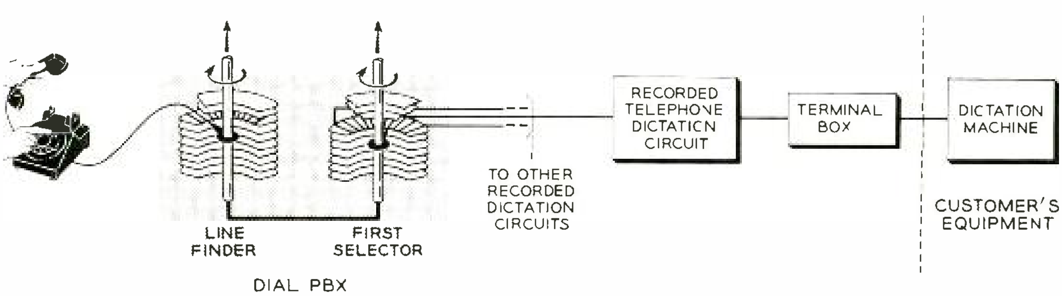


Fig. 2 — Each extension has access to the switch level set aside for recorded telephone dictation.

RECORDED TELEPHONE DICTATION CIRCUIT

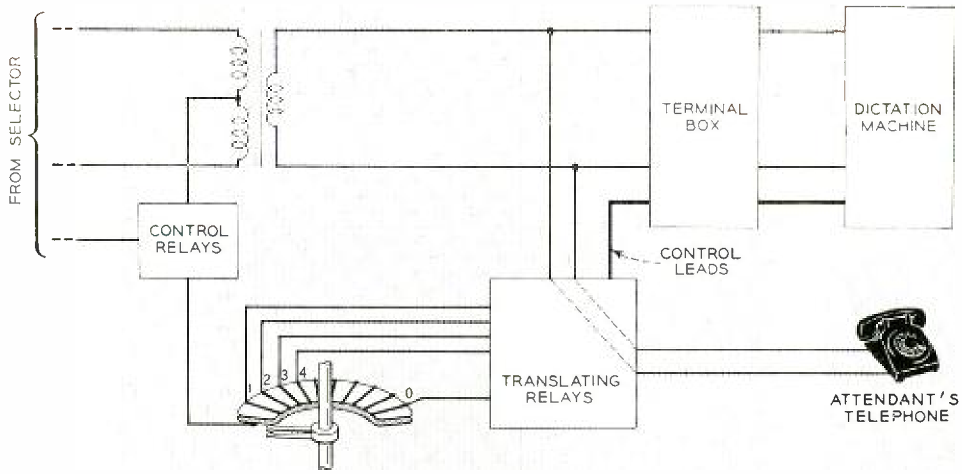


Fig. 3 — Relays and a resetting-type selector switch control the machine according to the digit dialed.

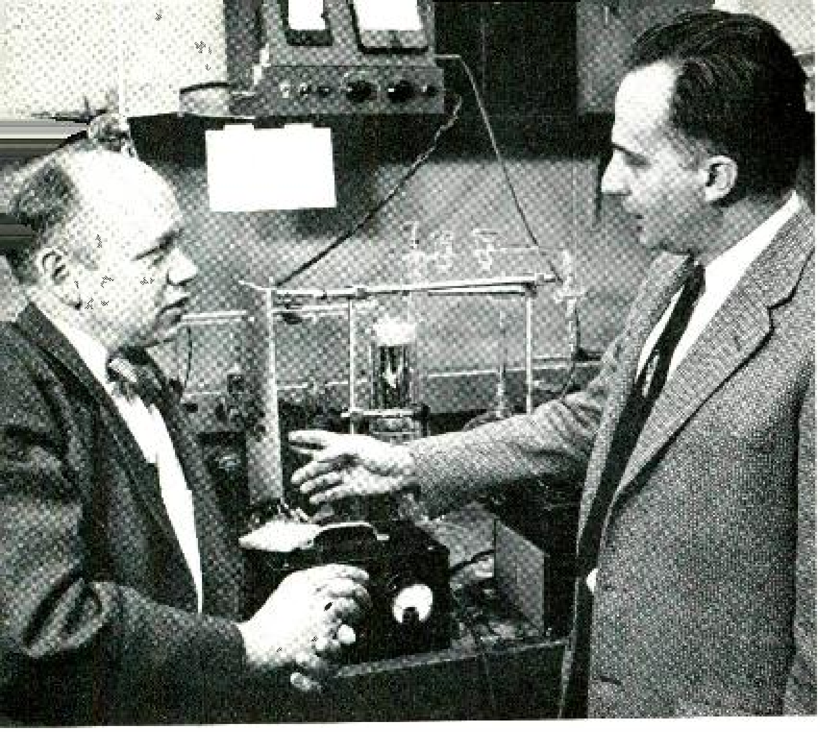
of course, is that the digit 0 is associated in most telephone user's minds with an operator — to give any assistance necessary. This dialing of 0 causes the dictation machine to stop, rings the attendant's telephone, and returns an audible ringing signal to the calling telephone. When the attendant answers, the incoming line is transferred from the dictation machine to the attendant and ringing ceases. After speaking with the telephone user the attendant hangs up her telephone, automatically reconnecting the telephone line to the machine and leaving the system in the "stop" condition with the "ready" tone on the line.

Physically, the system is quite small, occupying only a few inches on a standard telephone equipment bay, Figure 1. Control relays, Figure 3, connect the particular calling line from the PBX selector switch to translating relays through a 10-point resetting-type rotary switch. At the same time, the talking path is connected through to the dictation machine and a "ready" tone is sent back to the person wishing to dictate. When he dials 1, the rotary switch steps to position 1, causing the translating relays to start the machine, and then returns to normal. Dialing any of the single-digit codes steps the switch to the corresponding level and causes the translating relays to send the appropriate control signals to the dictation machine and, in the case of the digit 0, to the attendant.

Recorded telephone dictation offers particularly attractive possibilities for more efficient stenographic service in business organizations where a large number of employees each have individual dictation requirements of too small a volume to warrant the use of individual dictation machines.

THE AUTHOR

JOAN H. COYNE received a B.S. degree from Chestnut Hill College in 1952, and immediately joined the Laboratories. For about a year she was involved with the preparation of descriptive information on PBX and Community Dial Office systems. Since that time Miss Coyne has been engaged in engineering studies on special systems, including development coordination, the formulation of requirements, and the preparation of general descriptive practices. She has been concerned with load-dispatching equipment for right-of-way companies, switchboards and the concentrator-identifier for telephone answering service, and other PBX systems.



Alloyed-Junction Transistor Development

J. J. EBERS *Transistor Development*

The search for new methods of producing transistor structures has been under way since the day the transistor was invented. Each new method is carefully investigated for useful electrical characteristics, ease and economy of fabrication, and potentialities for reliability and long life. Alloying layers of high-conductivity material onto a body of germanium results in a set of properties particularly suited to switching applications.

At the present time there are two widely used methods of producing triode junction transistors of either the n-p-n or the p-n-p variety. One method consists of growing a single crystal of germanium and doping the melt from which the crystal is grown at appropriate times with the proper impurity atoms. This growing operation produces a crystal with, say, a p-type layer sandwiched in between two n-type layers. Such transistors have been described in previous articles.*

The other method is to produce the junctions by an alloying process. A small pellet of a donor (n-type) metal, or of a mixture of metals containing a donor metal, is placed in contact with the surface of a p-type germanium body. The two are then heated together, and a small pool of molten germanium-metal mixture forms at the place of contact. Upon cooling, the germanium from this mixture recrystallizes onto the parent material, but retains enough of the donor metal in solid solution to become converted to n-type. The excess metal is rejected to form a button on the surface (see the cross-section of this structure in the right part of Figure 2).

In practice, the various process steps in the fabrication of an alloyed-junction transistor are as follows. Single crystal germanium containing a controlled amount of conductivity-producing impurity is prepared by crystal-pulling or zone-leveling. This germanium, of n- or p-type, depending on whether it is desired to make p-n-p, or n-p-n transistors, is cut into slices which are then ground to a thickness of seven or eight thousandths of an inch. These slices are cut into wafers about one-eighth of an inch square, then etched down to three or four thousandths of an inch in thickness. The wafers are placed in jigs which locate them relative to holes in which small pellets of the alloying metal are placed in contact with the wafer surfaces. Such a jig can be seen in Figure 3 – the rectangular carbon blocks into which cylindrical wells and tiny holes are drilled. For p-n-p transistors, indium or lead-indium is used as the alloying material; for n-p-n transistors, lead-arsenic or lead-antimony is used. The jigs are placed in an oven containing the appropriate

* Record, *June*, 1954, *page* 203; *October*, 1955, *page* 374.

atmosphere, and are heated to 500-750°C, depending on the alloying material. The indium or lead dissolves germanium in the area where contact is maintained to a depth of one to three thousandths of an inch, depending on the quantity of alloying material, the area of the contact, and the alloying time and temperature.

Thus, to control the thickness of the base layer between emitter and collector junctions, it is necessary to control all of these factors, as well as the initial thickness of the base layer itself. The final thickness of the base layer between the emitter and collector is, of course, the distance between the two junctions. The alloying material diffuses through the position of farthest advance of the liquid-solid interface, so that the junction will actually lie a small distance beyond this interface. As the temperature of the oven is lowered, germanium begins to freeze out and to recrystallize at the interface. If the temperature is lowered sufficiently slowly, most of the dissolved germanium regrows as single-crystal material on the original single-crystal base wafer, with the excess metal appearing as a button on the surface. Enough of the alloying material is retained in the recrystallized germanium, however, to change its conductivity type and depress its resistivity to a value in the neighborhood of 0.001 ohm-centimeter or less, so low as to have almost metallic electrical behavior.

After alloying, the alloyed wafers are etched to remove condensed foreign material from the surfaces (see Figure 5). Such material, if permitted to remain, would short-circuit the junction or degrade the subsequent performance and reliability of the units. Both acidic chemical etches and alkaline electrolytic etches have been used. The wafer is then alloyed to a gold-plated, ring-shaped base contact, which surrounds the emitter button. Contact is made to the emitter and collector buttons. Some of the fabrication stages can be seen in Figure 3. At the right of this illustration, tubes are shown

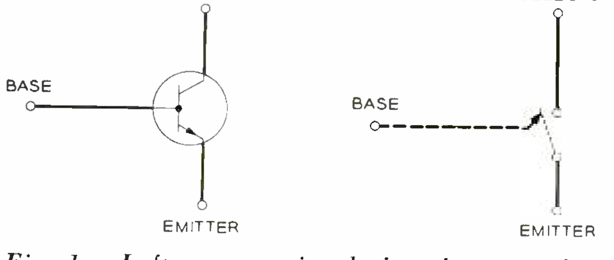


Fig. 1 — Left: conventional junction transistor symbol; right: equivalent circuit behavior of a transistor when used as a switch.

leading into the transistor enclosure. These are used for some transistor types to control or change the ambient conditions surrounding the transistor element after the unit is enclosed in the can.

A comparison of the electrical properties of an alloyed-junction transistor with those of its predecessor, the grown-junction transistor, reveals a number of interesting similarities and differences. As a switch, for example, the alloyed-junction transistor has a distinct advantage over the grown-junction transistor. This switching behavior is illustrated in the two diagrams of Figure 1. On the left is the conventional circuit symbol for a transistor, with the three terminals marked base, collector and emitter. When used in a switching circuit, as shown at the right of the figure, the transistor can be considered as having – between the collector and emitter terminals – a simple switch. This switch is closed by the application of the proper

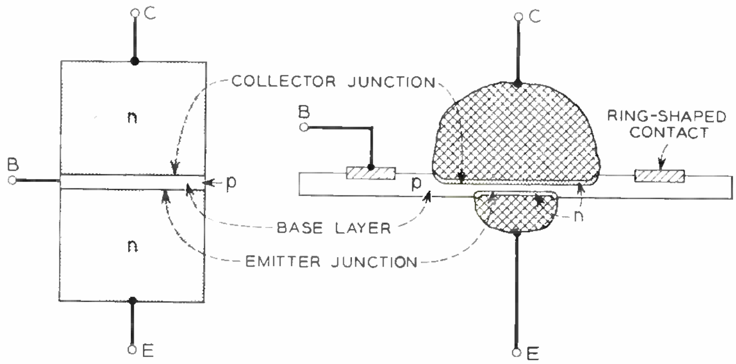


Fig. 2 — Left: section through grown-junction n-p-n transistor element; right: section through alloyed-junction n-p-n transistor element showing alloyed layers.

electrical stimulus to the base terminal; removal of the stimulus opens the switch. In this application, a transistor may have an open impedance of many megohms, a closed impedance of only one to ten ohms, and an operate time in the microsecond range. The body resistance of the emitter and collector regions of a grown-junction transistor may result in a resistance in series with the switch of fifty ohms or more. In alloyed-junction transistors, the collector and emitter regions are essentially metallic and have practically no resistance. Other differences also exist which throw the scales decidedly in favor of alloyed devices for switching applications.

Another significant property of these junction transistors is the ratio of minority-carrier or emitted current crossing the collector to the total current across the emitter – the current multiplication fac-

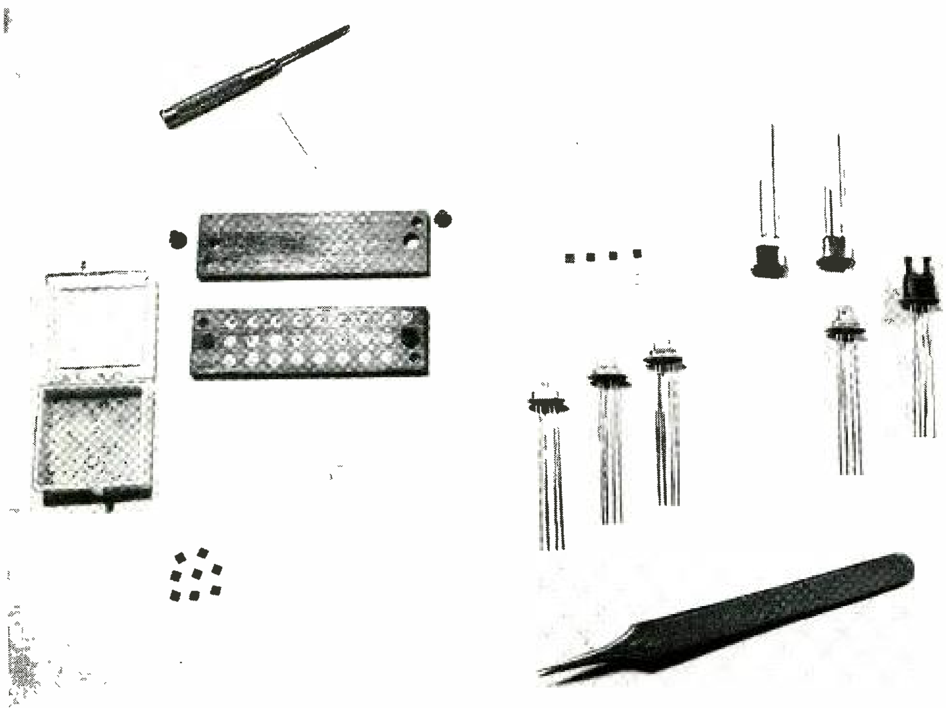


Fig. 3 — Pellets and wafers (left) are placed in large rectangular jigs and heated in an oven to form junctions. At right are shown partially assembled and completely assembled alloyed transistors.

tor, alpha. In a grown-junction transistor, alpha is primarily determined by the thickness of the base layer. However, in an alloyed structure, much minority-carrier current can be lost in and on the surface of the base wafer, resulting in a severe reduction of alpha. For low-power alloyed devices it has been found that this loss can be largely prevented if the diameter of the collector is made approximately twice that of the emitter. Values of alpha comparable with those of grown-junction devices are thus obtainable, provided the thicknesses of the base layers between the junctions are comparable. The thickness of the base layer also controls the frequency behavior of the device. For n-p-n alloyed-junction transistors, an emitter-to-collector spacing of one thousandth of an inch causes the output power to drop to one-half of its maximum low-frequency value at about 4.5 megacycles. Such spacings are obtainable in alloyed transistors, of both the n-p-n and p-n-p types.

