The Combination Wire-Wrapping Tool

R. F. MALLINA and F. RECK
Switching Apparatus Development

As part of the Bell System's continual effort to give better service at less cost, a power-driven wrapping tool was developed to speed up the connecting of wires to terminals before soldering. The effects of various terminal shapes on the wrapping operation were subsequently studied, and led to the introduction of solderless wrapped connections. The most recent Laboratories development in this field is the combination tool, which cuts the wire, skins it, and wraps the connection, all in essentially one simple operation.

Two of the more recent developments of the Laboratories are the companion ideas of solderless wrapped connections* and in cooperation with Western Electric the wire-wrapping tool for making such connections.† These ideas offered the Bell System better methods at lower costs. Consequently, considerable Laboratories activity has been devoted to the possibility of extending the gains made with the solderless feature of the wrapped connection by improving the wire-wrapping tool, its method of use, or both. The new combination tool that resulted has several advantages over previous wire-wrapping tools in that it cuts the wire, skins it, and wraps the connection – essentially in a single operation.

In the Laboratories, a preliminary test installation of a No. 5 Crossbar office has been set up to evaluate new designs based on wire-spring relays and other recently developed apparatus. Combination tools were used to make a large number of the solderless wrapped connections, with considerable savings in time and labor over connections made with conventional wrapping guns. Based on this experience, the use of combination tools, when they become available, may prove economically worthwhile in the manufacture, installation, and maintenance of equipment using solderless wrapped connections.

In the conventional wrapping tool, a stationary outer sleeve, notched at the tip, guides and controls the wire. An inner shank has a hole in its tip to fit over the terminal being wrapped, and a slot for the skinned wire-end. Rotating the inner shank wraps the wire tightly around the terminal.

The combination tool, Figure 1, is the same as the conventional tool in that it has a concentric outer sleeve over a rotatable inner shank, with a center hole to fit over the terminal and a second

Above — F. Reck, one of the co-authors, illustrates how the combination tool is used for surface wiring. The same methods can be used for point-to-point or "loose" wiring, seen at the right.

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* Record, *February*, 1954, *page* 41. † Record, *July*, 1951, *page* 307.

hole to accommodate the wire, but here the resemblance ends. In the new tool, Figure 1, the outer sleeve is not stationary, but can slide axially along the inner shank for about 1/4 of an inch. When in the forward position, the sleeve becomes part of the wrapping tip and the assembly of shank and sleeve rotates as a unit.

Two pairs of cutting knives are provided. Near the middle of the tool are two wire-cutting edges; when the tool is open, they form a gap to accept the wire. Closing the tool brings the cutting edges together, shearing the wire to its proper length. The second pair of cutting edges is not so readily seen, since they are part of the specially designed tip. When the tool is closed, they form an insulation-cutting die just the size of the wire. Rotating the tool then strips off the insulation of the wire-end that is held in the tool, while wrapping the bared wire on the terminal. After the connection is completely wrapped, releasing the trigger assembly automatically stops the wrapping-tip shank in the proper position for further wiring. Advantages that are gained by the use of the new wrapping tool are perhaps best appreciated when it is used to terminate cable leads on terminal strips. Here, the cable is often at the rear of the frame, with the wires projecting through the frame toward the front. Each wire must be connected to its proper terminal and dressed so as not to interfere with any other wire or terminal on the frame. When a conventional wrapping tool is used, the wires of the cable must be pre-cut to the proper length and pre-skinned before connection.

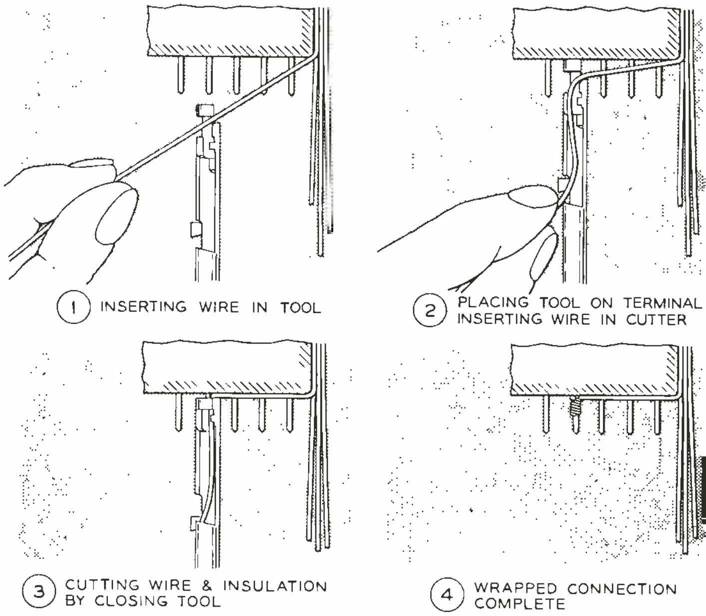


Fig. 2 — The sequence of operations in cable wiring.

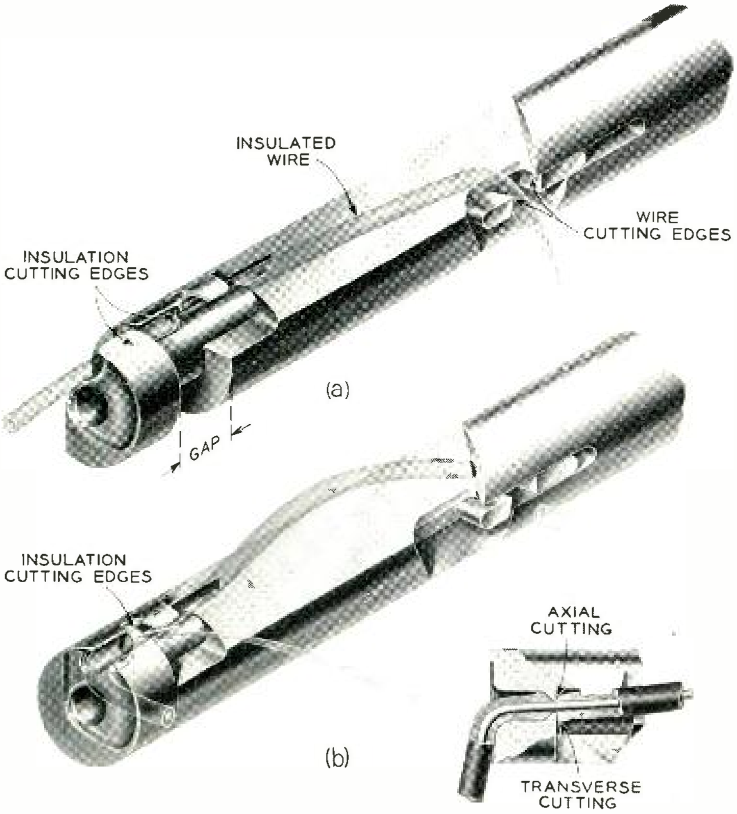


Fig. 1 — The combination tool (a) open and (b) closed, showing how the insulation and wire are cut by the two sets of cutting knives.

Using the combination tool, the installer would simply lay the wire into the open gap at the spindle tip, Figure 2. Since the wire would come from behind the frame, it would be in a perfectly natural position. Depending on the particular situation, the wire could be placed in the tool either before or after the tool is placed over the terminal. When the wire is in the gap and the tool is on the terminal, the wire is pulled back along the shank of the tool and dropped into the wire-cutter gap. These too, are natural motions.

Now, in wrapping the connection, the user holds the pistol-grip of the tool firmly and squeezes the trigger assembly. This forces the outer sleeve forward, cutting the insulation at the tip and the wire at the wire cutter. The trigger assembly, Figure 3, is actually a lever that controls the axial position of the sleeve, with a small "button" portion at its top. After squeezing the trigger assembly with the last three fingers, a slight pressure of the index finger on the switch "button" will start the motor that rotates the shank of the tool.

What, specifically, are the advantages offered by the new tool? The wiring man in the field no longer would be required to trim a cable wire to length and then strip it by hand before wrapping connections. This use of a gap-loading tool would also permit the user to work with a *length of wire*, so that he would not have to insert a wire-end into a small hole in a gun tip. With simple, natural motions, he could take the wire and make a connection whereas with the conventional tool, extra, less natural, and more precise movements would be required.

The new combination tool also lends itself to surface wiring. An additional simplification results since the first connection is made with a wire-end. In this case, the wire is laid into the front gap with the wire-end at or slightly beyond the wire-cutter, the supply wire emerging from the tip and being held to the left of the tool. There is no reason to cut the wire to length in this first operation, since it is already a wire-end. The connection is wrapped as before, but with the supply wire held taut and as nearly at right angles to the tool as possible. The tool is then moved to the next terminal to be connected. Laying the wire into the front gap as for cable wiring, the second connection is made. The wire will be automatically dressed into the proper position; however, if desired, it can be held taut so as to provide sufficient wire length for later dressing by hand.

Because the tool normally wraps a connection in a clockwise direction, certain of the many possible surface wiring procedures are preferred. The six basic wiring conditions are illustrated in Figure 4, with the preferred sequences indicated. Although there may seem to be no logic to the wiring sequences shown, they all stem from two things: the tool wraps in a clockwise direction, and there are certain "natural" motions that are easier to perform than any others. Each sequence has been carefully worked out so that the wire falls in a natural, logical position, and so that the wire may be readily laid into the front gap. All undesirable positions of the tool and of the operator's hands have been eliminated in these sequences.

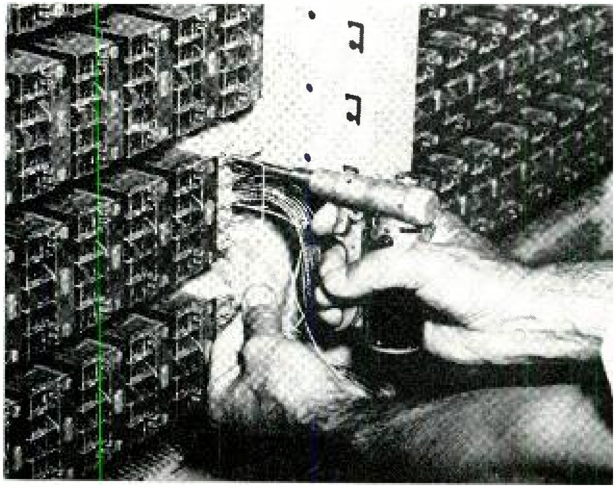


Fig. 3 — In this example of cable wiring, the trigger assembly is seen to consist of a lower portion, grasped by three fingers, and a small "button" operated by the index finger.

The foregoing examples of switchboard cable and surface wiring are generalizations. In addition, there are local cables, loose wiring, point-to-point wiring, and jumpers. Switchboard cabling and jumpering are generally done in the field, and the remaining types of wiring in the shop. Basically, local cabling, loose wiring, and surface wiring accomplish the same purpose — the interconnection of parts of an equipment assembly. The preferred type of wiring, economically, is surface wiring, applicable to the smaller assemblies. For larger assemblies there are two choices, controlled by the character of the equipment. One alternative is the use of local cable — a separately made cable laced with twine. The other is unitization permitting the use of surface wiring on sub-assemblies and of local cables or loose wiring between them. The headpiece shows examples of loose wiring where a wire connects between terminals; the wire is not cabled,

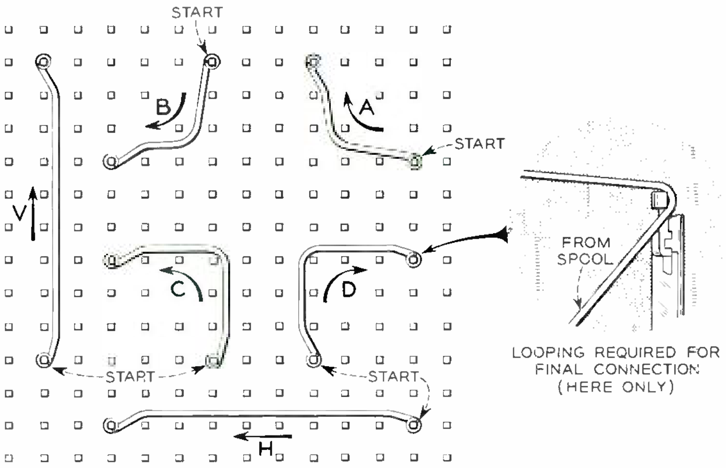


Fig. 4 — These wiring sequences are preferred for surface wiring since the wire and combination tool are always in a convenient position.

but is dressed into position after wiring. Constraining rings are used to keep the wires properly dressed and close together on long runs between terminals.

The combination tool is ideally suited for use with the recently developed plastic-insulated wire and such wire is recommended for use with the tool since there is no paper or cloth insulation on the wire, only a thin coating of plastic. The outer diameter is smaller than that of equivalent wire using other insulations and this wire is used with solderless wrapped connections where space is at a premium. It is ideal for use with the combination tool, because the skinning action of the tip depends on a "crushable," free-stripping insulation. The "jaws" of the tip, Figure 1, close in such a manner that the insulation is cut by a combination of transverse and axial cutting; the axial cutting results from one of the jaws "crushing" through the insulation with a sliding motion.

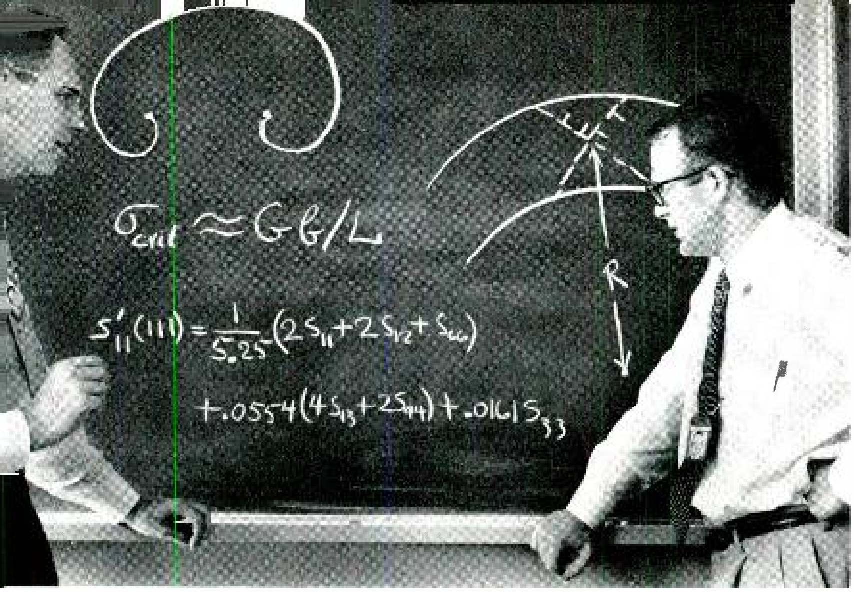
Although a similar number of operations is required for a connection with the combination tool as with the usual wrapping tool, some of these – squeezing the trigger assembly, for example – are almost instinctive actions to the operator. It is natural to squeeze the trigger assembly; a firm grip helps to keep the tool steady during the wrapping operation. Laying the wire in the gap at the tip, pulling it to give the tension for proper lead dress, feeding it into the cutting edges, and keeping the remainder of the wire always in the left hand are all easy, normal operations when using the combination tool. These "natural" actions were considered in the design of the tool, and are partly responsible for the faster wiring that is possible. In addition, use of the combination tool should eliminate the need for pre-cut and pre-skinned wires in the wiring of equipment. Further, selection of the proper piece of wire to use for a specific connection should no longer be a factor in wiring efficiency. The elimination of unnecessary motions and decisions has always improved the performance of a given job.

Although still undergoing tests at the Laboratories, the combination tool may prove a real asset not only in wiring and assembly but also in field installation and maintenance. For the latter applications, hand-operated combination tools have been developed.

THE AUTHORS

R. F. MALLINA was graduated from the Vienna Technical College in 1912 with the M.E. degree, and from the London Institute of City and Guild in 1914. Prior to joining the Laboratories in 1929, Mr. Mallina was employed as an Acoustical Engineer with the Wurlitzer Grand Piano Company, and later, as head of the Apparatus Development Department of the RCA Victor Company. At the Laboratories Mr. Mallina worked initially in acoustical research where he developed the first magnetic telephone message recorder and the five-reed telephone set. From 1936 on he was engaged in fundamental development on machine switching apparatus, first on AMA, later with the wire-spring relay project. In connection with the latter, he developed the solderless wrapped connection. He is also a research associate at New York University, Department of Education.

FRANK RECK joined the Laboratories in 1928. He worked on development of magnetic tape recording machines, automatic switching equipment and push-button telephones until World War II. During the war Mr. Reck was engaged in work on anti-aircraft computers, optical apparatus and the ribbon frame camera. He was also involved in rocket development work for the National Defense Research Committee. From 1944 to 1950 Mr. Reck was associated with mechanical development of automatic message accounting machines and with work on the wire-spring relays. He has since been concerned with solderless wrapped connections and tools from 1950 to 1953. Mr. Reck holds patents on various tools and on a mechanical page turner for the physically handicapped.



Strength of Small Metal Specimens

CONYERS HERRING *Physical Research*

Increasing attention has been paid in recent years to "dislocation theory" and its experimental verification. According to this theory perfect crystals should be very much stronger than those ordinarily encountered. Some very small but nearly perfect filamentary crystals discovered in a telephone maintenance problem have been used to provide striking substantiation of our picture of dislocation phenomena.

When a piece of any solid material is bent very slightly, it returns to its original shape after the bending force is removed. But if a large enough force is applied, it remains bent after removal of the force (unless it is brittle and has snapped). This is the phenomenon of *plastic deformation*, a phenomenon of great practical importance. It forms the basis of the blacksmith's work, the drawing of wires, the stamping of sheet metal parts. It also imposes annoying limits on the design of structures which are supposed to remain rigid in use.

Because of its importance and the many curious facts associated with it, plastic deformation has long been an object of scientific study by metallurgists and physicists. These studies have led to a number of widely accepted theoretical concepts and principles relating plasticity to the behavior of the atoms of which a solid is made. In the last few years these concepts and principles, formerly related only indirectly to experiment, have yielded themselves to direct observation and verification. Several recent investigations by different groups in the Laboratories have contributed to this strengthening of our understanding, and to filling the gaps in the theory. A series of such investigations, dealing with the so-called *dislocation* concept, was described by F. L. Vogel Jr. in an earlier RECORD article.* The present article will deal with the properties of *ideal crystals*, defined as crystals without any imperfections of structure. This work, like that described by Vogel, provides a nice example of how the interaction of practical engineering with basic research can yield unexpected benefits, not only to the practical work, but to our understanding of the laws of nature. Here, as we shall see presently, a surprising failure of a piece of telephone equipment led to a previously unattainable opportunity to test some basic ideas of the theory of plasticity.