To obtain a small base layer thickness and the attendant good frequency performance, the junctions must be very nearly parallel planes. Considering the way most melting operations on the surfaces of materials tend to result in hemispherical puddles of the melt, this would seem to be almost an impossible requirement to place on an alloy structure. Fortunately, however, the crystal structure of germanium provides a solution. Through the crystal, there are planes in which the germanium atoms are most densely packed — the (111) planes. These are the planes that are exposed if, in a cubical array of atoms, we cut off a corner of the cube along a plane perpendicular to a diagonal running through the body of the cube. Thus, if we cut the crystal surfaces to coincide with the (111) planes, the molten material will have less tendency to penetrate these densely packed layers and will instead tend to spread out longitudinally. As a result it has been possible to obtain junctions thirty thousandths of an inch in diameter which are flat within one ten-thousandth

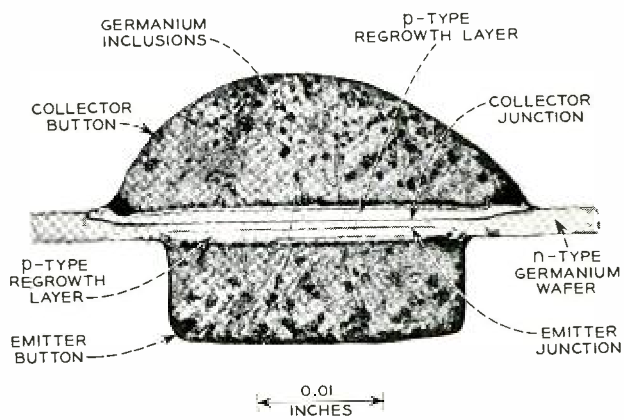


Fig. 4 — Micrograph section of an alloyed-junction transistor element (magnification about 60 diameters). Note flat planes of junctions and thinness of the base layer of n-type germanium.

of an inch. A photographic cross-section of an alloyed transistor prepared in this manner is shown as Figure 4. Note the planarity of the junctions and the extremely small spacing between the emitter and collector buttons.

Another interesting point of comparison between alloyed-junction and grown-junction transistors lies in the properties of the junctions. Because of the nature of the alloying process, alloyed junctions are very abrupt transitions — that is, the electrical resistivity changes sharply from the semi-conducting base layer to the almost metallic emitter and collector alloyed regions. In comparison, grown junctions are usually more gradual, and for this reason their capacitances per unit area are smaller, and higher voltages can be applied in the reverse direction before such junctions break down. The high junction capacitance limits the usefulness of alloyed junction transistors at high frequencies to some extent. However, this effect is compensated by a lower base resistance, which is obtained with the large-area, ring-shaped base contact around the entire periphery of the wafer. This type of base contact also improves the power dissipation ability of the transistor. If the transistor can is filled with a heat-conducting medium, the temperature of the unit will rise only about 0.3 to 0.4°C per milliwatt of power dissipated.

Table I compares the characteristics of two alloyed transistor types and one grown-junction type, for both small-signal and switching applications in amplifier, oscillator, or other small-signal electronic circuits. It is seen that alloyed units compare quite

TABLE I

Small-Signal Characteristics	*Alloyed p-n-p M-1778*	*Alloyed n-p-n A-1853*	*Grown n-p-n W.E.4A*
Current gain (alpha)	0.985	0.99	0.98
Collector reverse leakage current in microamps	2.5	3	1
Collector capacitance in micro-microfarads	25	25	11
Cut-off frequency, mc	4.0	2.5	2.0
Noise figure in db	20	14	17.5
Gain per stage in db	40	40	40
Switching Characteristics			
Max. collector current in milliamps	100	100	25
Closed-switch impedance in ohms	5	5	50
Open-switch impedance in megohms	30	30	10
Turn-on time in microseconds	0.5	0.8	1
Turn-off time in microseconds	1	2	10

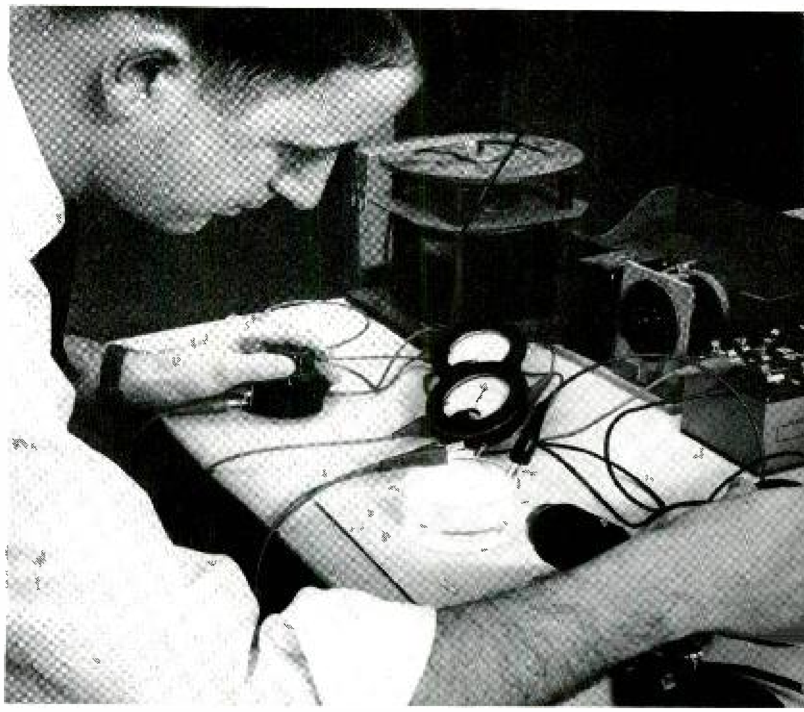


Fig. 5 — W. P. Herzer etching germanium wafer to remove debris from the alloying operation and to improve surface properties of this material.

favorably with the grown-junction unit. In switching applications, the table shows that the alloyed-junction units are superior.

For some time it has been thought that one of the chief advantages that alloyed transistors have over grown-junction transistors is the ease of fabrication. This advantage waxes and wanes as improvements are made in the technology of first one type and then of the other. A significant factor is that single-resistivity type germanium is needed for alloyed devices, whereas it is necessary to have material with the junctions already grown in for grown-junction transistors.

One of the problems that continuously confront the device engineer is that of reliability. The reliability of a device must always be expressed in terms of the conditions under which the device is called upon to operate. For example, transistors may have practically infinite life in hearing-aid circuits but very short life if the operating voltage is close to the limiting voltage, and if the devices are subjected to an environment having a temperature of about 65°C. In the Bell System, the problem has been to build transistors to operate at this temperature and at moderately high voltage and power levels.

The reliability of transistors is defined with reference to the slow changes in electrical characteristics that take place with time. When the value of one of these characteristics falls outside its acceptance range, the transistor is said to have failed. There is no appreciable evidence that failure results from processes occurring within the body of the semi-conducting element. Instead, aging is usually associated with slow changes in the surface of the transistor, particularly in the vicinity of the junctions. Solution of the reliability problem, therefore, consists of obtaining and then maintaining the desired surface conditions during the life of the device by appropriate fabrication and encapsulation techniques. Results of recent improvements in etching and final sealing indicate that satisfactory reliability can be obtained, even under adverse operating conditions. For example, p-n-p transistors have been life-tested at temperatures up to 65°C, and at collector bias potentials up to 28 volts, with a power dissipation of 40 milliwatts. The manner in which these transistors aged seems to have been governed by the same law that describes chemical changes on the surface. This is an indication that transistor technology is coming to the point where devices can be produced which will age in a predictable manner.

The alloyed-junction transistors described here were developed as prototype units intended for either transmission or switching applications. Additional types have been and will continue to be developed for more specific uses. Although the transistor art is fast-moving, it appears that for some time, at least, alloyed-junction devices will hold advantages that will be particularly useful in the field of switching applications.

THE AUTHOR

J. James Ebers received a B.S. degree from Antioch College in 1946, an M.S. degree from Ohio State University in 1947, and a Ph.D. from the same school in 1950. After serving as an assistant professor of Electrical Engineering at Ohio State, Dr. Ebers joined the technical staff of the Laboratories in 1951. His early work with the Laboratories was concerned with the development of transistors for switching applications, and for the past several years he has been principally engaged in the development of the alloyed junction transistor. Dr. Ebers is now based at the Allentown Laboratory. He is a member of the American Physical Society and the Institute of Radio Engineers.

Dr. Kelly Honored by Sweden's Royal Academy of Sciences

Dr. Mervin J. Kelly has been elected a Foreign Member of the Swedish Royal Academy of Sciences, one of the world's foremost learned societies. In his letter, the Secretary of the Academy declared:

"Our Society is most happy in conferring on you this token of profound respect, called forth by your masterly researches in the domain of Electronics and Electrotechnics, which have forever enrolled your name in the Annals of these Sciences."

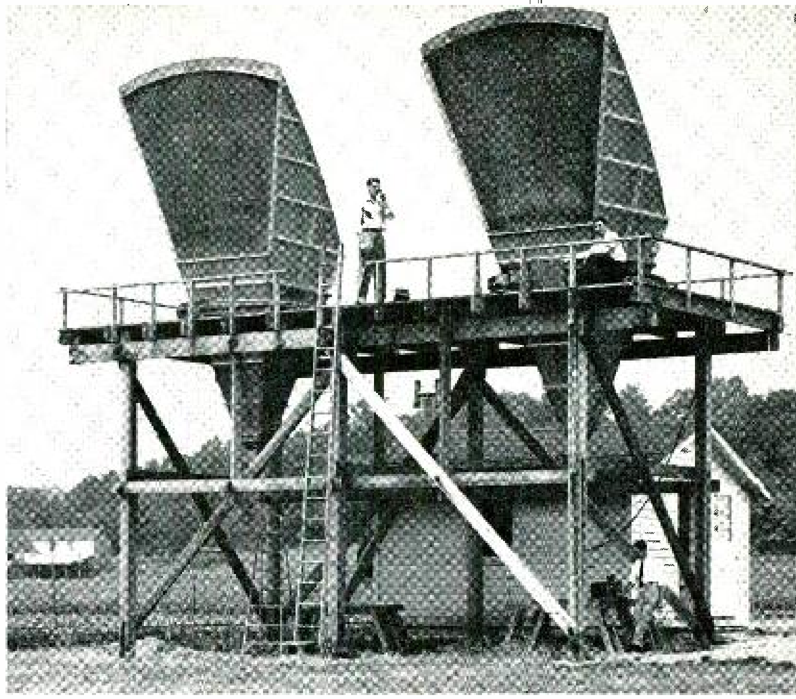
The Swedish Royal Academy of Sciences was founded in 1739 by Carl Linnaeus and others for the encouragement of the natural sciences and mathematics. It awards two of the prizes of the Nobel Foundation, in Chemistry and Physics.

The Academy, which is associated with a number of Swedish museums, carries out its work mostly through scientific institutions, publication of scientific pamphlets, and in providing funds to outstanding scientists and authors.

Dr. Kelly is one of 108 foreign members from countries outside Sweden. This number is constant. Swedish membership consists of a maximum of 140 and a minimum of 108 members.

Among the distinguished Americans who are members of the Swedish Royal Academy of Science are Irving Langmuir, Harlow Shapley, Harold C. Urey and E. O. Lawrence. The late Dr. Albert Einstein was also a member.

Pulse Equipment for Microwave Antenna Tests



1,000,000,000,000 to 1 is the ratio of power transmitted by one of the antennas, shown above, to the level of crosstalk received by the adjacent antenna. Measurements of this magnitude can be made with equipment employing radar pulse techniques. Useful not only in measuring antenna performance characteristics, but also in accurately evaluating minor changes in design, this pulse test equipment has contributed to the development of improved antennas for "backbone" microwave routes.

E. J. HENLEY AND L. G. YOUNG *Transmission Systems Development I*

Development of the KS-15676 horn-reflector antenna* for the TD-2, TH and TJ microwave systems posed a problem of measurement. What test equipment and techniques could be used to measure an antenna's relative response in different directions or the crosstalk response of one antenna to an adjacent one – how could one measure antenna directivity patterns with ratios up to 90 decibels and crosstalk ratios up to 140 db at frequencies in the 4,000,- 6,000- and 11,000-mc common-carrier bands? Radar supplied the answer.

The development of equipment employing radar pulse techniques permits more accurate measurement of intrinsic antenna properties than conventional continuous-wave methods. It has already been established that foreground reflections, even from relatively distant objects, may limit the effective directivity of an antenna.† If an antenna's characteristics are to be accurately determined, the effects of these reflections must be eliminated from the measurements. Conventional methods, using a continuous-wave test signal, do not furnish the required information. Figure 1 illustrates a typical reflection condition and shows how it can interfere with a continuous-wave measurement of the rearward response of an antenna.

The relationship between the forward and rearward responses of an antenna is known as the front-to-back ratio, and may be expressed in decibels. Continuous-wave measurement of an 80 db front-to-

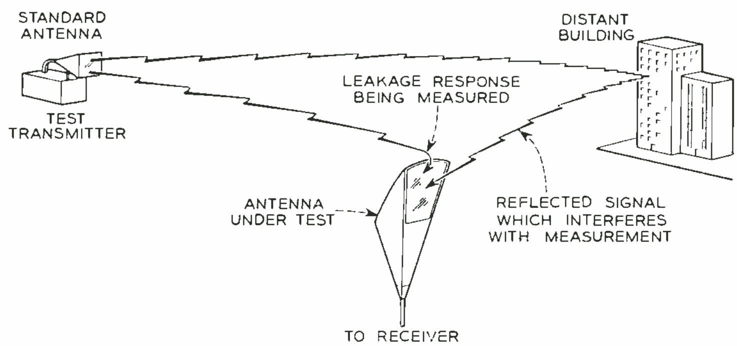


Fig. 1 — Interference with antenna measurements caused by reflection from surrounding objects.

* RECORD, *November,* 1955, *page* 401. † RECORD, *December,* 1953, *page* 486.

back ratio would require a clear area with a radius 100 or more times the distance between the test transmitter and receiver. Of course, not all objects are efficient reflectors, nor are they necessarily located on the axis of the antenna under test, but it is still possible for objects many miles away to interfere with accurate measurement of minor lobes in the antenna response.

Pulse techniques, increasingly useful in the laboratory* as well as in the field of radar, provided the basis for a new antenna test set. Desired signals can be displayed on an oscilloscope and visually separated from undesired ones. Resolution of the desired signal on a time basis is made possible because the pulse lengths are short compared with

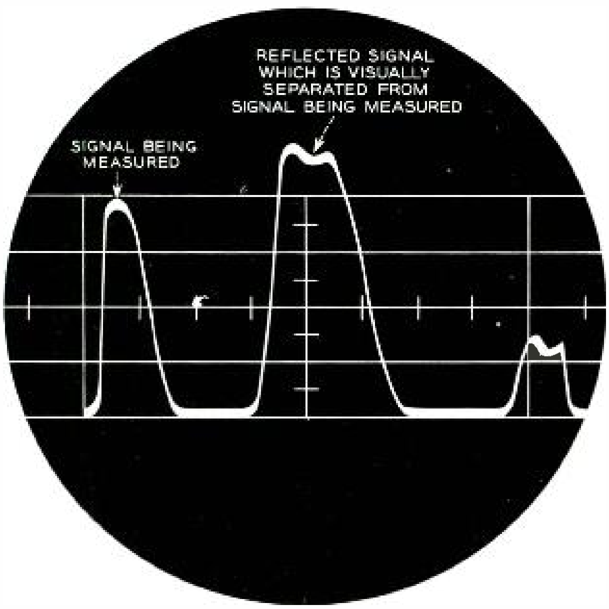


Fig. 2 — Oscillogram of typical test signal observed under conditions illustrated by Figure 1.

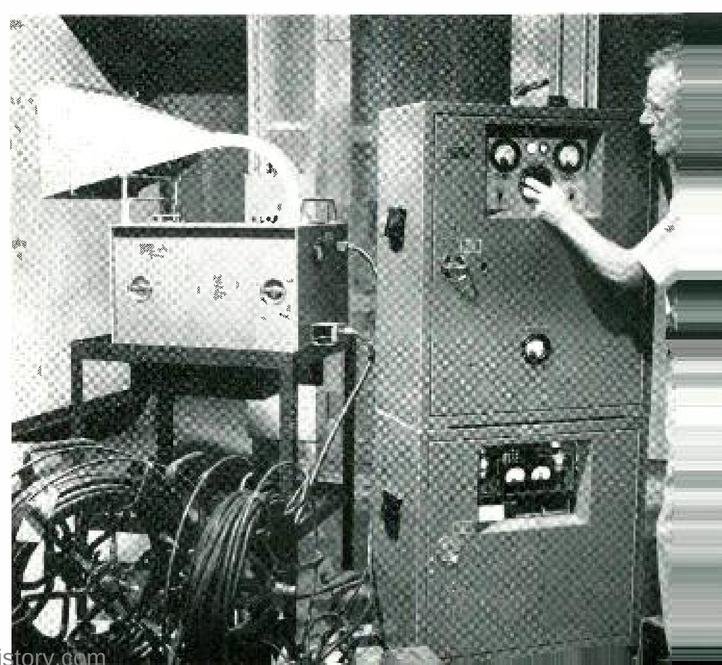
the difference in travel time between direct and reflected signals. The use of very short pulses permits a great reduction in the clearance requirements for the test range. A clearance of about 200 feet beyond the antenna is all that is required for satisfactory resolution when using test signals 0.25 microsecond long. Figure 2 is an oscillogram of a typical signal measured at the Holmdel antenna test range.

Another advantage of pulse equipment is the availability of high power. Magnetrons similar to those commonly used for radar are employed to deliver pulses of radio-frequency energy with a peak power of 75 kw or more at the frequencies used in these tests. Since it is the amplitude of the pulse peaks that establishes the limit of measurement, much greater front-to-back and crosstalk ratios can now be measured than would be possible using any continuous-wave signal source presently available.

Design of satisfactory equipment included considerations of safety, portability, availability of standard components, shielding, accuracy of measurements, and stability during a long series of tests. These were not unusual problems, except that magnetrons for two of the three frequency ranges did not even exist; the only standard type which could be used was a 4J59 operating at 6,325 mc. The solution to one problem was obtained by making a few minor modifications to a 4J36 magnetron to raise its frequency to 3,740 mc. The last problem was solved by the Laboratories' Tube Department at Allentown, where a 4J52 magnetron was successfully modified to operate at 10,960 mc, an increase of more than 1,500 mc above its normal operating frequency. With these critical items as a nucleus, the balance of the test set was assembled with standard components.

The pulse transmitter shown in Figure 3 consists of five separate portable units and associated interconnecting cables: a control and modulator unit, a high-voltage rectifier unit, and three radio-frequency units operating at 3,740, 6,325, and 10,960 mc, respectively. Pulse lengths are 0.25, 0.19, and 0.17 microsecond, and the peak powers are 300, 150, and 75 kw. All units are equipped with interlock circuits so that primary power will be disconnected

Fig. 3 — The pulse transmitter. L. G. Young makes voltage adjustment in the control and modulator un below is the high-voltage rectifier unit, and at the left one of the radio-frequency units.



* Record, *December*, 1954, *page* 457.

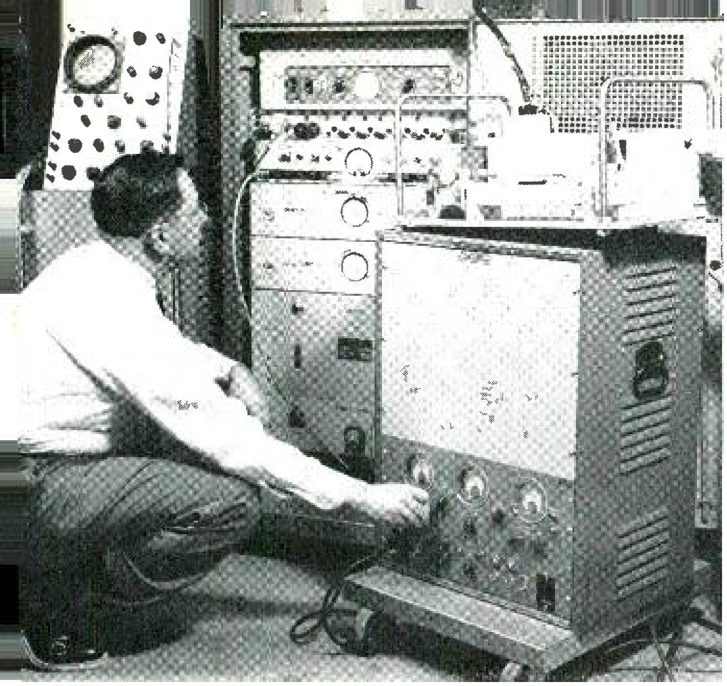


Fig. 4 — The pulse receiver. E. J. Henley adjusts the attenuator in the power supply unit, on which is resting one of the converter-preamplifier assemblies. The oscilloscope at the far left stands beside an intermediate frequency amplifier and power supply unit.

if a door or cover on any unit is opened or if any plug is removed from a socket.

The electrical design of the transmitter is conventional, but the equipment layout was planned for maximum utility in making antenna tests. This applies particularly to the design of the radio-frequency units, each of which contains a magnetron, a filament transformer, a pulse transformer, a pulse shaping network, a cooling blower, and metering facilities. Each of the radio-frequency units may be operated as much as 125 feet from the control unit to which it is connected by suitable cables. This provides a high degree of flexibility and permits the radio-frequency unit to be hoisted to the top of a tower while the balance of the equipment remains at ground level near a source of primary power.

Careful fitting of the cabinet and access cover were required to keep the leakage to a value about 65 db below full output. Two clusters of small brass tubes mounted on the top surface of the cabinet constitute "waveguides below cutoff" which permit circulation of air to cool the magnetron without allowing radio-frequency energy to escape. This may be explained by the fact that for a given radio frequency there is a minimum cross-section which a hollow conductor (waveguide) must have in order to pass energy without high attenuation. In this case, the brass tubes which pass the cooling air have small diameters and are very far "below cutoff" with respect to the operating frequency of the magnetron.

The pulse receiver shown in Figure 4 consists of four portable units: a power supply for the receiver local oscillator, an oscilloscope for viewing the detected pulses, an intermediate frequency amplifier and power supply unit, and a cabinet which houses the 4,000,- 6,000- and 11,000-mc converter-preamplifier assemblies. When in use, the required converter assembly is removed from the cabinet and connected to the antenna by means of flexible waveguides. Shields over the preamplifiers reduce spurious responses to a value 65 db below normal input. At this point microwave leakage at the input waveguide flange connection becomes the limiting factor. In tests where very high ratios are to be measured, it is possible to reduce the stray pickup an additional 15 db by packing "lossy" material around all waveguide flange connections.

One of the principal uses of the pulse test equipment is to obtain a polar plot of the response of an antenna. The one shown in Figure 5 is but one of many required to define fully the performance of the KS-15676 horn-reflector antenna. Characteristics

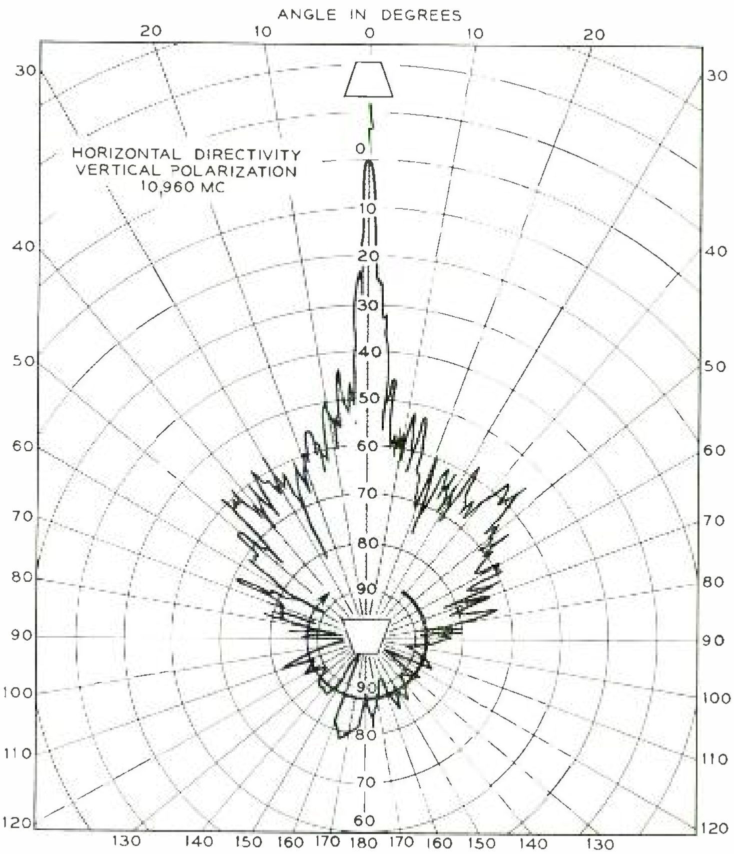
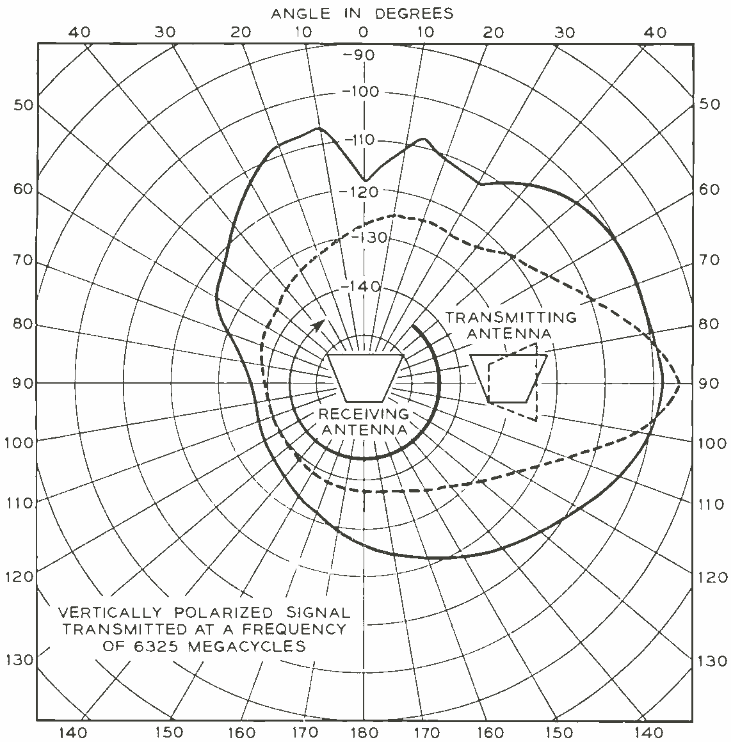


Fig. 5 — Polar plot of the response of a KS-15676 horn-reflector antenna.



vary considerably with frequency and polarization of the test signal. Equipped with these data, the systems engineer is in a better position to evaluate potential interference from converging routes or reflections from surrounding objects.

Another useful measurement is the ratio of crosstalk coupling between two antennas at the same location. This might at first appear to be simply the sum of the antenna responses, but it must be remembered that the angle subtended by each antenna encompasses many minor lobes of response of the adjacent antenna. These combine in random phase to produce the envelopes of cross-talk response peaks shown in Figure 6. This figure illustrates only the maximum values measured as the receiving antenna was rotated on its axis. The responses are shown for two orientations of the transmitting antenna. Finely detailed plots would show that at most points the crosstalk was far below the values indicated.

Fig. 6 — Measured crosstalk between two KS-15676 broadband microwave horn-reflector antennas.

THE AUTHORS

EDWARD J. HENLEY was employed by the Illinois Bell Telephone Company in 1936 and served in a number of capacities in the plant department until 1942 when he transferred to the Long Lines Department of the American Telephone & Telegraph Company. During the following years his work included operation and maintenance of overseas radiotelephone equipment, toll testroom facilities, and microwave radio relays. In 1952 he transferred to the Laboratories where he has worked on the design of microwave test equipment and seals for the seams of microwave antennas. He also participated in the preparation of maintenance instructions covering mobile radiotelephone equipment. In July of 1955 he transferred to the Western Electric Company where he is currently engaged in work on special communication systems. Mr. Henley is an associate of the Institute of Radio Engineers.

L. G. YOUNG was graduated in 1919 from the Carnegie Institute of Technology with a B.S. in electrical engineering. He joined the Western Electric Company in 1920 and transferred with the group that became Bell Telephone Laboratories in 1925. Until 1926 he was engaged in coil and impedance-bridge design and later did design work on broadcast transmitters and on long-wave transoceanic transmitters. From 1940 to 1952 he was engaged principally in military work having to do with short-wave transoceanic transmitter design. Currently, Mr. Young is engaged in the TH radio relay system project.

In the past few years, negative-impedance voice-frequency repeaters have become increasingly popular with the Operating Companies. Their relatively low cost and small size, together with simplicity of installation and maintenance, have proved major factors in the rapid growth of exchange area plant. These repeaters operate on a different principle from that of conventional repeaters, and a simple means of testing them was desired. The Laboratories has developed a versatile new test set that provides not only for testing the repeaters but also for measuring the transmission and impedances of the lines used with them.

E-Repeater Test Set

J. O. SMETHURST *Transmission Systems Development*

Many thousands of repeaters are used in Bell System voice-frequency lines, and equipment must be available to check these repeaters for transmission efficiency. Several transmission measuring sets have been developed in the past for use with conventional repeaters but the newer negative-impedance repeaters require a different approach. The E2 and E3 are the latest versions of this type of repeater, and a new test set has been developed at the Laboratories to check their performance.

A conventional repeater for two-wire operation consists of two one-way amplifiers and two hybrid coils with line-balancing networks. The balancing networks are adjusted to approximately equal the line impedances, and the amplifier gains are set to a predetermined value low enough to avoid "singing". Once these adjustments have been made, the repeaters may be divorced from the lines and their gain performances checked in a conventional transmission measuring set.

Negative-impedance repeaters operate in a different manner, involving a more intimate association with the telephone lines. Every telephone line offers series and shunt impedances that attenuate the speech currents. If, in the ideal case, equivalent values of negative series and shunt impedances could be provided, the speech energy would be transmitted with zero loss. Negative impedance repeaters do just this. They do not function as conventional amplifiers; they simply act as series and shunt types of negative impedances to offset a large portion of the positive impedances.

Two basic types of negative-impedance repeaters are used on telephone lines. The E1,* and its newer counterpart the E2, are series repeaters having negative resistance and negative reactance which combine to minimize the attenuation and equalize the transmission over the voice-frequency band. The E3 repeater is a shunt type, for bridging across a telephone line, that provides gain in much the same way as a series repeater. While a shunt repeater does provide gain, another useful function is its use in combination with an E1 or E2 series repeater for impedance-matching purposes.

The introduction of a series negative impedance in an otherwise uniformly-loaded line causes an

* Record, *February*, 1952, *page* 56.

impedance discontinuity that reflects a substantial amount of energy as "echo."* On long inter-office or toll-connecting lines, the magnitude of the impedance irregularity caused by the repeater increases with the gain and the "echo" may become intolerable. In such cases, a combination of series and shunt negative-impedance repeaters can be used to minimize the "echo" effect. The E-repeater test set can measure the gain and stability of individual repeaters or any of their possible combinations.

Repeater gain could be determined, for any particular trunk, by making transmission measurements between the two ends of the trunk, with and without the repeater. The difference between the measurements would be the repeater gain. However, the originating office, terminating office, and repeater points are often several miles apart and the services of a man at each location would be required for long periods of time. A more economical

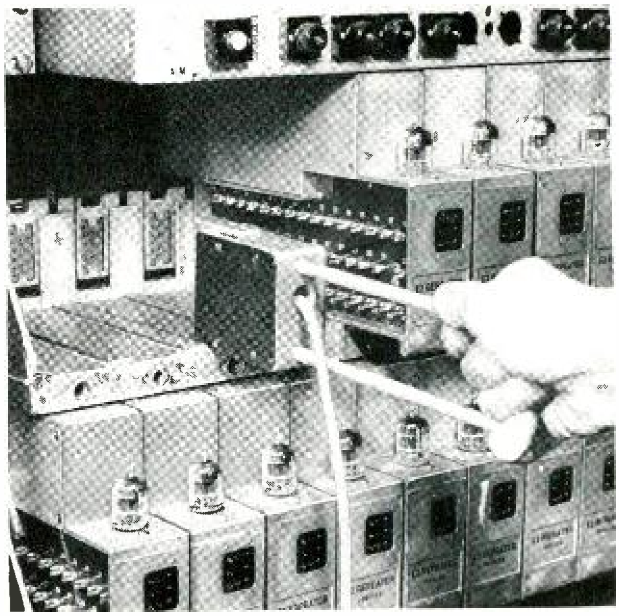


Fig. 2 — A special plug-in adapter permits the set to be connected in place of the repeater during tests.