To describe these ideas which were in need of testing, we ask two questions: *How strong do we expect an ideal crystalline solid to be* and *Why do real crystals deform so easily?*

Figure 1(a) shows a cross section of a typical arrangement of atoms in an ideal crystal, with no forces applied. In Figure 1(b) a small shearing stress has been applied, as shown by the arrows, with the result that the crystal has been sheared elastically through the angle θ. Hooke's law tells us that for small values of θ the shearing stress is proportional to θ. This proportionality of course breaks down when θ becomes sufficiently large; for example, Figure 1(c) shows the configuration corresponding to $\theta = 30°$. Here the stress is zero in consequence of the symmetry with which each atom is surrounded by its neighbors; that is, no external force needs to be applied to keep the atoms in these positions, once they have been brought there. The configuration of Figure 1(c) is of course one of unstable, rather than of stable equilibrium, but equi-

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* RECORD, *March*, 1955, *page* 104.

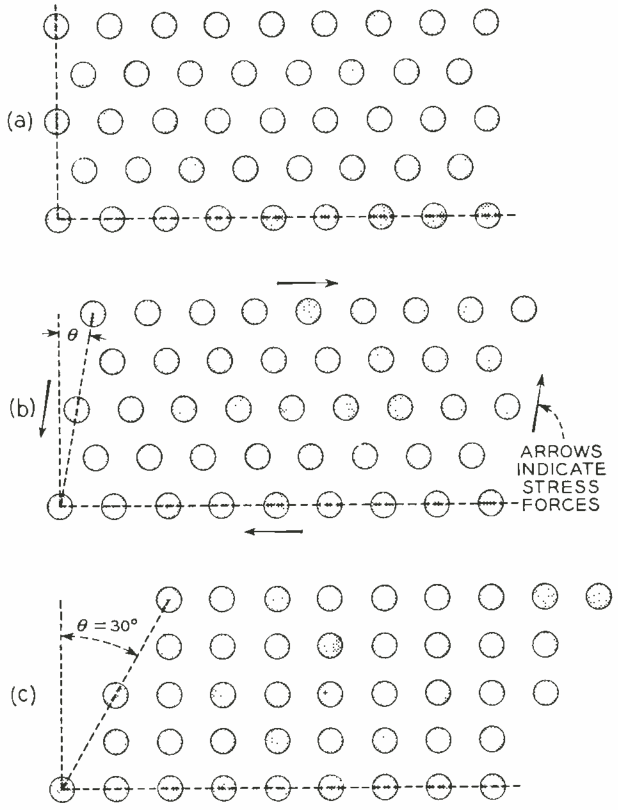

Fig. 1 — (a) Schematic arrangement of atoms in an unstrained crystal; (b) same crystal subjected to a shearing stress measured by angle θ: (c) unstable equilibrium (zero applied stress) at $\theta = \theta_0 = 30°$.

librium it is nonetheless. Thus a plot of shearing stress against θ must look something like Figure 2, rising linearly at small θ, bending over, and passing through zero at some value θ_0. For the model of Figure 1, θ_0 equals 30°; for actual three-dimensional crystals, θ_0 will have a different, though easily calculable value. Somewhere between $\theta = 0$ and $\theta = \theta_0$ the shearing stress must have a maximum value σ_m. If we try to apply a stress greater than σ_m, there will be no possible position of elastic equilibrium, and one or more pairs of neighboring planes of atoms will slide over each other for an indefinite distance. Thus σ_m is the critical stress for plastic deformation of an ideal crystal.

The slope of the σ versus θ curve at $\theta = 0$ is the shear constant G of the crystal, which can easily be measured for any given substance. However, the height of the maximum depends not only on this slope, but on how soon the curve bends over. This in turn depends on the exact nature of the forces which the atoms exert on each other. Various people have made calculations using what are believed to be fairly realistic assumptions about the interatomic forces in metals. The result is that θ_m should be something like a twentieth of a radian (about 3°) or σ_m a few percent of G. This is the theoretical elastic limit for shearing a typical ideal crystal of metal.

A comparison of this prediction with a few typical measurements by various workers is given in Table I. Since we are interested in ideal crystals, only data on carefully prepared single crystals of high purity are included. These data disagree violently with the predictions of the theory just outlined; plastic deformation seems to occur at stresses σ of from a few millionths to a ten-thousandth of the shear constant G, instead of a few percent of G. Moreover, there is a marked variation from specimen to specimen, with a tendency for the crystals of highest purity and greatest perfection, which we might expect to approximate most closely to the behavior of an ideal crystal, to have the smallest σ's. This is in line with the fact that the σ's in the table, which refer to well-annealed single crystals, are some tens of times lower than the "yield strengths" usually quoted for practical work with polycrystalline metals of ordinary commercial purity.

The data just described force us to conclude either that the above estimate of critical shear stress for an ideal crystal is somehow fantastically far from the truth, or else that even the best laboratory single crystals contain defects of structure which prevent them from behaving ideally. Workers in the theory of plasticity have usually followed the latter course, that of attributing plasticity to imperfections. The resulting theory will be described briefly here. It makes the interesting prediction that plastic deformation of a crystal should require less and less stress as the number of imperfections becomes fewer and fewer, *as long as some imperfections are still present.* This agrees with the data in Table I.

TABLE I — COMPARISON OF TYPICAL MEASUREMENTS OF MINIMUM SHEAR STRESS σ FOR SLIP (IN THE EASIEST CRY LOGRAPHIC DIRECTION) WITH THE SHEAR CONSTANT G IN SAME DIRECTION (AT ROOM TEMPERATURE)

Specimen	*Purity Per Cent*	σ, gms/mm²	G gms/
Aluminum single crystal	99.8 99.99+	210 104	2.4
Zinc single crystal	99.999+ 99.9	18 9	4.0
Silver single crystal	99.999 99.999	53 36	3.9
Tin single crystal	99.996	60	1.7

But when the last imperfection is eliminated, the critical stress should rise abruptly to the large value characteristic of an ideal crystal.

There are many possible types of imperfections in crystals, but most of them do not seem to be capable of reducing the critical shear stress by orders of magnitude. However, there is one type of imperfection which does have this property and, happily, it is a type which ought to be of almost universal occurrence. This is the so-called "dislocation," whose connection with plasticity was suggested in the early thirties by G. I. Taylor in England and independently by E. Orowan in Hungary and M. Polanyi in England. This type of imperfection can be briefly described as follows: Suppose a perfect crystal like that of Figure 1 is subjected to a gradually increasing applied stress which varies slightly in magnitude from place to place. Plastic deformation will commence in the regions of maximum stress, when the stress in these regions exceeds the critical stress for an ideal crystal. However, spontaneous deformation will not occur simultaneously in regions of lower stress. The configuration of the atoms immediately after yielding has commenced will therefore look like the pattern seen in Figure 3. Here the row of atoms above the line AB has slipped one space to the left with respect to the row below AB; to the left of A and to the right of B no such slip has occured. The result is that near A, and again near B, the atoms are badly out of register. In three dimensions, a disregistry of this sort must occur whenever slip has occurred over part of a plane of atoms but not over the rest; the disregistry will be localized along the line in this plane separating the regions which have slipped from those which have not. Such a line of disregistry is called a *dislocation.*

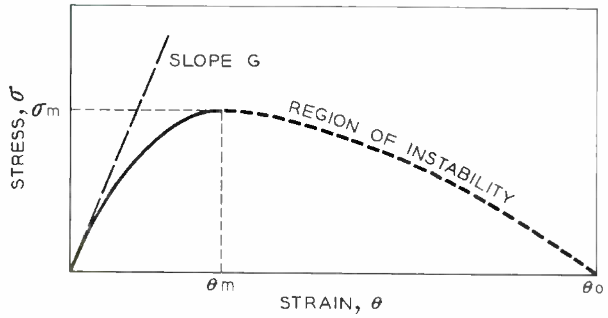

Fig. 2 — Form of stress-strain curve of the crystal in Figure 1.

If slip starts in some small region and extends progressively over a whole plane cross section of the specimen, the boundary of the region which has slipped sweeps over this plane; in other words, the dislocation moves across the specimen. This illustrates the general principle that a progressive shearing deformation constitutes a motion of dislocations, and vice versa. Motion of a dislocation all the way across a specimen produces a slip of one atomic spacing. Now the important thing about dislocations is that it can be shown to require very little effort to move them, once they have been created. Therefore, if a crystal contains a number of dislocations before the start of a deformation experiment, it will deform very easily, the ease of deformation being limited, in most cases, by such factors as interference of the dislocations with each other, or their interactions with impurity atoms.

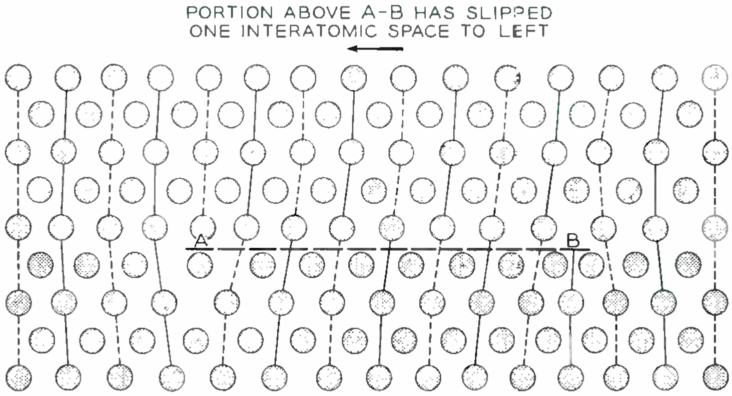

Fig. 3 — Atomic arrangement in a crystal in which slip has taken place over part of a layer of atoms. Before this deformation, the atoms formed a perfect crystal in which the rows represented by full lines above AB joined full-line rows below AB, and dashed-line rows below joined dashed-line rows above.