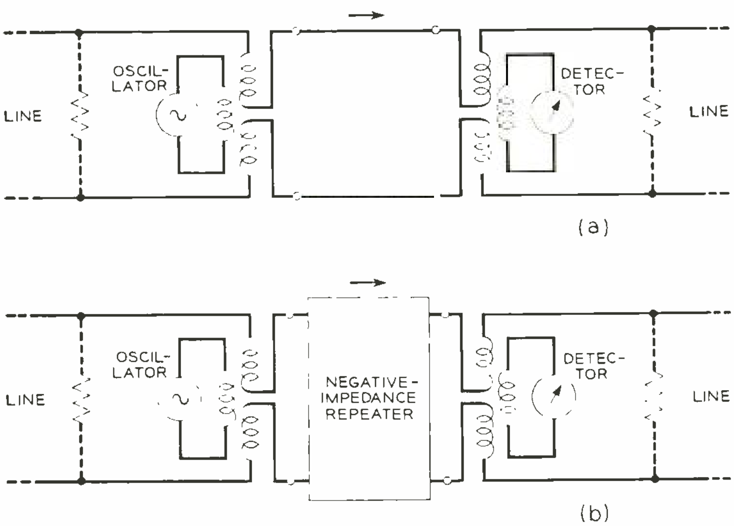


Fig. 1 — Insertion gain is determined by comparing a reference measurement (a) and a second measurement with the repeater in the circuit (b).

approach is to adjust the gain directly at the repeaters to a value suitable for a specific length and type of line.

When a conventional repeater with a certain gain is inserted in a telephone line, the insertion gain is primarily that of the repeater as measured in a test circuit. However, when a given value of negative impedance is inserted in a line, the insertion gain depends on the actual impedance values of the connecting lines. If a conventional transmission measuring set is used to test a negative-impedance repeater, the correct value of insertion gain will be measured only when the test set is terminated by impedances duplicating those of the actual line. Many different types of lines are used in the exchange area plant with various lengths, types of loading, and sizes of wire, and characteristic impedances varying between wide limits. Determining the insertion gain of negative-impedance repeaters with a conventional measuring set would require that terminating impedances covering a wide range of resistive and reactive values be included. Since it is impracticable to furnish such a large number and variety of test terminations for each measuring set, a different approach is required.

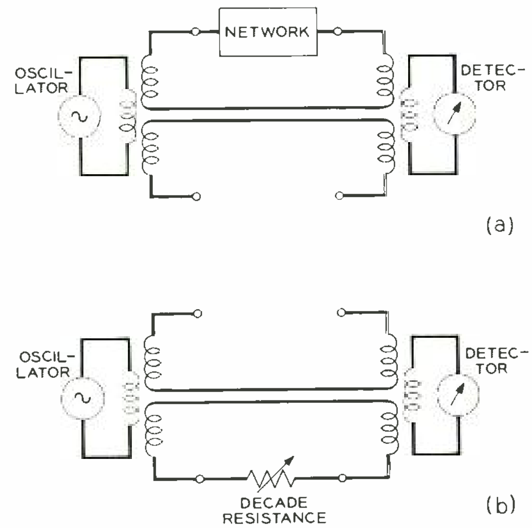
In measuring the insertion gain of negative-impedance repeaters with an E-repeater test set, the telephone lines themselves are used as terminating impedances. The test voltage and current-measuring detector are connected in series with the line through very small impedances so as not to affect the gain and stability of the repeaters. The low-impedance voltage source is an oscillator working through a step-down transformer with an impedance ratio of 600/2 ohms. The low-impedance side, consisting of two equal, well-balanced windings, is inserted into the line on one side of the repeater, to form a balanced-to-ground circuit, Fig. 1(a). The current-measuring detector is connected in series with the line through an identical transformer on the opposite side of the repeater.

The insertion gain of an E-type repeater is mea-

* RECORD, *August*, 1954, *page* 281.

sured by first establishing a reference condition without the repeater, and then measuring the increase in transmission when the repeater is inserted in the line. The change in line current is a measure of the insertion gain, and the current-measuring detector is provided with a db scale so that the change in transmission can be read directly in db.

Simplicity of operation is attained by using a multi-position rotary switch to make all connections necessary for the various tests. Five positions of the switch are used for transmission purposes; one reference and four measure conditions are required for determining the gain (or loss) of an individual repeater or any combination of them used in the telephone plant. Connections to E1 repeaters are made through appropriate cords and plugs while E2 and E3 repeaters are plugged directly into the test set. While the E-repeater test set was designed primarily for testing and maintaining E-type re-



g. 3 — The magnitude of an unknown impedance is deter- ned by adjusting the decade resistance until transmission ·ough it (b) is the same as that through the network 'ng measured (a).

peaters, convenient jacks have been added to make the test set adaptable for general field usage. With the jack-ended connections, it is possible to measure insertion gains or losses in lines using other types of telephone repeaters.

Sometimes a particular E-type repeater connected in a line will not meet transmission objectives with the predesigned configuration of the repeater impedance networks. This failure to meet requirements is, in general, caused by an impedance irregularity in the line, such as a missing loading coil or a missing repeating coil. In certain of these cases, it may be expedient and less costly to trim up the network design at reduced gain than to open up the cable to correct the difficulty. Trial strapping arrangements of the built-in repeater networks would require many soldered connections. Therefore, identical jack-ended networks have been included in the test set so that trial gain-adjusting networks can be easily and quickly patched up.

Occasionally, low values of return loss* at repeater points will limit the gain so that transmission objectives of a line cannot be met. Low return losses are caused by large impedance discontinuities in the line, such as defective loading coils, faulty repeating coils, or the joining together of two unlike wire facilities. Since these conditions must be cleared, it is important to know exactly where the trouble spots are located along a line. Their location can be determined quite accurately if the im-

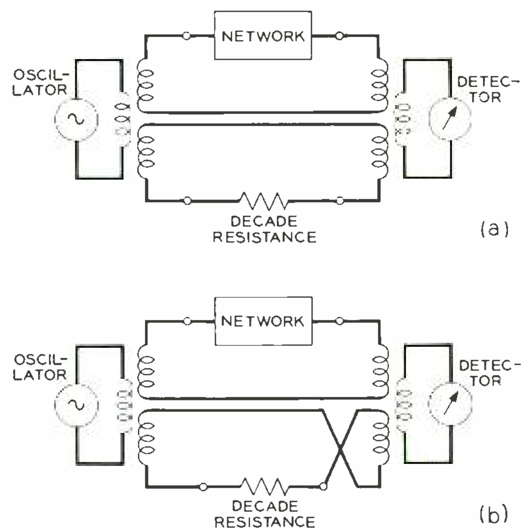


Fig. 4 — Phase angle of an impedance is proportional to the difference in transmission through two equal magnitudes for additive (a) and subtractive (b) polings of one transformer winding.

pedance characteristics of the line are known over the voice-frequency spectrum. As an aid in locating these irregularities, an impedance-measuring circuit is included as part of the E-repeater test set.

In measuring impedances, the test-voltage source and current-measuring detector are connected to the 600-ohm windings of the two step-down trans-

* Return loss is a measure of the equality between the output impedance of a line or network and its terminating impedance. For equal impedances, the return loss is infinite; it decreases as the impedances become further mis-matched.

formers used for making transmission tests. The unknown impedance is connected between the two transformers, Figure 3(a), and a reference measurement established. The decade resistance is then substituted for the unknown, and its value adjusted until the measured current is the same as the reference current. The ohmic value of the impedance is that read from the dials of the decade resistance.

With the magnitudes of the decade resistance and the unknown impedance equal, the phase angle of the unknown impedance can be determined by comparing the transmission for two polings of one of the low-impedance transformer windings. The reference poling, Figure 4(a), is a measure of transmission where the unknown and standard branch currents in the detector winding are additive. In Figure 4(b), one of these two currents is subtracted from the other. The difference between the two detector indications is the return loss between two impedances equal in magnitude but differing in phase-angle. Since the phase angle of the resistance standard is zero, the return loss is a function only of the phase angle of the unknown impedance. A chart, Figure 5, is supplied with the test set for finding the phase angle.

Once the value of the phase angle is found, it is necessary to determine the "sense" – that is, whether the angle is positive or negative. With the test set in the condition of Figure 4(b), a new reference-current value is set up by connecting a small capacitor across the resistance standard. The capacitor is then switched across the unknown impedance. A decrease in transmission indicates a positive impedance angle while an increase indicates a negative angle. For a positive return loss, the phase angle is between 0 and 90 degrees; for a negative return loss, the angle is between 90 and 180 degrees.

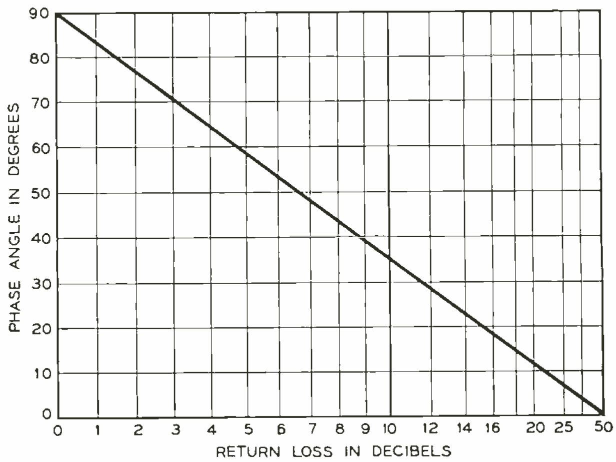


Fig. 5 — Phase angle is proportional to return loss.

Physically, the test set is a portable unit 12 by 15 by 8½ inches in size. The multi-position switch and decade resistance standard are mounted on a sloping part of the front panel for convenience; the main jack field is below on a vertical front section of the panel. Connections to E1 repeaters, E2 and E3 repeater lines, and power facilities are made through receptacles on the right side of the test set. The E2 and E3 repeaters plug into sockets at the rear of the top plate, as in the headpiece.

The increasing use of negative-impedance repeaters in the telephone plant makes the new test set an ever more valuable tool. In addition, its adaptability to various transmission, return loss, and impedance measurements makes the E-repeater test set a useful adjunct to other testing and measuring equipment.

THE AUTHOR

J. O. SMETHURST, after receiving the degree of B.S. in Communications from Tufts College in 1929, joined the Laboratories that same year. For many years he was concerned with overseas telephone circuits, concentrating especially on control terminals for such circuits. He was associated with Government projects during World War II, and subsequently was engaged in the NIKE guided missile project. Since 1953, Mr. Smethurst has concentrated on E2 and E3 negative-impedance repeaters for voice-frequency lines.

New Military Carrier Telephone Systems

C. W. SCHRAMM

Military Communication Development

Because military carrier telephone systems proved their worth during World War II and in the Korean campaign, Bell Telephone Laboratories was given the job of developing new and much improved equipment for such service. As a result of this development work, the armed services now have available four- and twelve-channel cable carrier systems that can operate together and can be used with companion radio-relay links.

The military organization is quite cognizant of the importance of carrier telephone systems and is relying more and more upon this communication means. Such carrier systems played an important part during World War II and were used even more extensively in the Korean campaign. The CF-1 carrier telephone terminal was used in providing the carrier communications during these periods. Recently, however, two new and much improved carrier systems have been developed by the Laboratories for tactical operation in combat areas. This is part of an extensive program intended to increase the flexibility of the military communications network. These systems consist of a four- and a twelve-channel carrier telephone system developed for operation over a new type of spiral-four cable recently designed for military use.

The four-channel system was designed to operate over loaded cable for distances up to 100 miles, with repeaters spaced at about 25-mile intervals. The frequency range used by the four carrier channels is 4 to 20 kc. There is, in addition, an order wire channel using frequencies below 4 kc.

The twelve-channel system was designed for operation over a nonloaded cable for distances up to 200 miles with attended repeaters spaced at intervals of about 40 miles, and unattended repeaters about every 6 miles. The frequency range used by the twelve carrier channels is 12 to 60 kc and there is, again, an order wire channel using frequencies below 4 kc.

The four-channel terminal is a self-contained, ac operated unit. It is assembled in two man-transportable, shock-mounted cases. The larger case houses the common amplifying and equalizing equipment, carrier supply, power supply and auxiliary circuits. These auxiliary circuits consist of alarm, ringing, and measuring circuits, and wide-band connecting and switching facilities. The smaller case contains the four individual channel modems (modulator and demodulator units). Each channel contains a transmitting and receiving section, and a flexible switching circuit. This arrangement provides the means of meeting a wide variety of operating conditions.

The four-carrier channels use lower side-band transmission with the carrier suppressed. Each of the channels is capable of carrying one voice circuit, or up to sixteen Teletype circuits. The fifth channel (order wire) is a voice circuit used for maintenance purposes by operating personnel.

Each four-channel repeater is a self-contained unit, assembled in a single shock-mounted transit case. Such a repeater provides equalization and amplification for signals received from either direction over the spiral-four cable. It also contains an order wire, measuring circuit, and ringing circuit. These circuits have similar functions in both the terminal and the repeater. The measuring circuit is used for equalizing the system and for testing circuit performance. The ringing circuit is provided for establishing contact to repeater or terminal attendants.

The transmission medium over which this system will generally operate has the characteristic of increasing loss with higher frequencies. Therefore, some "equalization" must be introduced into each line section to complement the line losses so that transmission levels at all frequencies in the band will be approximately equal. This is done by adding adjustable equalizers, and the range of these controls gives considerable flexibility as to the type and length of lines over which the system can operate.

Correcting the loss adjustments with time and temperature is called "regulation," and in some types of systems this is a separate operation. In the four-channel system, however, both equalization and regulation are accomplished by one set of manual controls which are adjusted by an attendant as he observes the transmission over the several channels. In fact, the regulation is accomplished on an "in service" basis by adjusting a control while the transmission is being observed on the order-wire channel. This equalization and regulation of the four-channel system depends largely on the selection of a particular loading inductance. By using a value of 6 millihenries, it was possible to secure the desired attenuation, and also to provide a transmission characteristic that could be equalized by simple line-loss compensation and control.

The twelve-channel carrier system, consisting of two terminals and a number of attended and unattended repeaters, is capable of operating over distances up to 200 miles on the new nonloaded spiral-four cable. This system provides twelve voice frequency message channels, derived from three of the telephone modem units previously mentioned. It also has an order wire circuit and facilities for transmission of wide-band signals over any four adjacent channel bands or over the entire band occupied by the twelve channels.

The twelve-channel system uses a band of fre-

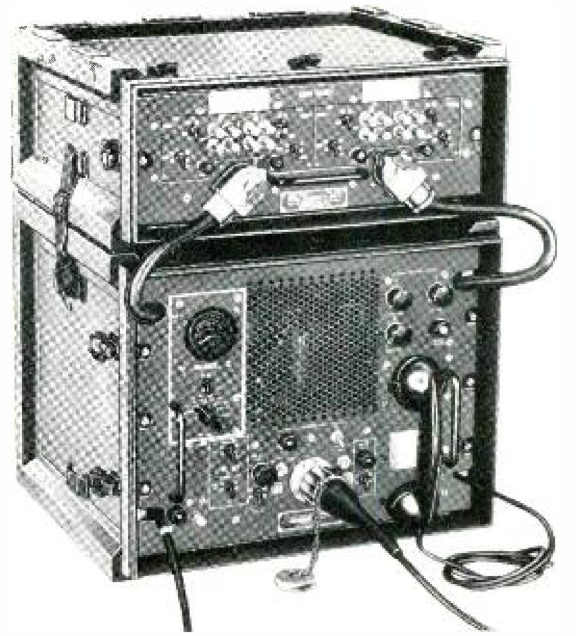


Fig. 1 — Four-channel modem unit mounted above its associated amplifier-power supply.

quencies 48 kc wide. Three steps of modulation are used to develop the frequencies within this band. The first step occurs in all three telephone modem units where a band of frequencies from 4 to 20 kc is developed. A second step of modulation, using the upper side-band frequencies, raises the channels to the 60- to 108-kc band. This is done by modulating each one of the three telephone modem units with a different carrier frequency; carriers of 56, 72, and 88 kc are used. In the third modulation step, a 120-kc carrier modulates with the 60- to 108-kc band to translate the channels to their line frequencies between 12 and 60 kc. This frequency range is the same as that used in the Bell System multichannel facilities and has been selected to simplify the line regulation and equalization problems to the greatest possible extent.