Starting with the foundation just described, the dislocation theory of plasticity has been developed in great detail during the last two decades, and has been applied to many scientific problems. In many cases it has been found to give a plausible account of the phenomena. However, until recently no direct check of the basic ideas of the theory has been available. These basic ideas are, first, that an ideal crystal is tremendously strong; second, that real crystals practically always contain dislocations; third, that these dislocations move easily under an applied stress; and fourth, that in their motions they create new dislocations.

Recently, it has been possible to verify the first of these ideas — that an ideal crystal is tremendously strong. Heretofore, the difficulty in measuring the strength of an ideal crystal has always been that crystals without defects seemed almost impossible to prepare. Estimates which have been made for crystals of moderately high perfection have suggested that these contain dislocations something like 10^{-4} cm apart. Thus a specimen millimeters or centimeters on a side will contain millions of dislocations. However, if a specimen of the order of 10^{-4} cm in diameter could be found, it might prove to be free from dislocations, the more so as dislocations as close as this to the surface of a crystal can be shown to be strongly attracted to the surface, and this attraction might cause them to move out of the crystal altogether. An excellent source of such tiny specimens presented itself a few years ago when, in the course of investigation of short-circuit failures of channel filters, it was discovered that multitudes of very tiny whiskers grow slowly out from surfaces of tin and many other metals.* These whiskers can be grown to lengths of several millimeters, and have diameters of about 2×10^{-4} cm and smaller, most of them being near this upper limit of size.

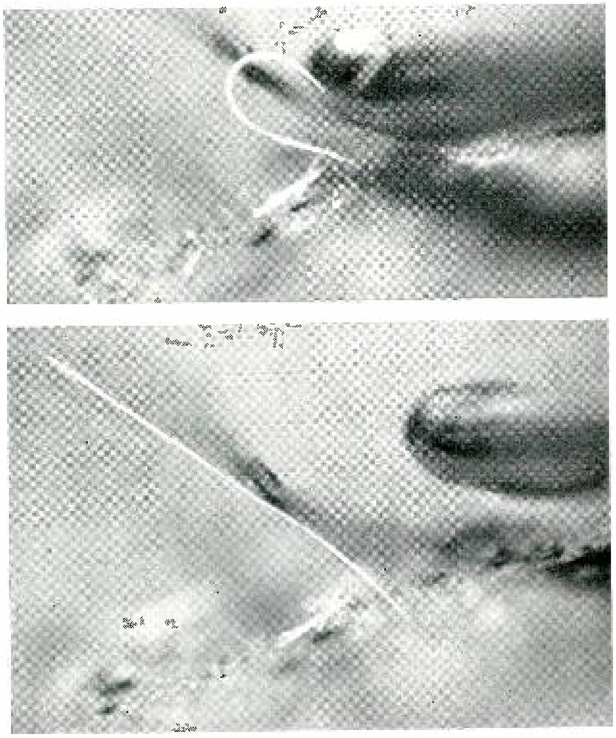
Fig. 4 — (Above) Tin whisker bent into loop of radius 0.009 cm: (Below) same whisker after removal of constraining probe.

When the proposal to study the plasticity of such whiskers was made, S. M. Arnold offered a tin-plated sheet covered with a 2½ year "beard." C. J. Calbick had previously made electron-microscopic studies of the diameters of whiskers grown on this material. Bending was chosen as the simplest type of deformation to study. The experiments, carried out in 1951 by J. K. Galt, are illustrated in Figure 4. (The illustration on the first page of this article shows Mr. Galt [right] discussing the mathematics of crystal deformation with the author.) The metal sheet was mounted on the stage of a microscope and manipulated until a whisker was in horizontal plane and in focus. A No. 44 formex-covered copper wire, stretched normal to the focal plane, was brought into contact with the whisker midway along its length. The end of the whisker was then pushed with a micromanipulator point in such a direction as to bend the whisker around the copper wire, as shown in Figure 4, top. The radius of curvature of the bent whisker was noted, and the micromanipulator was then removed. In many cases the part of the whisker between the copper wire and the end straightened out perfectly, as shown in Figure 4, bottom; the wire was not permanently deformed.

From the radius of curvature of the bent states and the (statistically) known diameters of the filaments, one can easily calculate how much the outer edges of the loop have been stretched, or how much the inner edges have been compressed. Values above 1 per cent elongation of the outer edge were observed sufficiently often to give assurance of their reality and reproducibility. This means that the shearing component of stress at the outside or inside of the loop must have been of the order of 1 per cent of the shear constant G, that is, a sizable fraction of the theoretically predicted strength of an ideal crystal. More extreme deformations were sometimes produced. In such cases the whisker never became

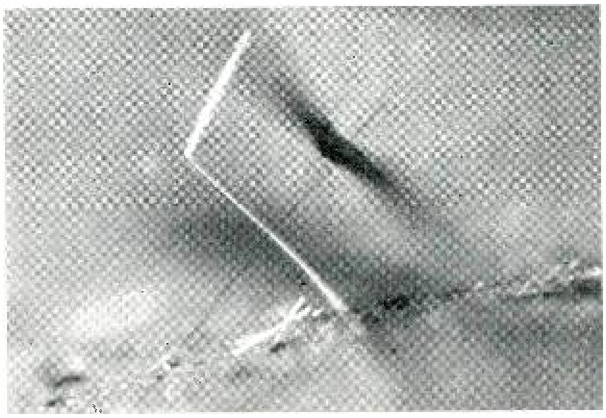
Fig. 5 — Typical bend in a tin whisker, produced by excessive stress.

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* Record, *June*, 1951, *page* 260, and *November*, 1954, *page* 417.

homogeneously deformed, but instead usually developed a sharp bend, as shown in Figure 5. This bend was presumably caused by an excessive concentration of stress, perhaps at an irregularity in the whisker. It is quite plausible, in fact, that all the whiskers which developed permanent bends did so at regions were the stress was several times the value calculated from the curvature. If this were true, the stress at yielding would be in approximate agreement with the theoretical yield stress for an ideal crystal. At any rate, the two are of the same order of magnitude.

This experiment seems thus to confirm the expectation that the whiskers are practically ideal crystals and that ideal crystals should be very strong. However, one might imagine the strength to arise from the whisker's being a very imperfect crystal, with many dislocations but with many impediments to their motion. This is what is believed to occur for most everyday "springy" materials, such as piano wire. If this were the case here, the whisker should deform slowly under stress, at least at temperatures high enough for thermal agitation to "wiggle" the dislocations around appreciably. In an experiment to test this possibility, a whisker was held in the bent position for a week. No observable deformation occurred. By contrast, the rates of deformation which have been observed on large crystals of tin under stresses hundreds of times smaller would have produced a deformation many tens of times larger than the minimum observable value. Thus it seems likely that the whiskers were indeed behaving as ideal crystals should.

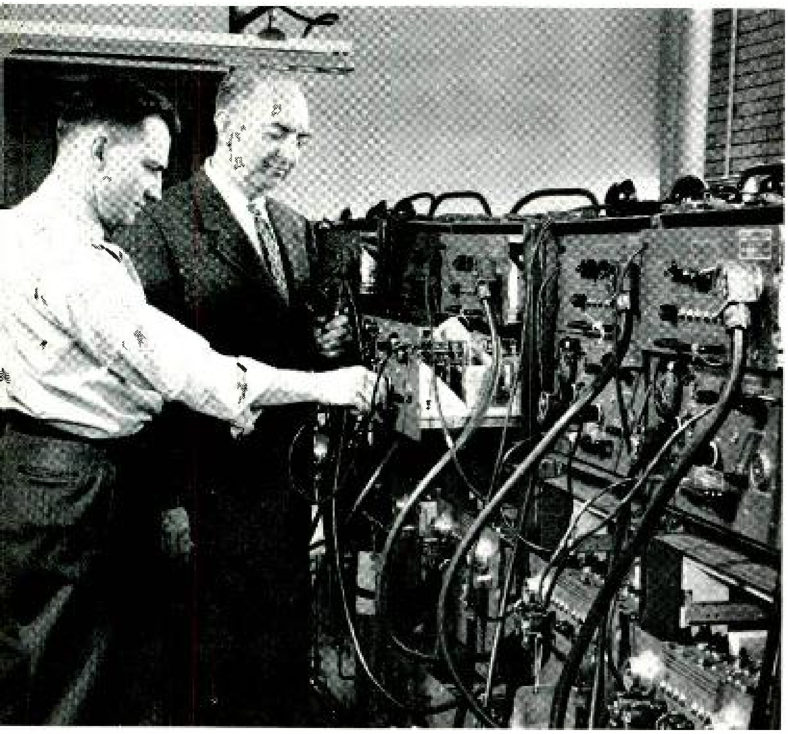
This experiment, though striking in its conclusion, is of course only a preliminary exploration of a field which merits much further work. Investigators in a number of other institutions have subsequently taken up the study of whiskers and their properties. Some remarkable results have recently been published by Piper and Roth of the General Electric Company. They succeeded in making what apparently were ideally perfect crystals of zinc sulfide as large as 5×10^{3} cm in diameter. These could be bent about as much as the tin whiskers described above, without any permanent deformation.

Thus the evidence is piling up that the first premise of the dislocation theory of plasticity is correct: an ideal crystal requires a remarkably high stress to produce plastic deformation.

Fig. 6 — J. K. Galt using micromanipulator to bend a metal whisker on a specimen.

THE AUTHOR

Conyers Herring received an A.B. degree from the University of Kansas in 1933 and his Ph.D. degree from Princeton in 1937. He later was a National Research Fellow at M.I.T. and a Research Associate at Princeton. Still later he was an Instructor of Physics at the University of Missouri, held a position with the Division of War Research at Columbia University, and was Professor of Applied Mathematics at the University of Texas. Since joining the Technical Staff of Bell Telephone Laboratories in 1945, Mr. Herring has been engaged principally in research in physical electronics and solid state physics. He was a member of the Institute for Advanced Study at Princeton, New Jersey, during 1952 and 1953. He is a Fellow of the American Physical Society and a former member of the executive committee of the Society's Division of Solid State Physics. He is also a member of the American Association for the Advancement of Science and from 1952 to 1954 was on the Board of Editors of the Physical Review.



The new telephone communication equipment recently developed by the Laboratories for the military permits great flexibility of field operations. A main long-haul route transmits twelve telephone message channels over cable and radio, and four-channel cable routes branch out where required. All of this equipment has been greatly reduced in size compared with the World War II versions and it meets stringent Signal Corps requirements for high-quality transmission.

G. H. HUBER *Military Communication Development*

A Military Communication Network Using Wire and Radio

Systems for placing several telephone conversations on a single pair of wires or on a single radio channel are not new to military communication. One of the communication standards of World War II, the CF1 carrier telephone terminal*, was used with cable, open-wire, and radio in both the European and Asiatic theaters with much success. It was in continued demand so that, when the Korean Campaign was in progress, these carrier telephone terminals were again put in production in substantial quantities and were produced until the middle of 1953. About this time, the AN/TCC-3†, a new version of this carrier telephone technique application, was placed in quantity production. The AN/TCC-3 terminal gives better transmission in a much smaller package, with components designed in accordance with the latest military specifications. It provides four telephone-message channels plus one voice-frequency maintenance channel. It is a self contained, ac operated, manually regulated carrier telephone terminal. An associated AN/TCC-5 repeater was designed to extend the operation of these terminals up to about a hundred miles. For longer transmission distances, similar 100-mile "links" are connected together in tandem.

While the four-channel system was being planned, a thorough study of military communication needs was in progress. On the basis of Signal Corps experience, it was determined that a longer-distance system with increased channel capacity would be required. For greater flexibility in difficult terrain situations, it was also determined that radio-relay links would be desirable. Bell Laboratories therefore developed both a twelve-channel system for circuits up to 200 miles between terminals and radio equipment suitable for use with either the four- or twelve-channel cable systems.

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* Record, *December*, 1943, *page* 168.

† Army-Navy Ground, Transportable Carrier Communications No. 3.

A possible military setup that uses all three types of equipment is shown in Figure 4 on pages 292 and 293. At the left we have twelve channels – four on each of three short-haul cable systems. For any single telephone message channel we can substitute one telephoto channel or sixteen telegraph channels. With various combinations of repeaters and terminals, these four-channel systems feed into one twelve-channel terminal (AN/TCC-7). From this point on, the illustration represents the long-haul, backbone portion of the network. The twelve channels are transmitted via unattended repeaters (AN/TCC-11), attended repeaters (AN/TCC-8), and radio (AN/TRC-24) to another twelve-channel terminal at the right. The distance represented in the drawing is only about 180 miles, but additional links can be extended from the twelve-channel terminal to give communication distances up to about 1,000 miles. At any such terminal, four-channel equipment can branch off from the main route. Each terminal, repeater (except the unattended repeater AN/TCC-11), and radio set of this twelve-channel system is self-contained and ac operated. Each is also automatically regulated to compensate for variations in temperature and for cable attenuation. This is done with sufficient precision to permit stable, low-loss operation of all channels, with any type of service in both arctic and tropic conditions.

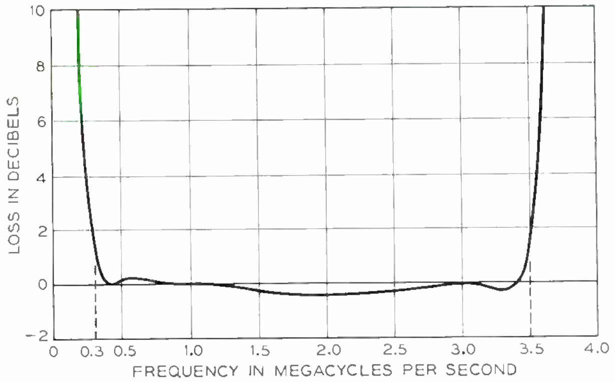


Fig. 1 — Attenuation characteristic for 100-mile four-channel system or 200-mile twelve-channel system.

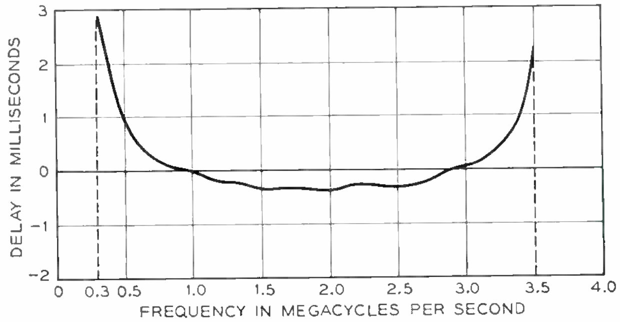


Fig. 2 — Delay characteristic for 100-mile four-channel or 200-mile twelve-channel systems.

Fig. 3 — For purposes of demonstration, complete four- and twelve-channel terminals and radio equipment are here assembled with AN/TRC-24 antennas in background. In operation, units would normally be under protective cover.

This communication system has been developed to meet the severe requirements of military use. Military use requires that the equipment be capable of working satisfactorily with a wide range of supply voltages and line frequencies, as well as in all ranges of humidity and temperature. It must be capable of being moved and installed quickly and must stand rough usage under tactical field conditions when operated by relatively untrained personnel.

A new design of four-conductor cable, known as "spiral-four," is to be used as the wire transmission medium for the new systems. This cable, developed for the Signal Corps, is polyethylene insulated, is extremely well balanced electrically, weighs less and is more rugged than the World War II rubber-insulated counterpart. The same band of frequencies is used in each direction of transmission, 4 to 20 kc for the four-channel system, and 12 to 60 kc for the twelve-channel system. In addition, a voice channel 300 to 3,000 cps with the four-channel system, and 300 to 1,700 cps with the twelve-channel system, is provided for maintenance only.

Loading coils will be added to the spiral-four cable at intervals of one-quarter of a mile for the four-channel application. At 50°F, such inductive loading decreases the loss at 20 kc from 2.9 db per mile to 0.8 db per mile. This allows the repeaters to be spaced about 30 miles apart. Loading would not be effective, however, in reducing loss at 68 kc, the top frequency of the twelve-channel system, unless coils were introduced at intervals much shorter than one-quarter of a mile. This is undesirable because the cable is designed to be readily handled in one-quarter mile sections. Therefore, to keep the attended repeaters spaced at substantial intervals, an unattended repeater is added to the cable every five and three-quarter miles. This spacing is dictated by crosstalk characteristics in the spiral-four cable. The unattended repeaters receive power over the same spiral-four cable used for channel transmission and permit the attended repeaters to be spaced up to 40 miles apart. The gain of the twelve-channel cable system is automatically regulated at the un-