To demodulate the 12- to 60-kc band in the receiving direction, these same modulation steps are reversed. All of the carrier frequencies for the three modulation and demodulation steps are derived from a 64-kc crystal-controlled oscillator stabilized by thermistors.

The equalization of this system has been arranged to provide a flat response over a 200-mile system with all cable sections and repeaters at a temperature of 45 degrees Fahrenheit. When the temperature varies, the cable attenuation changes in a predictable manner. Automatic regulation supplemented by manual adjustments compensates for these attenuation changes due to temperature. Because the recently designed spiral-four cable has a more uniform loss-frequency characteristic than previously used cables, only one pilot tone is required for automatic regulation. Transmission for a 200-mile system over the 48-kc band may be equalized well within ±2 db, and the automatic regulation will hold this to less than ±3 db for at least a ±30 degree temperature change.

Equalization of the twelve-channel system is somewhat more complex than that of the four-channel system. The larger system uses a basic equalizer at the terminal, and at both the attended and unattended repeaters. This equalizer provides loss which compensates for transmission variations in the five-and-three-quarter-mile cable lengths (distance between unattended repeaters). In addition, a deviation equalizer is located in each terminal and in the attended repeaters. This equalizer corrects the various deviations at the attended points, and also corrects any failure of the basic equalizers to compensate exactly for the cable loss. At the attended points, adjustable cable loss is made available in steps corresponding to a range from one-quarter to five and one-quarter miles. These so-called "building-out-networks" allow flexibility in the positioning of system attended points. Each attended point also has flat, slope and bulge equalizers. The slope and bulge equalizers provide control of the equalization at 68, 28 and 12 kc. These controls are necessary to correct for the departures of the cable and the equipment from their design center values, and to compensate for temperature variations.

Power for each attended point is supplied from its own regulated power supply. In addition, these attended points deliver power over the cable for a maximum of three unattended repeaters. At terminals this power is supplied in one direction and at the repeaters, in both directions. The supply delivers a constant current of 100 milliamperes at 600 volts dc to the line. High- and low-voltage alarm circuits remove the power from the cable under trouble conditions for the protection of personnel and equipment.

Terminals and attended repeaters also have complete transmission testing facilities. These measuring sets, plus a portable set for in-service testing of the unattended points, make available a means for complete system line-up and maintenance. Using this equipment, it is also possible to locate unattended repeaters that are in trouble.

A unique feature of the portable test set is a transistor oscillator used as a 1600-cps signaling source. The unit is powered from the rectified output of the lineman's hand-operated generator. This arrangement makes use of the rapid starting property of the transistor and is probably one of the first applications of a transistor in quantity-produced military equipment.

The military carrier telephone systems described in this article have been developed to meet the needs of military service in global warfare. These needs have imposed severe requirements on the design of the equipment in many respects. As a result, circuits have been developed for great reliability with simple operating procedures, automatic alarms for good maintenance practices, and great flexibility as to usage. In addition, the equipment has been made rugged, compact, light in weight and capable of operating over a very wide range of temperatures and humidities.

THE AUTHOR

Charles W. Schramm received his degree of B.S. in E.E. from the Armour Institute of Technology, now known as the Illinois Institute of Technology, in 1927. Mr. Schramm was associated with the Toll Transmission Engineering Department of the Illinois Bell Telephone Company from 1927 to 1929. He joined Bell Telephone Laboratories and has assisted in the development of a number of carrier systems for telephone message circuits as well as for the transmission of radio programs. During World War II he was engaged in the development of microwave resonant cavities and their military applications. Since the war he has been concerned with coaxial transmission systems and military carrier telephone systems. He is a member of the American Institute of Electrical Engineers, Institute of Radio Engineers and Eta Kappa Nu.

Magnetic Test for Relay Cores

B. Stauss holds the armature clamped against a relay core being tested while he operates the test switch. After operating the switch to the left, back to normal, then to the right, releasing the armature will complete the test.

Relay operation depends to a large extent on the magnetic properties of the relay structure. Relay armatures and cores, for example, can have vastly different magnetic properties, even though made from the same lot of ferromagnetic material. Conventionally, magnetic properties are determined indirectly from studies of the hysteresis loop of a material, measured on an especially-made ring sample. Once this curve has been determined for a specimen, three points are of interest: (1) the magnetic flux density at some fixed value of magnetizing ampere-turns in the region of magnetic saturation, (2) the maximum permeability, and (3) the coercive force.

When measurements are made on a relay with a fixed magnetizing current, the magnetization is greatly affected by the air-gap between armature and core. The parts must be carefully set and aligned to determine accurately the magnetic contribution of the material alone; this is not convenient for large-scale testing. Furthermore, the air gaps tend to mask the magnetic contribution due to the material, resulting in reduced accuracy of the measurements. Only the coercive force remains unaffected by changing air gaps; the same negative magnetomotive force value on the decreasing magnetization curves applies for all gaps when the flux is exactly zero.

In the development of the wire-spring relay, it was desirable to have a simple, rapid test of armature and core properties that would provide a reasonably accurate classification of their general magnetic qualities. Since a high value of maximum permeability is usually associated with a low coercive force, a measurement of the coercive force

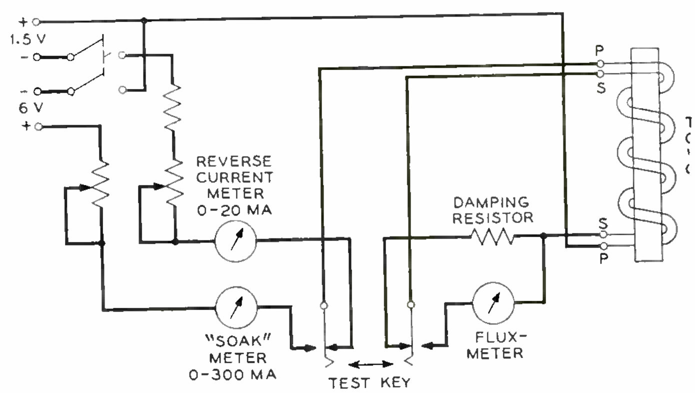


Fig. 1 — Circuit of the test set. The test key is operated to the left, to normal, and then to the right for the indication on the fluxmeter.

alone was considered a satisfactory screen to indicate whether a more exact examination of the magnetic properties would be necessary. A test set was therefore designed for use with AF, AG, and AJ wire-spring relays that provides the necessary information on coercive force quickly and easily.

When a piece of iron or other ferromagnetic material is magnetized, it retains a small amount of residual magnetism after the magnetizing energy is removed. To remove the residual flux completely, an opposing magnetic field is required. The value of this field is equal to the coercive force, as shown in Figure 2. Since the magnetizing force H is equal to a constant times the ampere-turns NI divided by the length of the magnetic path, the coercive force (in terms of H) is directly proportional to some value of NI for a given core length L.

The test set, Figure 1, uses a fixed coil with two low-resistance windings. Wound together, they produce identical fields when the currents through them are equal. They have 1,000 turns each and therefore current values in milliamperes give a direct indication of the number of applied ampere-turns. A core is slipped into the fixed coil, and the armature is then clamped tight to the core. The test key is first operated to the "soak" position, where a large magnetizing current is applied through one coil winding. When the key is returned to normal, a small reverse current is applied to the same winding, in such a direction as to cancel any residual magnetism. Finally, the key is operated to connect the flux-meter in series with the second winding, while maintaining the small reverse current in the first winding. If the reverse current was not of the correct value, some residual magnetism will remain; there may even be a small amount of magnetization in the reverse direction.

The armature, previously held tight against the core, is then mechanically opened. Any residual magnetism remaining will be indicated by some movement of the flux-meter pointer. The test procedure is repeated with different values of reverse current until the flux-meter shows no movement, and the reverse current in milliamperes then indicates the coercive force in ampere turns.

The advantage of this type of measurement is that it is a null balance and is nearly independent of the mechanical fit of the relay parts and the velocity with which the parts are separated. When the reverse current is just sufficient to demagnetize the core, there is no magnetic flux through the pole-face gap, regardless of the position of the armature. This permits large-scale testing without requiring adjustment for fit of the pole-face pieces.

When large-scale testing of magnetic properties is desired to determine tolerance within specified

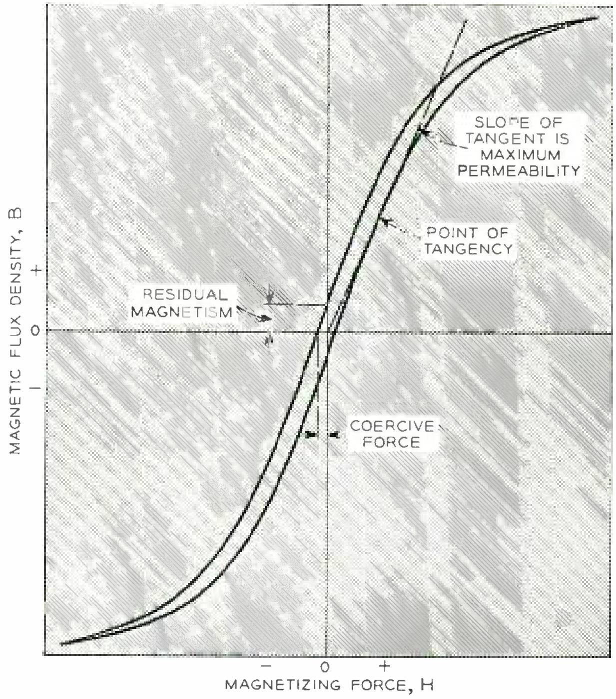


Fig. 2 — The magnetic conditions of interest are shown by a hysteresis loop.

limits, standard test armatures and cores are used. A standard armature is used when testing cores, and vice versa. The reverse current is preset to a standard value; a deflection of the flux-meter then indicates that the part under test varies from standard, and in which direction. The test set can, of course, be used for similar measurements on other magnetic structures by simply changing the size and shape of the coil and its mounting.

B. Stauss
Switching Apparatus Development

A New EA Type Relay

F. A. ZUPA *Component Development*

Better performance and lower cost of telephone apparatus and equipment are constant objectives of Bell Telephone Laboratories. In cooperation with the Western Electric Company, it has frequently been possible to make design modifications in existing apparatus which achieve these objectives. An example of this is the E type relay, which appears in almost all telephone customers' line circuits. Changes in design since World War II have produced the EA type relay, and recently, further improvements have resulted in a still more efficient and lower cost EA type design.

One of the widely used types of relays in the Bell System is the EA type relay. Annual production of this type is now about 2,600,000 – because almost all telephone customers' line circuits require either one or two of these relays. In recent new installations of equipment for the crossbar systems, one EA type relay is used as the line relay; in new step-by-step systems, one is used as the line relay and one as cutoff relay.

The EA type relay was introduced after World War II, when large production of E type relays followed rapidly increasing demands for telephone service. Modifications proposed for the E type prior to the war were then introduced to obtain very substantial savings, and the redesigned relay became known as the EA type.* Several new designs of line and cutoff relays were also evaluated at this time, but none was found that would warrant the replacement of the EA type. This inspired further efforts to improve the EA design, with the result that additional gains of considerable magnitude have been obtained, both in reduced manufacturing cost and in the over-all improvement of performance.

Basically, the EA type relay design is still the same as the flat type relay design introduced many years ago by the late E. B. Craft, then Chief Engineer of the Western Electric Engineering Department, the forerunner of Bell Telephone Laboratories, and subsequently Executive Vice President of the latter. In both the E and EA type designs, the relay core and armature are simple punchings from 0.109-inch thick sheet iron. The rear end of the core has two lugs, formed at right angles to the core, which serve to mount the relay. The rear end of the core, just forward of the mounting lugs, is also widened to permit the attachment of two separate contact spring pileups. The armature is supported by a thin soft iron reed in the E type and in the older EA type design, which serves as the hinge for the armature. In the new EA design the hinge material is stainless steel, to withstand the greater forces developed by virtue of the hinge gap magnetic shunt to be described later. Contact springs are flat reeds of nickel silver and the electrical contacts, arranged on them in single pairs for each switching element, are welded to the springs.

* Record, *August*, 1948, *page* 340.

Palladium capped contacts only are employed on the EA relays because these relays are generally used in talking circuits. Each stationary spring has an adjustable tab which rests on a spoolhead notch, from which the name "spoolhead spring" is derived. The spoolhead is a phenol fibre punching with a centrally located rectangular slot making a tight fit on the knurled portion of the core just in front of the coil. The moving contact springs are actuated by the armature through hard rubber studs; some of the studs have a brass wire insert for added strength. Although a single relay has a capacity of operating 12 contact springs, six in each pileup, some of the relay codes have only one pileup of three contact springs. The coils for EA type relays, as already described in a previous article,* are form-wound with cellulose acetate insulation between each layer of wire. Each coil is slipped over the front end of the core and bonded to the cellulose acetate facing on the rear spoolhead. The rear spoolhead is also phenol fibre and is secured to the core in the same manner as the front spoolhead.

As illustrated by Figure 1, the recent changes that have been made on the earlier EA design are (1) the elimination of the adjustable backstop stud and nut for the armature, (2) the addition of armature backstop lugs as an integral part of the front spoolhead, (3) bridging the hinge gap at the rear end of the armature legs by a magnetic shunt, and (4) changing the armature hinge material from zinc plated magnetic iron to stainless steel.

On the earlier EA relay design, like that of most of the various types of neutral relays, a screw stud was riveted to the front end of the core and a special lock nut on it was used as the adjustable backstop for the armature. The position of the backstop nut determined the distance that the armature would travel during the operation of the relay, and the magnitude of the armature travel was a requirement fixed by the type of contact spring combination to be actuated.

To adjust the millions of EA type relays manufactured each year, therefore, the practice has been to insert a prescribed thickness gauge, the thickness varying with the spring combination, between the armature and the core, and to turn the backstop nut until the gauge just fitted. Since the armature travel was a specified engineering requirement, each relay was subject to inspection for that requirement during manufacture of the relay and at later stages of the assembly of the equipment using the relays. Consequently, from a manufacturing cost standpoint, the armature travel requirement has been an appreciable item in the adjustment cost of each EA relay; hence the elimination of this requirement represents an important cost saving. In addition to this adjustment cost saving, there is also the reduction in cost derived from the elimination of the adjusting stud, the backstop nut, the broaching operation on the stud hole in the core, the stud riveting operation, and the initial assembly of the backstop nut.

The engineering basis upon which elimination of the adjustable feature of the armature travel on the EA relay design is justified, was determined by the following analysis.

When the relay coil is energized by the operating current, the resulting magnetic forces exert a pull on the armature. The magnitude of that pull, plotted

Fig. 1 — Earlier EA relay using the adjustable armature backstop nut (left), compared with the new EA relay using the fixed spoolhead backstop and the magnetic shunt.

* Record, *August*, 1948, *page* 340.

graphically in Figure 2, follows a typical curve P-P′ for the earlier EA type design. This shows that as the armature moves from its backstop toward the core, the pull on the armature rises at an increasing rate. The load corresponding to the contact spring tensions of a frequently used combination as the armature actuates the springs, changes in value as indicated by the broken lines L-L′. The load values represented by the lines L-L′, the lower boundary of the shaded area, are the averages of the load values that can be actuated by the earlier EA design. Frequently, with the older EA type relays, the nominal spring load is much less than the pull at any point in the travel of the armature.