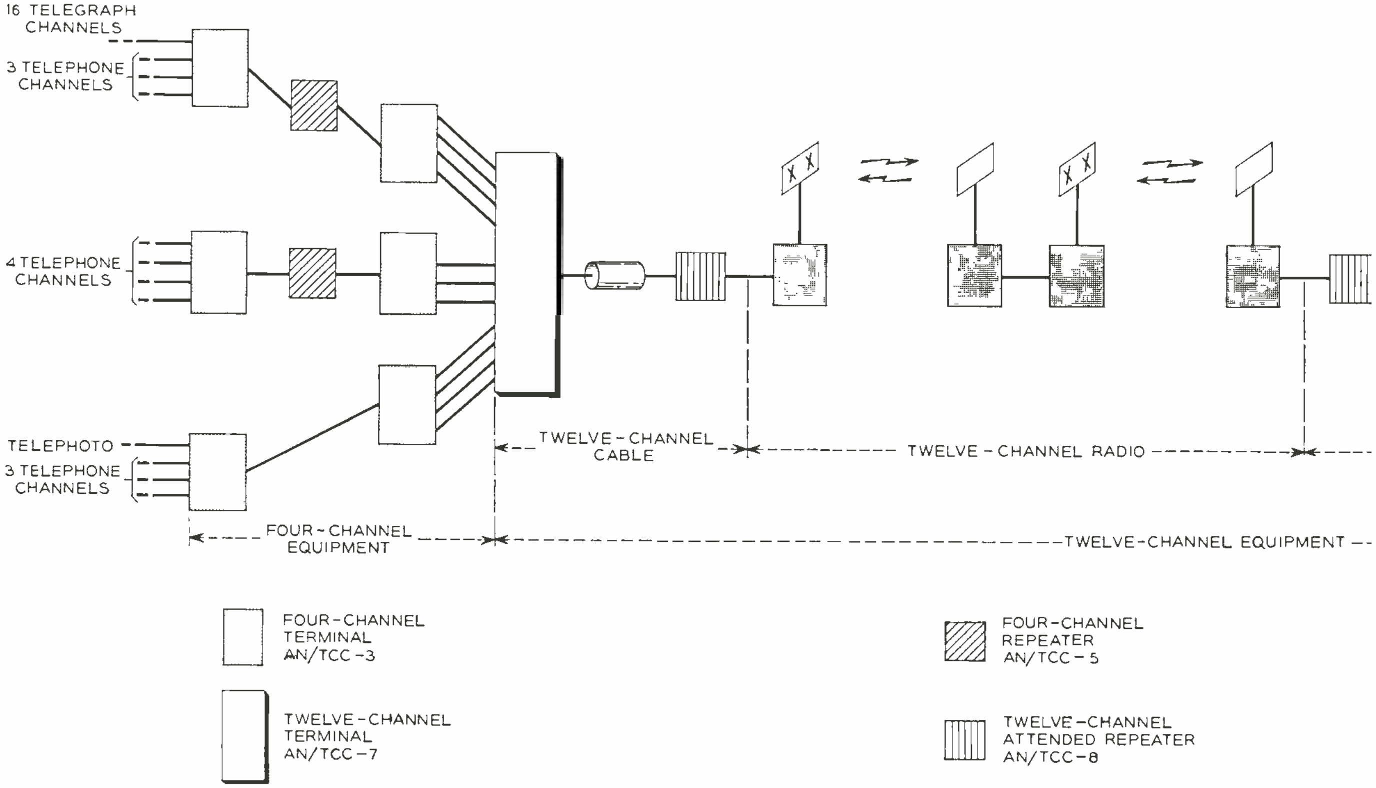
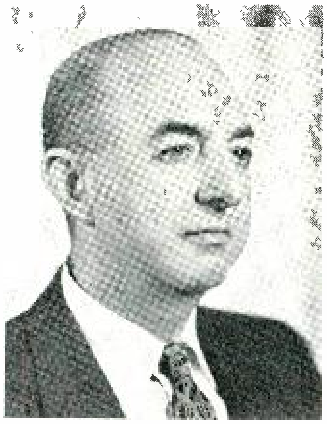


Fig. 4 — Possible section of complete network, using both cable and radio equipment and covering about 180 miles

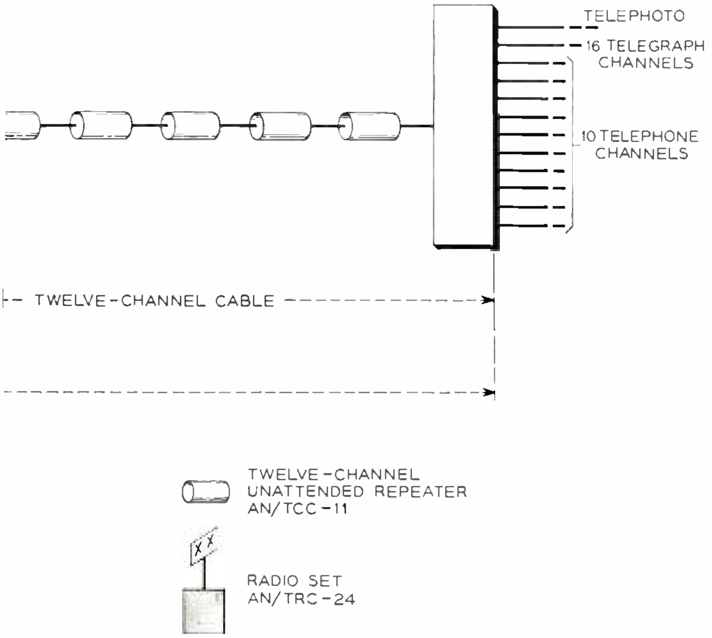
THE AUTHOR



George H. Huber joined the Engineering Department of the Western Electric Company in 1920. Upon completion of company-sponsored and other studies he became a member of the Technical Staff of the Laboratories. With the Transmission Research and Transmission Development Departments, he has been responsible for advancements in the C, J, K, and L carrier telephone systems. During the war years he was engaged in the development of radar test equipment and of a microwave radio-relay system for the Armed Forces. He was the Laboratories Project Engineer for the AN TCC-3, 5, 7, 8 and 11 during the study and the development phases of these projects. He is a senior member of the I.R.E., a member of the A.I.E.E., the American Institute of Physics and the Acoustical Society of America.

attended repeaters by thermistors sensitive to ambient temperature. Further automatic regulation is provided at each attended repeater and receiving terminal by thermistors that are guided by the 68 kc control frequency.

The AN/TRC-24 radio sets operate in the upper very-high-frequency and the lower ultra-high-frequency ranges from 100 to 400 mc where antennas can be easily aligned and where fading problems are not serious. Many services operate in this frequency range, so it is essential that the radio-relay system use the minimum radio-frequency bandwidth consistent with good performance. The radio sets use a modified type of frequency modulation to obtain a balance between best crosstalk and noise performance. The radio transmitter and receiver are operated on separate frequencies to obtain different channels for the two directions of transmission. The sets may be placed on any of 425 radio channel frequencies. Radio repeaters may be spaced about 25 to 30 miles apart with favorable terrain, and about seven or eight radio transmitters and receivers will operate in tandem between terminals to form a 200-mile link. Each radio channel will carry either the four or twelve carrier channels plus the maintenance channel.



The low distortion introduced by the terminals and radio sets to make the multi-channel, multi-link operation possible is one of the distinguishing characteristics of these military systems. When 35 radio transmitters and 35 receivers are operated as a five-link system with five transmitting carrier terminals and five receiving terminals, the over-all interference due to the summation of cross-talk produced by distortion products plus noise is at least 34 db below the average wanted signal. Equally low interference is present with an equivalent all-cable system with about 170 repeaters.

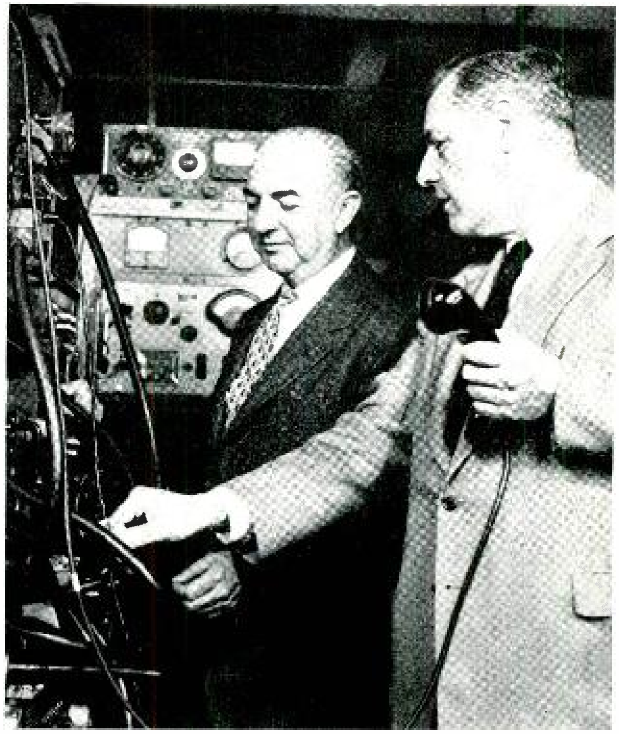
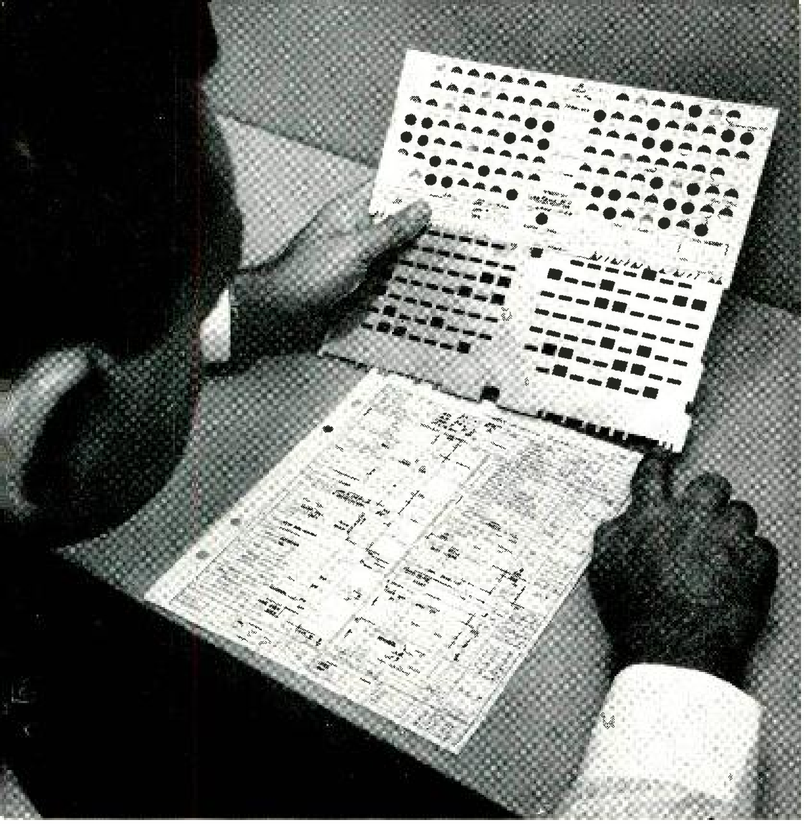


Fig. 5 — At the Marion Shops of the Western Electric Company, the author (left) and R. R. Andres inspect twelve-channel terminal equipment.