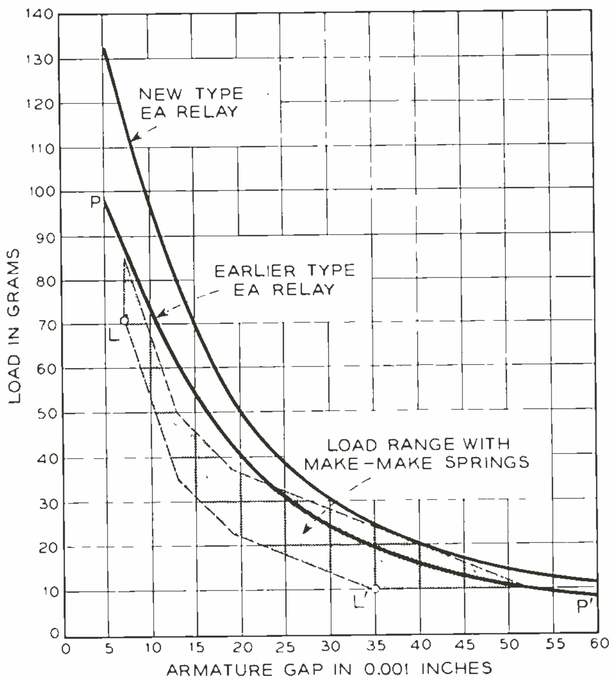


Fig. 2 — Typical magnetic pull curves and contact spring load characteristics for the new and old EA type designs of relays.

It is shown, therefore, that the armature travel can be increased considerably beyond the value required for the specified contact gaugings, as long as the load due to the springs is not greater than the available magnetic pull at any instantaneous gap.

This analysis shows that the armature backstop can be a fixed point, such as a projecting lug on the front spoolhead, provided the fixed point will assure the minimum armature travel required by the contact spring arrangement on the relay. This is accomplished on the new EA type relay by locating the lug relative to the core poleface at a distance which takes into account all the manufacturing variables in

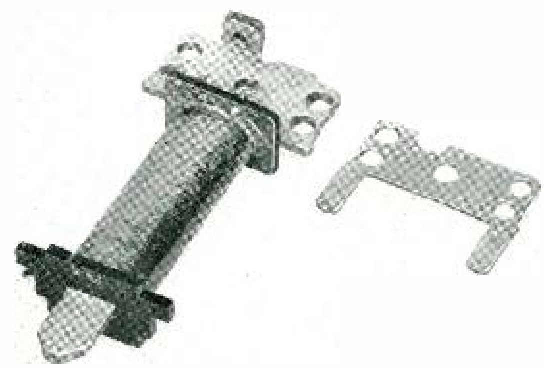


Fig. 3 — New EA relay coil assembly, spoolheads with backstop lugs, and the magnetic shunt.

producing the assembled relay. The contact spring arrangements used on all the EA type relays were analyzed for the minimum number of fixed armature travel values required for satisfactory adjustment, and it was found that three different fixed travel values would be sufficient. Only three front spoolheads, therefore, each of which represents a different travel, are required. Although only one lug on each spoolhead is needed for the armature backstop, two have been provided. The geometry of their location is such that any misalignment of the armature or the spoolhead will reduce the resulting armature travel. That is, the maximum travel is obtained only when the parts are in perfect alignment with each other.

With the fixed armature travel arrangement, the travel that may be encountered on a relay may be considerably greater than the former maximum travel provided by the adjustable backstop. The added travel results from compensating for the misalignment of the spoolhead and armature relative to the core and for the dimensional tolerances of the spoolhead backstops. All of these tolerances have to be added to the minimum travel necessary to meet the contact spring adjustment requirements in establishing the distance of the backstop lugs from the core pole face. When the misalignments are not present, the resulting travel will consequently be equal to the minimum travel plus all the tolerances. To avoid the necessity of having very light forces returning the armature to the fixed backstop, when the backstop is at a maximum distance from the core pole face, the magnetic pull of the relay has been increased by providing a magnetic shunt across the armature hinge gap. This magnetic shunt, as shown in Figure 3, is a simple low-cost punching of sheet iron mounted in the spring pileup assembly. Its effect is to reduce the magnetic reluctance between the rear end of the core and the armature legs, and thereby increase the magnetic flux in the working air gap. Since the magnetic pull varies directly as the square of the flux density in the working air gap, and the hinge gap reluctance on the earlier EA type relay is an appreciable part of the total reluctance, a marked gain in pull capability was obtained. The net gain was found to be from 25 to 35 per cent, as indicated by the pull curves of Figure 2. With the improved magnetic pull, the permissible load range that can be actuated by the relay is therefore much greater, as indicated in Figure 2.

From a manufacturing cost viewpoint, the design of the magnetic shunt was carefully worked out so that it would not impose any added restriction on the simple soft iron reed hinge already in use. The legs of the magnetic shunt are offset to make an angle of about 1¾ degrees with the longitudinal axis of the core so that they will not touch or interfere with the armature legs. The angle of the offset represents the maximum angle which the armature subtends at its maximum open gap position.

Since the basic cost of the EA relay structure is appreciably lower than that of the larger neutral relays, its large demand is expected to continue. Design changes which lower its manufacturing and maintenance costs with no sacrifice of its operating range or service performance are, therefore, of especial interest to the Bell System. To safeguard the service performance expectations for this relay, conclusive laboratory tests were made to determine the characteristics of the spoolhead backstop from the standpoint of wear and stickiness – especially the latter – since line relay armatures had been known to stick against the backstop nut before the use of chromium finish. Test results show that the spoolhead backstop compares very favorably with the older EA relay design that made use of the chromium plated backstop nut.

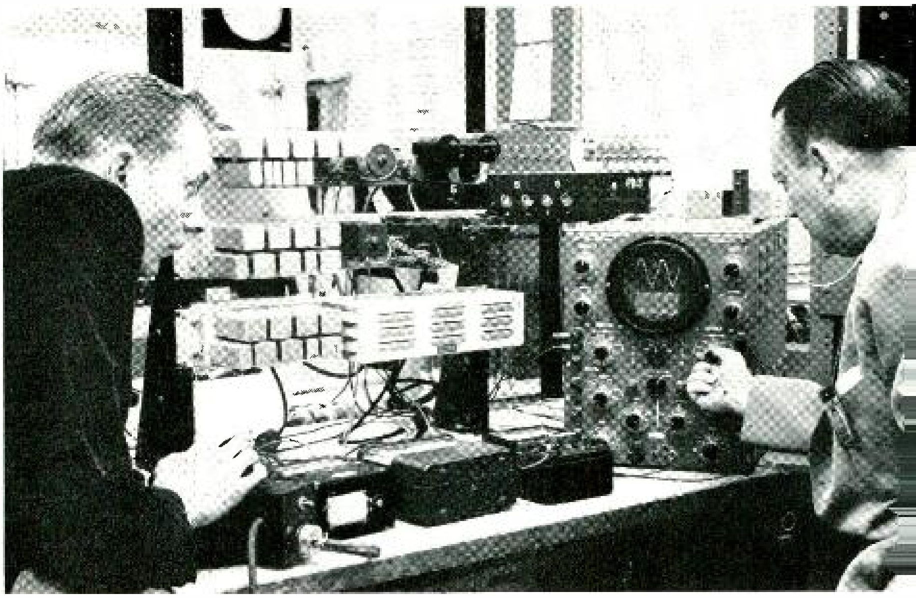
Fig. 4 — Evelyn Winkler measures the distance between the spoolhead backstop and core pole face.

The earlier EA type relay design and its redesign have been obtained with very little manufacturing preparation expense. For the older EA relay, tools were already available, except for the front and rear spoolheads and for the core; the redesign required only a new front spoolhead tool and one for the magnetic shunt. Consequently, manufacturing costs of both EA designs have been kept relatively low, so that, although newer designs have been proposed for performing its duties, the EA type design, because of its very satisfactory performance and low cost, continues to maintain its position in the Bell System. The improvement in operating capability provided by the magnetic shunt also makes it feasible to use the new EA type design in place of some codes of more costly relays, such as the R type.

THE AUTHOR

Frank A. Zupa joined the Physical Laboratory in 1918. He was engaged in the testing of component apparatus and materials, including photomicrograph work, until 1924. Then he transferred to the Apparatus Design Department where he was engaged in design and development work on neutral and polar types of relays, particularly in the design of the U, Y and UA types. During the war, Mr. Zupa carried out the design of packaging the optical proximity fuse, and was in charge of a group engaged in testing of the magnetic mine mechanism. Presently he is in charge of the group engaged in the engineering of relays and message registers. Mr. Zupa attended C.C.N.Y. and Cooper Union, at night. He received the degree of B.S. in E.E. from Cooper Union in 1922.

Harmonic Generators for Telephone Tones



Telephone users hear dial, ringing, and busy tones, but many other tones are also needed in a central office. Recent developments have made available a new line of tone generators that have no moving parts or electron tubes. These units are small, efficient, and low in cost, and they produce stable, high-quality tones for various telephone uses.

A. B. HAINES *Power Apparatus Development*

Audible tones and signals of various types play an important role in the operation of the modern telephone system. We are all familiar with some of the tones used to advise the telephone customer of the functioning of the system – such as dial tone, which tells the calling customer that the "mechanical" operator is ready to handle the call; audible ringing tone, which tells him that the called party's bell is being rung; and busy tone, which tells him that the called party's phone is in use. Other types of tones with which most of us are perhaps not so familiar are those employed by operators for checking trunks, routing calls, handling coin collections and returns on pay station phones, and the like.

In the past, these tones have been generated in telephone ringing plants by various mechanical means. In very small offices, such tones as dial and busy tones and operator's tones were produced through the use of vibrating relays or reeds. These operate from dc battery in combination with other circuit elements, such as coils and capacitors, to produce the audible signals. In larger offices, rotary drum interrupters have been used for interrupting battery to produce high frequency tones. In the still larger offices, rotary tone alternators have been employed. These various tone-generating mechanisms, with the possible exception of the tone alternator, are characterized by relatively high initial cost as well as by high maintenance expense for contact cleaning, replacement, and care of moving parts. In addition, the tones produced, particularly from the vibrating relays and rotary interrupters, involve problems in controlling the quality and stability. In most instances, in older-type offices, audible ringing tone was obtained by using the high frequency noise or ripple produced from the generator slots of the machines used to supply 20-cycle ringing current. This system is difficult to control and it results in low quality of tone and other undesirable performance characteristics.

In recent years, a new type of tone generator operating on magnetic principles has been developed to produce many of the tones used in telephone offices. This new type of generator has no moving parts or electron tubes and is therefore completely static. Depending upon the design, these generators can produce a single frequency, say 600 cycles, or a combination of frequencies with a desired low frequency modulation or sideband pattern when operated from 60- or 20-cycle power sources. The units are characterized by low initial cost, freedom from maintenance, and long life. In addition, the quality and stability of the tones have been substantially improved.

A number of different arrangements have been employed in these generators, but the basic principle of operation can be explained with the aid of Figure 1. At the top of this illustration are two circuits of the sort used in the lower-power tone generators. We use a transformer (T1) whose core is highly saturable magnetically, and in series with the primary circuit we place either a linear inductor (L1) or a linear capacitor (C1). The current which flows from the source through the circuit is controlled by the non-linear impedance characteristic of T1 and is highly non-sinusoidal, even though the driving voltage at the input is of sinusoidal form of frequency f_1. The voltage drop across the linear element (L1 or C1) then produces a non-sinusoidal voltage across T1. This voltage will consist of the input frequency f_1 plus its odd harmonics f_3, f_5, f_7, f_9, and so on. Sometimes a capacitor (dashed lines in the figure) is placed in the secondary circuit to increase the amplitudes of the harmonic frequency components. For higher-power generators, a more novel arrangement has been used. All functions of the elements in the above lower-power unit are performed by a single transformer, in which inductor L1 is replaced by a third winding on the center leg of a three-legged core structure. Such an arrangement has a number of advantages, including increased power, efficiency and regulation as well as size and weight reductions.

A typical complete tone generator circuit is indicated in block form in the lower part of Figure 1. After the harmonic generator (A), a frequency doubler (a rectifier arrangement) circuit (B) is used if it is necessary to convert the odd harmonics to even harmonics. A selective network (C) then filters or shapes the train of harmonics into the

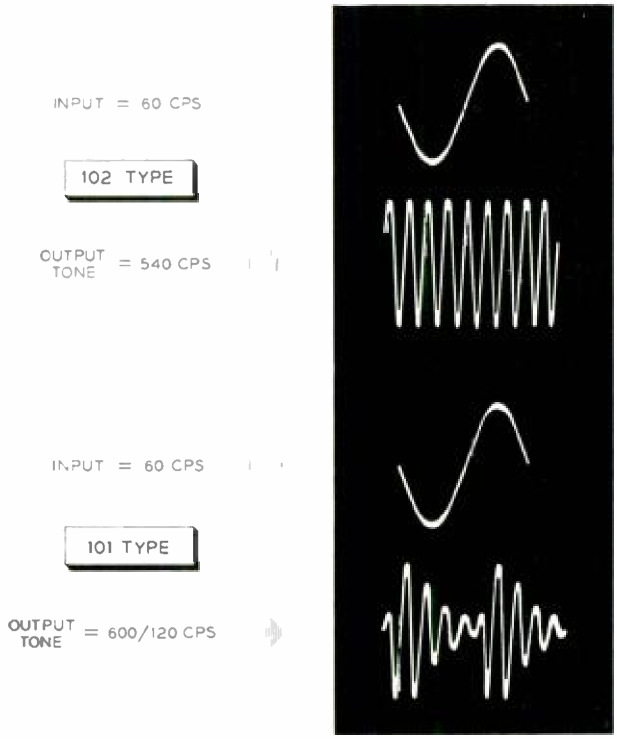
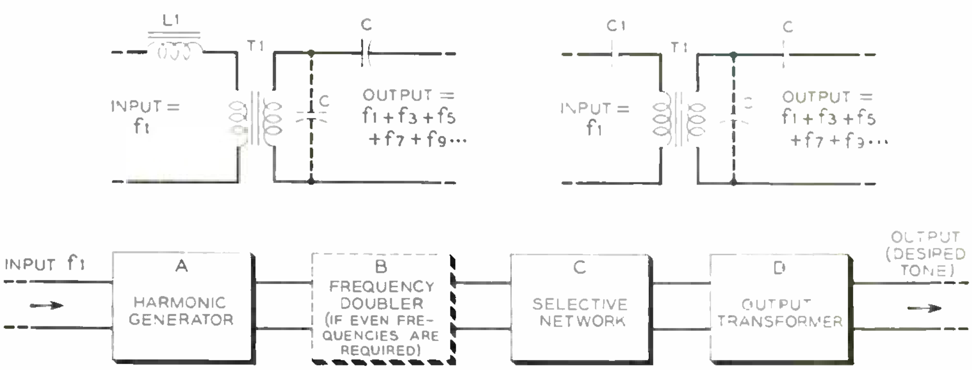


Fig. 2 — Input and output voltages of the 101- and 102-type tone generators for use in small dial offices.

desired tone pattern. Finally, an output transformer (D) provides necessary levels of tone and matches the impedance of the generator to that of the load to obtain maximum efficiency.

A line of these harmonic generators has been developed and is now in manufacture by the Western Electric Company. These consist of units of various sizes, tone power ratings, and output tone characteristics. The 101- and 102-type generators are

Fig. 1 — Simple circuit for harmonic tone generation, above, and block diagram of complete tone-generator circuit, below.



employed primarily in small dial offices such as the 355 and 356 types and are part of the 806D, E, and F ringing power plants. They operate from commercial 60-cycle power and produce about 25 milliwatts of useful tone energy. The 101-type produces a 600-cycle tone modulated at 120-cycles for dialing and busy tones. The 102-type produces 540-cycles (ninth harmonic of the fundamental) for operator's trunking and "zip" tones. Figure 2 indicates the input and output voltage wave-forms of these types of generators. DC output is also available in each of these generators for the operation of transfer and alarm relays. Each of the units is assembled in a small metal case for panel mounting and is equipped with input cord and plug and solder-type output terminals.

Larger generators, such as the 104 and 105 types, have been developed to produce the same tones as described above but with substantially larger tone-power capacity, about 500 milliwatts output. These generators are mounted on 23-inch relay racks with suitable covers, and they weigh about 20 pounds each. They are designed primarily for use in the 805C ringing power plant for No. 5 crossbar offices and provide adequate tones to handle from 12,000 to 15,000 busy-hour calls or to serve about 20,000 directory numbers.