The 1,000-mile circuits derived from either the cable system, the radio system, or both, are sufficiently stable to perform as well as the best commercial systems. Each link (100-mile four-channel system or 200-mile twelve-channel system) may be operated with no over-all loss when the transmitting and receiving paths are separately connected, or with a 3 db loss when the two paths are combined at a switchboard. The band filters which separate the several channels determine the over-all attenuation and delay characteristics of the channels. A typical band attenuation characteristic for one link is shown in Figure 1 and a corresponding delay characteristic is shown in Figure 2.

The development of these new carrier telephone systems together with the new spiral-four cable and new radio sets forms a basis for a comprehensive military communication network.



The Translator Car in Toll Crossba

D. A. JAMES *Switching Systems Development II*

Much of the flexibility of the 4A long-distance crossbar system in handling complex switching problems comes from the use of the metal cards in the 4A translator. Because a large amount of information can be entered on each card, the translator can help set up long-distance telephone connections with great speed and efficiency.

The relationship between the card translator and other parts of the 4A system has been discussed in several previous articles.* The card translator accepts input information in terms of telephone numbers dialed by customers or operators and "translates" this information into a language that helps to establish a connection from one customer to any other customer in the United States or Canada. The actual translator card is therefore a basic component of the entire 4A system, and it contains information that affects practically all other switching units.

The thin metallic translator card has an arrangement of tabs along the bottom edge and a number of rectangular holes in the face of the card. This card is prepared for use in a translator as follows: First, traffic engineering personnel tabulate the necessary information on a form termed the "translator card order." On the basis of this order, a cardboard template is then manually perforated and turned over to a punch machine operator. He uses the cardboard template to punch out or code the metal card. In this process, most of the tabs along the bottom edge are cut away, leaving a pattern of tabs corresponding to the input information. Then certain of the rectangular holes in the face of the card are enlarged to correspond to the desired output information. The illustration at the head of this article shows, from top to bottom, a cardboard template, a coded metal card, and a translator card order form.

As seen in Figures 1 and 2, the card before being coded has 38 tabs and 118 holes. A large amount of predetermined information can be entered on a single card, but for simplicity, only the more important operational features will be described here.

The first three digits dialed by the customer or operator will cause a translator card to be selected. This particular card will have all the tabs in groups D, E, and F cut away, but two tabs will remain in each of the groups A, B, and C. These remaining tabs correspond to the first three digits dialed in

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* Record, *October*, 1953, *page* 369; *December*, 1953, *page* 481; and *March*, 1955, *page* 93.

accordance with the two-out-of-five code.* For some situations this initial card will be sufficient for the entire translation, and the pattern of unblocked light channels will initiate the process of locating the desired trunk. In other situations, however, the output information of this three-digit card may determine that further translation is required. In this case, the first card will be restored and a second card will be selected. This card will have tabs remaining in all six of the groups A through F. In other words, the second card corresponds to the first six digits dialed by the customer or operator, instead of only the first three. The six-digit card will also be used for four or five digit codes, in which case the F digit tabs or E and F digit tabs will be removed completely.

The CARD GROUP tabs (lower right in Figure 2) are always coded on the basis of two-out-of-four tabs and indicate the type of card as THREE-DIGIT, SIX-DIGIT, ROUTE ADVANCE, or ALTERNATE ROUTE. The use of these tabs will be explained in the examples to follow. The transmission tabs VO (VIA ONLY) and NVO (NON-VIA ONLY) may be coded to permit a distinction between two groups of outgoing trunks to the same destination, differing only in transmission qualities.

Whether or not a second card is required on a specific call is determined from the PRETRANSLATION section of the output information of the first card. This section is seen in the upper left of Figure 2. If three digits are sufficient, a second card is not necessary, and the NCA hole will be enlarged, meaning NO COME AGAIN. If four digits are to be translated, a second card is required. In this case, the CA4 hole will be enlarged, meaning COME AGAIN WITH FOUR DIGITS. The CA5 and CA6 holes are similarly used for five- and six-digit translation.

In a typical office there may be several thousand six-digit cards located in the card boxes of various translator machines. Therefore the line of holes labeled TRANSLATOR BOX NUMBER in Figure 2 is used to identify the particular translator that has the desired six-digit initial routing card. The hole labeled HB will be enlarged on the three-digit card if the six-digit card is in the HOME BOX translator, and others of the holes in this group will be enlarged to identify other translators in the office.

Once the actual routing card is located (either the original three-digit card or the six-digit routing card), the basic function of locating the desired trunk is initiated by the groups of holes labeled TRUNK BLOCK CONNECTOR, TRUNK BLOCK, GROUP START, and GROUP END in the lower part of the card and by the OGT APPEARANCE (OUTGOING TRUNK APPEARANCE) at the top of the card. Enlarged holes in these groups must tell the switching equipment: (1) which one of thirty trunk block connectors is to be engaged for the call, (2) which one of ten trunk block relays in this connector is to be selected, and (3) on the span of terminals of this relay, where the search is to begin (GROUP START) and where it is to end (GROUP END).

If the trunks in this group are all busy, further information will be found on the ROUTING INSTRUCTIONS group in the middle left of the card. Two of these five holes will be enlarged to indicate the subsequent procedure. Among the various types of instructions provided, this group will tell how to find additional trunk groups, how to test for alternate routes, and how to terminate calls for which no further trunks are available. It may also indicate that the entire routing procedure must be repeated on a second trial.

These are only a few of the more important features of the output section of the translator card, but they illustrate the card's essential role in initiating a search for an idle trunk to connect the calling customer to the desired telephone. Other holes in the output section are best described by using

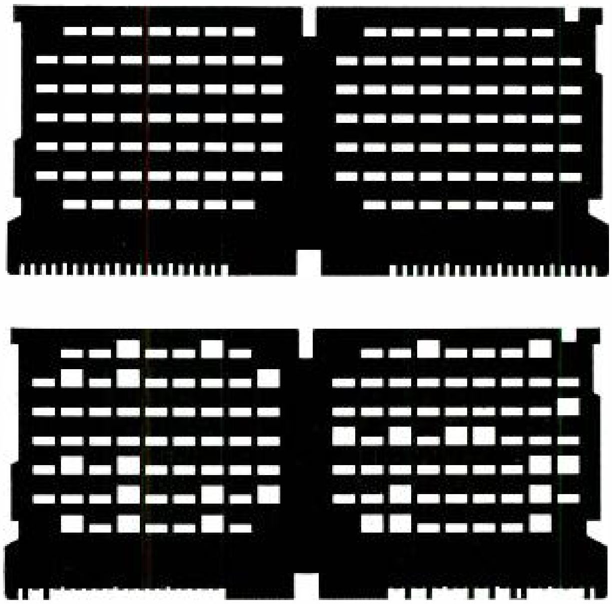

Fig. 1 — Above, shadowgraph of an uncoded translator card. Below, coded translator card, as viewed from phototransistor end.

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* By this coding system, two of the five values 0, 1, 2, 4, and 7 define the digit; for example, 0 and 4 define the digit 4, 2 and 7 define the digit 9, etc. The values 4 and 7 define the digit 0.

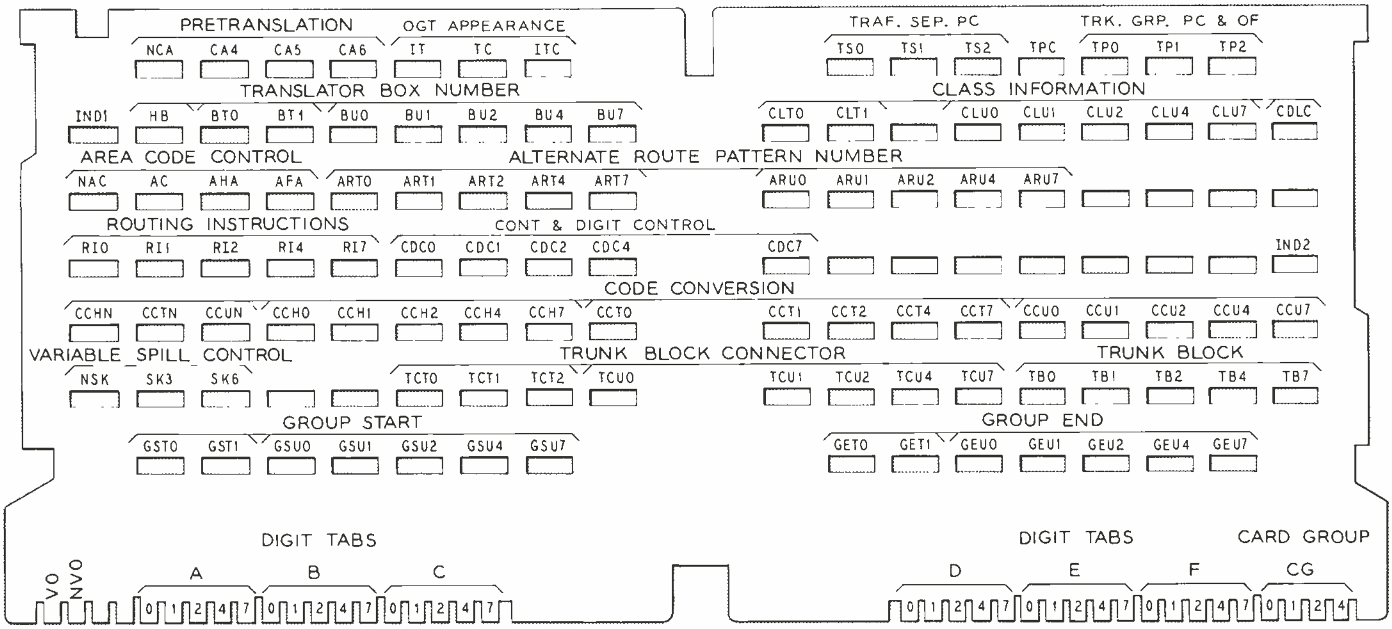

Fig. 2 — Drawing of card showing assignment of holes and tabs.

two specific examples of routing arrangements.