Additional harmonic generators, the 103 and 106 types, are available for operation from 20-cycle ringing machines. These produce tones of 420 cycles modulated at 40 cycles to be superimposed on the 20-cycle ringing current for audible ringing tone. The 103 type was developed primarily for use in No. 5 crossbar ringing power plants and has an output power of about 75 milliwatts. The 106

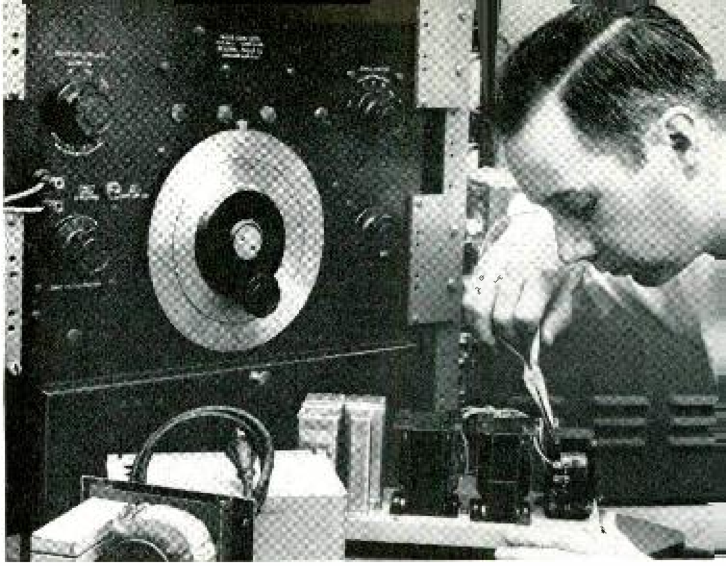


Fig. 3 — W. T. McMahon changing connections on tone generator in preparation for measuring harmonic output.

type is for use in larger plants such as the 840C plant for large crossbar offices, step-by-step systems, and the No. 11 manual system. It has a tone capacity of about 400 milliwatts.

All of these harmonic generators have been designed with major emphasis on low cost, and they utilize standard parts and components and low-cost magnetic materials as far as possible. As to future development in this new field of apparatus, progress is being made in the study and use of new types of magnetic materials and improvements in circuitry to obtain improved performance, increased tone efficiency and ratings, as well as reductions in size and cost. It is anticipated that frequency generators will be developed in the near future for many types of tones with outputs in the order of several watts of tone power, which will be competitive with the rotary-type tone alternators now used in larger telephone offices.

THE AUTHOR

A. B. Haines received a B.S. degree in Electrical Engineering from Virginia Polytechnic Institute in 1930 and joined the Transmission Apparatus Department at the Laboratories in that same year. He was engaged in the design of power transformers, inductors and harmonic generators, and in fundamental studies on power devices until 1945 when he was put in charge of a group engaged in these activities. In 1947, Mr. Haines was made responsible for the design and development of all types of power apparatus for military and Bell System uses. In 1953 he was appointed Transmission Apparatus Engineer. Mr. Haines is a member of the American Institute of Electrical Engineers, the Institute of Radio Engineers, and Phi Kappa Phi.

Dr. Kelly Sees Bright Future for Communications

The transistor is destined to be the giant of the coming electronic age and will have far-reaching effects not only in telephony but in almost every area of industry, business and military weaponry, Dr. M. J. Kelly declared recently.

He spoke on "Contributions of Research to Telephony – A Look at the Past and a Glance into the Future," before the Franklin Institute in Philadelphia, where he delivered the first Philip C. Staples Annual Lecture.

Dr. Kelly described the transistor as one of those big break-throughs in science which occur only at rare intervals. Just as the vacuum tube and the relay symbolize the past era of remarkable expan-

—r. Mervin J. Kelly being greeted by Wilfred D. Gillen, ·esident of the Bell Telephone Company of Pennsylvania ·enter), and S. Wyman Rolph, President of The Franklin .stitute (right), on the occasion of the first Philip C. aples Annual Lecture.

sion in communications, so the transistor, which overcomes the inefficiency of the vacuum tube and the slowness of the relay, will symbolize the era beginning to unfold.

Intercontinental television transmission over transistorized submarine cable, electronic switching centers about one-fifth the size of corresponding electromechanical relay systems, and the application of carrier telephony in local plant circuits are among the revolutionary advances the transistor will make possible, Dr. Kelly stated.

"It is definitely to be expected," he said, "that transistors will some day provide the amplification for submarine telephone cables, where submerged vacuum tube repeaters are just now being applied in the first transatlantic telephone cable. The transistors will permit much wider frequency bands, giving more telephone channels, and should also make it possible ultimately to transmit television between continents."

In the field of local transmission, Dr. Kelly predicted that carrier systems using transistors will be economical for shorter distances than are now considered desirable.

"Heretofore, the costs of vacuum tube operation have limited the economic field of carrier to transmission distances greater than some fifteen miles," he declared. "In time, transistor economics will remove all barriers to carrier systems applications. The use of transistorized carrier in local plant trunk circuits, in subscribers' lines, and in station sets will bring lowered costs, improved transmission and opportunities for completely new services."

Turning to the area of telephone switching, Dr. Kelly pointed out that, despite the many functional advantages of electronics as contrasted with electromechanical switching, the application of the electronic art to switching had to await the advent of the solid-state electronic devices, spearheaded by the transistor.

"The small size of these devices, their low power consumption and reliability with indefinite life, combined with the higher speeds of electronic operation, provide the framework for a revolution in switching technology," Dr. Kelly declared. "This revolution will provide large economies and make possible services of broader scope over the telephone network.

"The space required by the first electronic switching centers will be about one-fifth that of the corresponding standard relay or electromechanical system. The enormous decrease in size of equipment is due not only to the thousandfold increase in speed of operation made possible by electronics, but also to the miniature size of the transistors and associated circuit components. The power consumption of the electronic central office will also be greatly decreased, since the power required to close a relay contact is some hundredfold more than that required for the corresponding function when performed by a transistor or other solid-state electronic devices."

In addition to its impact on communications, Dr. Kelly predicted that solid-state electronics, coupled with the application of the information theory, will greatly accelerate the applications of automation in business and in industry. An increasing amount of the routine operations of the office and the factory will be done automatically under the programmed control of large-scale solid-state computers.

"This wholesale application of automation to business and industry will place new and added demands on the transmission networks of the nation," Dr. Kelly said. "The transmission between units of business and industry of suitably digitalized business and industrial data will be increasingly required in the new era of automation. Inventory, production, payroll and industrial control information, for example, will flow between the headquarters of a corporation and its widely separated branches. Many of the widely separated operations involved in these procedures can be effectively and economically done by transmitting coded data to a central data processing center where essential operations will be performed on the data. The processed information will then be transmitted to its source and to other centers interested in its use."

Dr. Kelly termed the expected advances in telephone usage and scope of service a "revolution by evolution," for the changes will not come overnight.

"Challenging and most difficult tasks await the men of research and engineering in the integration of the facilities of the electronic era with the facilities of the past in such a way that there is compatible, trouble-free and effective interconnection of the old with the new," he said. In the coming electronic era — as in the past decades of remarkable growth — expansion in quality, variety and economy of telephone service will be paced by progress in converting new scientific knowledge into communications technology through research and development.

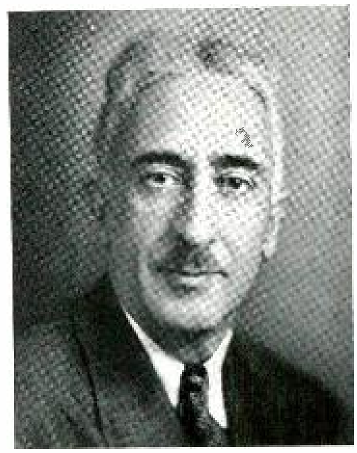
H. I. Romnes Elected to Board

H. I. Romnes, Vice President in charge of the Operation and Engineering Department of the A. T. & T. Co., has been elected to the Laboratories Board of Directors. He succeeds Eugene J. McNeely, Executive Vice President of the A. T. & T. Co.

Mr. Romnes was elected a Vice President of A. T. & T. on October 19, 1955. He had served as Chief Engineer since 1952. Mr. Romnes began his telephone career in 1928 as an installer for the Wisconsin Telephone Co. Since then he has held various engineering posts with the Laboratories, Illinois Bell and the A. T. & T. Co.

W. A. MacNair Named Vice President of Laboratories

Walter A. MacNair, for many years a member of the Laboratories and since May, 1952, Vice President in charge of Research of the Sandia Corporation, returned to the Laboratories as a Vice President on December 1. Mr. MacNair is now in charge of Switching and Transmission Development, succeeding Gordon N. Thayer, who was recently named Chief Engineer of the American Telephone and Telegraph Company.


W. A. MacNair

Mr. MacNair was associated with the Laboratories from 1929 until he joined the Sandia Corporation in 1952. He specialized in various fields of physical research, and he served as Commercial Products Engineer from 1937 to 1941 and as Research Physicist from 1941 to 1947, when he became Assistant Director of Switching Research. In 1949 he assumed the post of Director of the same department. He was named Director of Military Systems Engineering in January, 1951, and Director of Systems Research for Sandia in February, 1952.

Since 1941 Mr. MacNair has devoted much of his time and effort to various military and civilian government agencies, and has contributed to the study of fire-control problems and guided missiles. For his contributions in World War II, he was awarded the Presidential Certificate of Merit.

He received a bachelor of science degree from Colgate University in 1920 and a Ph.D. from Johns Hopkins University in 1925, and was a National Research Fellow in physics for two years thereafter. He completed other studies at Cornell and the Michigan College of Mines. He is a Fellow of the American Physical Society and the Acoustical Society of America.

Continued Advances by Bell System in 1955

Bell Telephone Companies added nearly 50 per cent more telephones in 1955 than in 1954. Long-distance calling increased. Earnings improved. To expand and further improve service, the companies spent a record sum on new construction. These are highlights of a year-end statement by Cleo F. Craig, President of the American Telephone and Telegraph Company.

"This has been a year of progress for the Bell System with big gains in service to the public and a very desirable strengthening of our share owners' position," Mr. Craig said.

"We added about 2,850,000 telephones in 1955, or close to 50 per cent more than in 1954. Long-distance conversations increased nearly 12 per cent, which is well above the average yearly growth.

"To enlarge and improve service the System spent nearly $1.7 billion for new construction, or about $800,000 every working hour. This was the largest construction program we have ever had.

"But we expect to do even more in 1956. The country keeps right on growing. Americans need and want more communication service of top quality. We are going full speed ahead to provide it."

Bell System telephones totaled 46,200,000 by year's end – more than double the number in 1945. People are talking more; the average daily number of telephone conversations was 169 million, up almost 10 million a day from the previous year. The number of dial-operated phones in the Bell System climbed to nearly 87 per cent, from 84 per cent at the beginning of the year.

In many areas, telephone users are dialing their own calls within an increasingly wider range. In 65 places, they are able to dial directly to any one of 18 million telephones located in various cities from coast to coast. While telephone mechanization continued, Bell System employment increased from 686,000 to 740,000 during 1955.

Progress was made on improving communications across oceans as well as within the country. The task of bridging oceans with telephone cables is one of the most dramatic in telephone history. First leg of a transatlantic telephone cable was laid this past summer. The second link in the transatlantic system will be laid this year. By December, the cable system is expected to be furnishing 36 telephone channels to supplement radiotelephone facilities between North America and England. It will make overseas telephoning more reliable, since it is not subject to the atmospheric disturbances that sometimes affect radiotelephone services over long distances.

Work proceeded on two other transoceanic cable systems. One, to Alaska, is also scheduled to be completed late this year. The other to Hawaii is in the planning stage. It is expected to go into service in the year 1958.

"Earnings to date in 1955 average about $13 a share on A. T. & T. stock. This improvement is both encouraging and necessary. It provides needed protection for the share owners' investment and will help furnish funds for construction to meet the growing volume of business we expect in 1956," Mr. Craig said.

Most of the new capital required for 1955 construction came from the sale of stock and convertible debentures. Financial history was made during the year when A.T.&T. issued $637,165,800 in convertibles – the largest offering of new securities ever made by a private company. It is expected that almost half were exchanged for stock by year's end. This would result in an increase of about 6.1 million shares of stock during the year and would bring the total number outstanding to around 54 million.

Share owners of A.T.&T. Co. have increased by almost 100,000, bringing the total to a new high of approximately 1,400,000.

Dr. Bown Named Chairman of Patent Office Committee

Dr. Ralph Bown, Vice President of Bell Telephone Laboratories, has been named by Secretary of Commerce Sinclair Weeks to serve as Chairman of the Advisory Committee on Mechanization of the Patent Office. Establishment of this Committee followed a recommendation of the Advisory Committee on Application of Machines to Patent Office Operations, Dr. Vannevar Bush, chairman, that a continuing advisory group be attached to the Office of the Secretary of Commerce to stimulate and coordinate an inter-agency program to develop machines and techniques specifically adapted to Patent Office operations.

Other members of the Committee are: Donald Harrison, General Patent Counsel, Union Carbide and Carbon Corporation; Dr. Warren Weaver, Vice President, Rockefeller Foundation; John von Neumann, Commissioner, U. S. Atomic Energy Commission; and Melvin R. Jenney, of Kenway, Jenney, Witter & Hildreth.

Bell System to Test New All-Electronic Switching System

The revolutionary recent advances of modern electronics will be put to work within the next few years to streamline the Bell System's gigantic task of interconnecting millions of telephone users, whether across the street or across the nation. The world's first electronic telephone exchange – forerunner of a radically improved and faster means of routing telephone calls – will go into experimental operation in Morris, Illinois, in two or three years, Bell Telephone Laboratories announced recently. It will provide telephone service to about 2,500 customers. Bell System engineers said that installation of the new exchange would mark the start of a gradual change to all-electronic switching systems throughout the country over a period of years.

Dial switching systems in use throughout the country today use electro-mechanical switches, called relays, which, at the command of the customer's dial, automatically connect the customer with the telephone being called. These relays, or switches, operate in about a thousandth of a second, but the elements in the new electronic switching system are expected to operate a thousand times as fast – in a millionth of a second. This tremendously fast operation will not only provide speedier service, without sacrificing reliability, but, because of its speed, fewer units of equipment will be required to serve a standard-sized exchange.

A key part of the all-electronic system will be the transistor, also invented at the Laboratories, which does most of the things an electron tube can do and has many advantages for the telephone business. The transistors and other modern electronic devices to be used in the new system – resistors, varistors, capacitors and other components which affect the flow of electricity in various ways – are very small in size, so small as to make considerable space saving possible. Not only will there be fewer units of equipment because of fast operation, but the units themselves will be much smaller in size. Eventually, the result will be a saving in the building space needed.

Creation of electronic switching systems is not simply the substitution of new devices for present switching mechanisms. Whole new systems involving complex circuitry must be devised. Planning and development are required to insure that Bell System objectives of service reliability and economy will be met.

"Packaged units" comprising groups of components and their circuitry are foreseen as system building blocks. Transistors are expected to have relatively long life, but to make maintenance easier it is probable that these packaged units will be built so that they may be plugged in place or removed from the equipment easily. Automatic indicators will signal an attendant in the event of trouble and indicate the cause so that faults can be corrected quickly.

The average telephone user will probably never realize that his call is going over the new electronic system, except for the increased speed with which the connection is made – and for one other thing. As part of the changeover to electronic switching, the familiar telephone ring will probably be replaced by a distinctive musical tone to signal the called party. The musical tone will be heard through a small loudspeaker built into the base of the telephone. It has been found pleasing, and as effective as a bell. The musical tone is better suited to electronic switching because it uses considerably less power than is needed to ring a bell.

Telephone Statistics

With one telephone, on the average, for every three persons, the United States had more than half of the world's 94.5 million telephones on January 1, 1955. About 5.3 million telephones were added throughout the world in 1954. This information was published recently by the American Telephone and Telegraph Company in its annual survey, "Telephone Statistics of the World."

Iceland has replaced the United States as the second talkingest nation in the world, the compilation revealed. Canada, with 417 conversations per capita, is in first place for the third consecutive year. Iceland with 394 conversations per capita, nosed out the United States, which had 393. More than half of Iceland's telephones are in its capital city, Reykjavik, as is 40 per cent of its population.

These figures are for the year 1954, since it takes almost a year to collect information from more than 250 governments and companies in other parts of the world. Telephone service in the United States is supplied by some 4,800 private companies, together with thousands of connecting rural or farm lines and systems.

The Netherlands installed its one millionth telephone in 1954, bringing the total number of countries on the "more than a million list" to 12–The

United States, the United Kingdom, Canada, German Federal Republic, France, Japan, Sweden, Italy, Australia, Switzerland, Argentina and the Netherlands, in that order.

Prior to 1927, the telephones of only three other countries could be connected with Bell System telephones. Those countries were Canada, Mexico and Cuba. Canada and Mexico were connected by landline, Cuba by cable. Then, in January 1927, the first overseas radiotelephone circuit was established – between New York and London.

At the beginning of 1955 a customer in the United States could call any one of 91 million telephones in more than 110 countries or areas, including the United States. Overseas service was extended to three new points during 1954 – Goa, in Portuguese India; British Malaya (including Singapore); and Thailand. In 1955, Ascension Island, in the South Atlantic, and French Equatorial Africa were added.

"Wide-Screen" Antenna for the Air Force

Veteran radio fans who remember stringing a wire from a house to the nearest tree could hardly be expected to recognize the massive structure in the accompanying illustration as a radio antenna. It looks more like the latest style of wide screen for a drive-in movie. Yet the Laboratories has designed and developed this huge reflector and feed horn to transmit and receive radio signals "over-the-horizon." It is to be a part of a communications network now being built in Alaska by Western Electric for the U. S. Air Force. Western is the prime contractor for the initial phase of this project – known as "White Alice" – which will integrate the communications serving Government agencies in Alaska.

In standard line-of-sight transmission, stations are so placed that the main beam of radio waves can be used. Some signals, however, drop off this main beam, just as some light from a searchlight is scattered to the ground by the atmosphere. The greater power and larger antennas of the "over-the-horizon" system permit recapture of a part of these signals and make them useful carriers. Scientists at Bell Telephone Laboratories and the Massachusetts Institute of Technology recently demonstrated that telephone conversations and television pictures can travel by ultra-high-frequency radio waves far beyond the horizon.

Distances of 200 miles between stations – across water or over rugged terrain – are thus possible. Television was first successfully transmitted by this technique in 1954 between the Holmdel, N. J., location of Bell Laboratories and an M.I.T. station near New Bedford, Mass., a distance of 188 miles.

The design incorporates many interesting mechanical and electrical features. For efficient transmission and reception, the reflecting surface is parabolic in contour, and the curvature must be held within very close limits of tolerance. The antenna has been built

A 60-foot parabolic reflector for receiving and sending radio waves "over-the-horizon."

to withstand winds of 150 mph. Where there is danger of icing, the supporting members behind the reflecting surface are enclosed (as in the illustration), and the entire structure is heated from within. The antenna is constructed principally from galvanized steel.

The antenna was constructed by a Western Electric sub-contractor (the Blaw-Knox Corporation) near Pittsburgh, and both mechanical and electrical tests were conducted by Laboratories engineers before antennas were shipped to Alaska. The trial installation was made with the assistance of the Bell Telephone Company of Pennsylvania.

Talks by Members of the Laboratories

During November, a number of Laboratories people gave talks before professional and educational groups. Following is a list of the speakers, titles, and places of presentation:

American Physical Society Meeting, Chicago

Brown, W. L. see Penman, S.

Feldmann, W. L., see Read, W. T., Jr.

Haynes, J. R., Recombination Radiation from Silicon.

Jacobs, I., Perturbation Calculation of the Volume Exclusion Effect.

Pearson, G. L., see Read, W. T., Jr.

Penman, S., and Brown, W. L., The Field Effect in Silicon.

Read, W. T., Jr., Feldmann, W. L., and Pearson, G. L., Mechanical Properties of Si, Ge, and ZnO Whiskers.

Shulman, R. G., Valence Bond Calculations of Acceptor Energies in Silicon and Germanium.

Shulman, R. G., and Wyluda, B. J., Copper in Germanium: Recombination Center and Trapping Center.

Wyluda, B. J., see Shulman, R. G.

Other Talks

Ambrose, J. F., The Angstrom Approximation as a Possible Method for the Spectrophotometric Determination of Carbon Black, A.S.T.M. Task Group 1, Subcommittee VII, Committee D20, Cincinnati.

Anderson, J. R., Digital Memory Devices and Their Applications, University of New Hampshire, Durham.

Arnold, S. M., see Treuting, R. G.

Beck, A. C., Waveguides for Long-Distance Communication, I.R.E. Professional Group on Microwave Theory and Techniques, Long Island Chapter, Garden City, L. I.

Bennett, W. R., Mathematics of Noise Analysis – II: Correlation Method, Wiener-Khintchine Relations, A.I.E.E. Basic Science Division Series on Fundamentals of Noise Analysis, R.C.A. Institute, New York City.

Bogert, B. P., Acoustics of Speech, National Council of Teachers of English, New York City.

Boyet, H., Gyromagnetic Resonance in Ferrites at Microwave Frequencies, Physics Department Colloquium, New York University.

Budlong, A. H., Control Circuits, Passaic County Engineering Society, Paterson, N. J.

Bullington, K., Results of Propagation Tests on 505 Mc and 4090 Mc on Beyond-Horizon Paths, Communication by Scatter, I.R.E., George Washington University, Washington, D. C.

Chapin, D. M., The Bell Solar Battery, Perrydale High School, Oregon; Oregon State College, Corvallis; University of Oregon, Eugene; and Willamette University, Salem, Oregon; Silicon p-n Junction Solar Converters, University of Oregon, Eugene; and Some Observations from a Year of Solar Battery Testing, Conference on Solar Energy, Tucson, Ariz.

Dacey, G. C., Bell Laboratories Diffused Base Transistors, American Ordnance Association, Guided Missile and Rocket Divisions, White Sands Proving Ground, N. M.

David, E. E., Jr., Distortion in Speech Processing Systems, Speech Communication Research Symposium, San Diego.

Eberhart, E. K., The Bell Telephone Laboratories, Past Masters Association, Masonic Lodge, North Andover, Mass.

Fisher, C. E., A Quality Assurance Program, American Society for Quality Control, Binghamton, N. Y. Section.

Flaschen, S. S., see Sauer, H. A.

Fuller, C. S., The Bell Solar Battery, New Jersey Mineralogical Society, Plainfield, N. J., and American Chemical Society, Rutgers University, New Brunswick; and Silicon and Some of its Applications in Communications Devices, duPont Experimental Station, Wilmington, Del.

Hannay, N. B., Diffusion Techniques for the Bell Solar Battery, American Chemical Society, New York City.

Hart, H. C., The Art of Communicating Complex Patent Matters, Practicing Law Institute, New York City.

Herring, C., Thermoelectricity and Thermal Conduction in Semiconductors, Physics Colloquium, Purdue University, Lafayette, Ind.

Keister, W., Mechanized Intelligence, A.I.E.E. Student Branch, Newark College of Engineering.

Keyser, C. J., Control Charts for Defects, American Society for Quality Control, Metropolitan Section, New York City.

Kohman, G. T., Chemistry of Quartz Crystal Growth, American Chemical Society, New York City.

Lumsden, G. Q., Timber and Its Preservation, Navigator's Club, New York City.

Matlack, R. C., The Role of Communications Networks in Digital Data Systems, The Eastern Joint Computer Conference, Boston.

Meyer, F. T., Improved Detached-Contact Type Schematic Circuit Drawing, Standards Engineers Society, New York City.

Moll, J. L., Large Signal Operation of Junction Transistors, A.I.E.E., New York City.

Moshman, J., Making Computers Serve Statisticians, Computer Conference, Oklahoma A. and M. College, Stillwater.

Pearson, G. L., Electricity from the Sun, A.I.E.E. San Francisco Section, and World Symposium on Applied Solar Energy, Phoenix, Arizona; and Silicon in Modern Communications, Electrical Engineering Seminar, California Institute of Technology, Pasadena, and Pacific Telephone and Telegraph Company, Portland, Oregon.

Pfann, W. G., Zone Melting Techniques, American Chemical Society, Trenton; and Ultra-Purity Materials for Transistors by Zone-Melting, American Chemical Society, New York City.

Pike, V. B., Some Fundamentals Involved in Corrosion Testing Underground Cable Plant, National Association of Corrosion Engineers, Niagara Frontier Section, Niagara Falls.

Prince, M. B., Silicon Power Rectifiers, I.R.E. Phoenix Section; The Bell Solar Battery, A.I.E.E. Basic Sciences Division, Los Angeles; and Diffused Silicon Diodes for the Telephone Plant, Pacific Telephone and Telegraph Company, Los Angeles.

Purvis, M. B., Temperature Distribution in the Journal Bearing Lubricant Film, American Society of Mechanical Engineers, Chicago.

Raisbeck, G., Recent Developments in Transistors, U.S. Naval Reserve Research Company 11-6, Naval Training Center, Phoenix; and The Sort of Research Which Has Brought Forth the Bell Solar Battery, Rotary Club, Phoenix.

St. John, G. E., Low-Noise Traveling-Wave Tubes, I.R.E. Professional Group on Microwave Theory and Techniques, Northern New Jersey Section, Murray Hill, N. J.

Sauer, H. A., and Flaschen, S. S., Oxide Thermistors with Large Positive Temperature Coefficients of Resistance, Rutgers University, New Brunswick, N. J.

Schawlow, A. L., Structure of the Intermediate State in Superconductors, Physics Colloquium, University of Pennsylvania, Philadelphia.

Sumner, E. E., Transistor Circuits – Digital Applications, I.R.E. Student Branch, New York University.

Taylor, R. H., Some Aspects of Transoceanic Telephony, A.I.E.E./I.R.E. Joint Meeting, University of Idaho, Moscow; A.I.E.E. Student Branch, Washington State College, Pullman; A.I.E.E./I.R.E. Joint Meeting, Seattle; and A.I.E.E. Student Branch, University of Washington, Seattle.

Tendick, F. H., Jr., Transistor Feedback Amplifiers, I.R.E. Professional Group on Circuit Theory, Philadelphia Chapter.

Terry, M. E., Analysis of Planned Experiments, American Society for Quality Control, Cleveland Section.

Thayer, P. H., Jr., NIKE I, A Guided Missile System for AA Defense, A.S.M.E. Plainfield, N. J. Section.

Treuting, R. G., and Arnold, S. M., Orientation Determinations in Whisker-Like Metal Crystals, Thirteenth Annual Pittsburgh Diffraction Conference.

Uhlir, A., Some Recent Developments in Semiconductor Diodes, I.R.E. Indianapolis Section.

von Aulock, W., Measurement of Ferrite Properties of Microwave Frequencies and Phase Shifting with Ferrites, U.S. Naval Ordnance Laboratory, White Oak, Md.

Wertz, H. S., Know-How and Pitfalls of Interference Practice, Practicing Law Institute, New York City.

Winslow, F. H., Corrosion of Organic Materials, American Chemical Society, New York City.

Papers Published by Members of the Laboratories

Following is a list of the authors, titles, and place of publication of recent papers published by members of the Laboratories

Anderson, J. R., Brady, G. W., Merz, W. J., and Remeika, J. P., Effects of Ambient Atmosphere on the Stability of Barium Titanate, J. Appl. Phys., Letter to the Editor, **26**, pp. 1387-1388, Nov., 1955.

Anderson, P. W., and Hasegawa, H., Considerations on Double Exchange, Phys. Rev., **100**, pp. 675-681, Oct. 15, 1955.

Anderson, P. W., Electromagnetic Theory of Cyclotron Resonance in Metals, Phys. Rev., Letter to the Editor, **100**, pp. 749-750, Oct. 15, 1955.

Barstow, J. M., The ABC's of Color Television, Proc. I.R.E., **43**, pp. 1574-1579, Nov., 1955.

Bemski, G., Lifetime of Electrons in p-Type Silicon, Phys. Rev., **100**, pp. 523-524, Oct. 15, 1955.

Bennett, W. R., Steady State Transmission Through Networks Containing Periodically Operated Switches, Trans. I.R.E., P.G.C.T., **2**, pp. 17-21, Mar., 1955.

Bömmel, H. E., Ultrasonic Attenuation in Superconducting and Normal-Conducting Tin at Low Temperatures, Phys. Rev., Letter to the Editor, **100**, pp. 758-759, Oct. 15, 1955.

Bömmel, H. E., Mason, W. P., and Warner, A. W., Jr., Experimental Evidence for Dislocation in Crystalline Quartz, Phys. Rev., Letter to the Editor, **99**, pp. 1895-1896, Sept. 15. 1955.

Brady, G. W., see Anderson, J. R.

Brattain, W. H., see Buck, T. M.

Brown, W. L., Surface Potential and Surface Charge Distribution from Semiconductor Field Effect Measurements, Phys. Rev., **100**, pp. 590-591, Oct. 15, 1955.

Buck, T. M., and Brattain, W. H., Investigations of Surface Recombination Velocities on Germanium by the Photoelectric Magnetic Method, J. Electrochem. Soc., **102**, pp. 636-640, Nov., 1955.

Celtin, B. B., see Galt, J. K.

Corenzwit, E., see Matthias, B. T.

Dail, H. W., Jr., see Galt, J. K.

Dillon, J. F., Jr., Geschwind, S., and Jaccarino, V., Ferromagnetic Resonance in Single Crystals of Manganese Ferrite, Phys. Rev., Letter to the Editor, **100**, pp. 750-752, Oct. 15, 1955.

Fagen, R. E., and Riordan, J., Queueing Systems for Single and Multiple Operation, J. S. Ind. Appl. Math., **3**, pp. 73-79, June, 1955.

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Galt, J. K., Yager, W. A., Merritt, F. R., Cetlin, B. B., and Dail, H. W., Jr., Cyclotron Resonance in Metals: Bismuth, Phys. Rev., Letter to the Editor, **100**, pp. 748-749, Oct. 15, 1955.

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Geschwind, S., see Dillon, J. F.

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Hornbeck, J. A., see Haynes, J. R.

Jaccarino, V., see Dillon, J. F.

James, D. B., see Neilson, G. C.

Kohn, W., and Schechter, D., Theory of Acceptor Levels in Germanium, Phys. Rev., Letter to the Editor, **99**, pp. 1903-1904, Sept. 15, 1955.

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Logan, R. A., and Schwartz, M., Restoration of Resistivity and Lifetime in Heat Treated Germanium, J. Appl. Phys., **26**, pp. 1287-1289, Nov., 1955.

McCall, D. W., see Shulman, R. G.

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Patents Issued to Members of Bell Telephone Laboratories During the Month of October

Avery, R. C. – *Line Selection System* – 2,721,903.

Avery, R. C. – *Routine Line Insulation Testing Circuit* – 2,721,910.

Bachelet, A. E., and Pullis, G. A. – *Alarm Sending System* – 2,719,960.

Braga, F. J. – *Relaxation Oscillator* – 2,721,937.

Dorff, L. A. – *Duplex Radio Telephone System* – 2,721,935.

Dubuar, A. S., and Riddell, G. – *Line Finder for Step-by-Step Telephone System* – 2,719,881.

Edson, W. A., and Lange, R. W. – *Orifice Coupling to Resonant Cavities* – 2,720,629.

Erving, C. H., Jr. – *Stylus Assembly* – 2,719,775.

Goodall, W. M. – *Time Division Pulse Code Modulation System Employing Continuous Coding Tube* – 2,720,557.

Hopper, A. L. – *Oscillator System* – 2,721,980.

Kannenberg, W. F., and Wilson, I. G. – *Orifice Coupling for High Q Cavities* – 2,720,630.

Karnaugh, M. – *Electrical Circuit Employing Magnetic Cores* – 2,719,773.

Karnaugh, M. – *Electrical Circuit Employing Magnetic Cores* – 2,719,961.

Karnaugh, M. – *Electrical Circuit Employing Magnetic Cores* – 2,719,962.

Lange, R. W., see Edson, W. A.

Llewellyn, F. B. – *Impedance Matching Networks* – 2,720,-627.

McGuigan, J. H., and Vaughan, H. E. – *Magnetic Surface Writing Circuit Utilizing Magnetic Cores* – 2,719,964.

McKim, B., and Neely, T. H. – *Electrical Transmission Testing System* – 2,721,235.

Neely, T. H., see McKim, B.

Oliver, B. M. – *Non-Linear Encoded Transmission* – 2,721,-900.

Pullis, G. A., see Bachelet, A. E.

Riddell, G., see Dubuar, A. S.

Schneckloth, H. H. – *Carrier Wave Communication System* – 2,721,897.

Shoffstall, H. G. – *Intertoll Trunk Testing System* – 2,719,-886.

Vaughan, H. E., see McGuigan, J. H.

Wilson, I. G., see Kannenberg, W. F.