Consider first a situation where both the calling and called telephones are in the same national numbering area, as illustrated in Figure 3. A call is to be switched through the Los Angeles 4A office for completion to the MAdison 5 (that is, 625) office. The traffic engineer setting up the translator cards must be fully cognizant of all the switching arrangements involved in such a call, and must prepare detailed instructions for the correct coding of the input tabs and output holes.

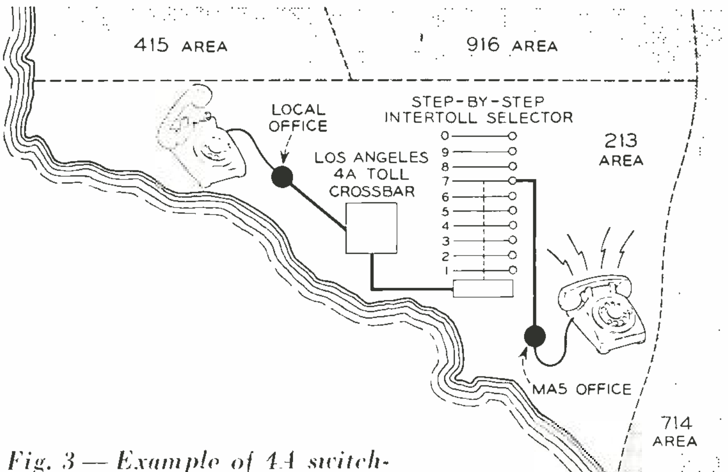

Fig. 3 — Example of 4A switching involving ony one numbering area, with no alternate routing.

Assume that there are 58 trunks from Los Angeles to the step-by-step intertoll selectors serving the MAdison 5 office. A card will have been prepared with the A, B, and C tab-groups coded 625, and this card will be selected in a Los Angeles 4A translator when these three digits have been received. In the CARD GROUP tabs, numbers 1 and 4 will remain, indicating that this is a three-digit card. The NO COME AGAIN hole will be enlarged, since only the three digits are required. The TRUNK BLOCK CONNECTOR, TRUNK BLOCK, GROUP START, GROUP END, and OGT appearance holes will direct the switching equipment to test the first 40 of the 58 trunks. Assuming that the trunks to the MA5 office are on the seventh level of the selector, the MA5 digits must be deleted and the 7 prefixed. The card will control this "code conversion" by the enlarged holes in the VARIABLE SPILL CONTROL group at the lower left in Figure 2, and in the CODE CONVERSION group in the center. The SK3 hole will be enlarged, meaning SKIP THREE DIGITS. The digit 7 will be entered in the code conversion group by enlarging the CCU0 and CCU7 holes.

If the forty trunks are all busy, the routing instruction holes will direct the testing of the other 18 trunks by means of another card. Also, the AREA CODE CONTROL group (upper left in Figure 2) will have the NAC hole enlarged, indicating that the MA5 is NOT AN AREA CODE. On this second card, the essential information will be identical to that on the original card, except that the trunk block connector, trunk block, group start, and GROUP END holes will refer to the 18 additional trunks. If these trunks are also busy, the ROUTING INSTRUCTIONS group in the second card will cause a reorder signal to be sent to the calling customer or to the operator.

This fairly simple illustration assumes that no alternate routing is provided and that all switching occurs in the same numbering area. The second example, however, involves a somewhat more complex situation. As shown in Figure 5, the call originates in AREA 213, at an office served by the Los Angeles 4A equipment, and is to be completed in AREA 415, at the YUkon 2 (982) office. Direct trunks to the San Francisco crossbar tandem office are available and also trunks to Oakland over an alternate route. In this case the complete telephone number dialed is 415-982-XXXX. Upon the reception of 415, a three-digit card with 415 coded on the A, B, and C tabs will be selected in the Los Angeles 4A office. On this card, however, the CA6 (COME AGAIN WITH SIX DIGITS) hole will be enlarged. Since there are now two routes to the called area, both the numbering-area digits and the office-name digits must be considered by the switching equipment. The translator BOX NUMBER holes will indicate the location of the desired six-digit card, and the AC hole will be enlarged in the AREA CODE CONTROL group to indicate that an area code is involved.

The three-digit card is then restored, and the new six-digit card with 415-982 entered on tab groups A through F is selected. Card group tabs 2 and 4 remain on this card, indicating a six-digit translation. As before, the new card will determine how the switching equipment is to search for an idle trunk among the direct trunks to San Francisco. Holes will be enlarged in the CLASS INFORMATION group (upper right in Figure 2) to indicate that the necessary digits are to be transmitted by the multifrequency method.* The SK3 hole in the variable spill control group will be enlarged, since the 415 code digits are not needed in the final switching of the call from San Francisco to YUkon 2.

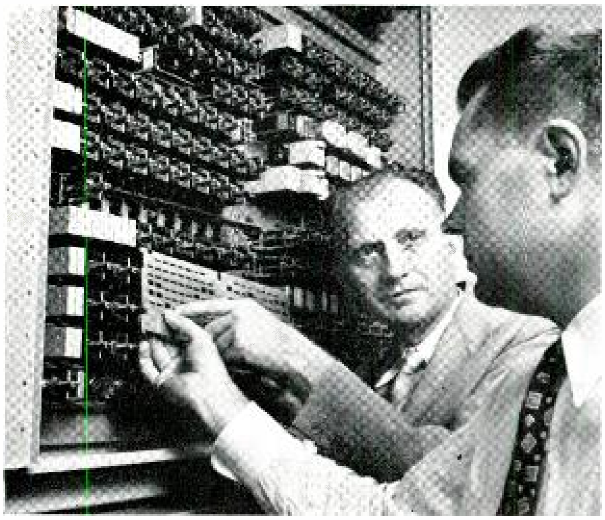

Fig. 4 — C. Clos (left) and the author discuss coded information on card as reflected in operation of 4A equipment relays.

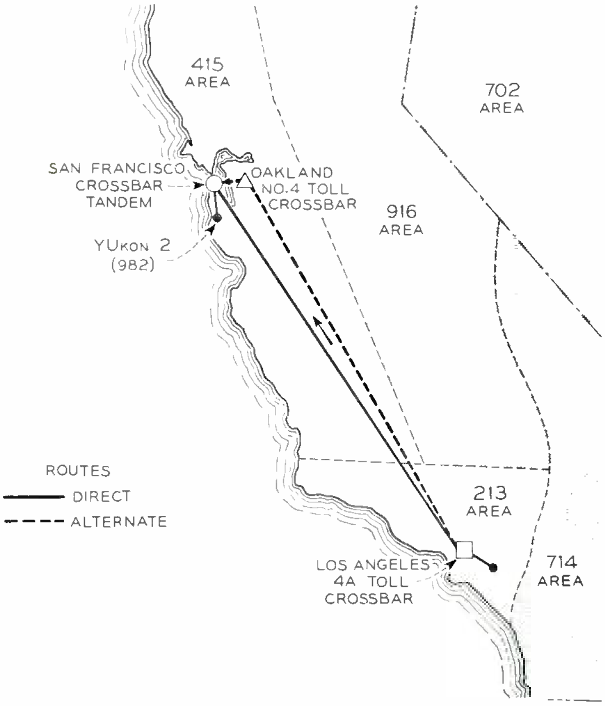

Fig. 5 — Example of 4A switching involving two numbering areas, with alternate routing.

In the previous example, the ROUTING INSTRUCTIONS holes controlled the search among 18 additional direct trunks. For this call, however, a different combination of these holes will be enlarged to indicate a different testing procedure involving the alternate route. Also required in this case is a combination of enlarged holes in the ALTERNATE ROUTE PATTERN NUMBER group in the upper center of Figure 2. If all the direct trunks to San Francisco are busy, a different three-digit code will be derived from the alternate route pattern number. A new card coded with these three digits and card group tabs 0 and 2 (indicating an alternate route card) will be selected in a translator. This card represents the trunks to Oakland. Appropriate enlarged holes will again govern the testing of the alternate-

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* RECORD, *June*, 1954, *page* 221.

route trunks, and two of the routing instructions holes will cause a second trial to be made if all the alternate trunks are busy. The area code 415 will be entered in the CODE CONVERSION group across the center of the card. This determines the number of digits to be skipped on alternate routes. Also the hole marked AFA (ALTERNATE THROUGH FOREIGN AREA) is enlarged in the AREA CODE CONTROL group, since the call will be completed in an area foreign to Los Angeles.

This example assumes that a six-digit card with 982 (YU2) in the D, E, and F tabs has been prepared. It may not have been desirable, however, to provide six-digit cards for all of the offices served in the San Francisco area. If this were the case, a PRINCIPAL CITY routing would have been provided on the original 415 three-digit card. Since this card has been used only to locate the six-digit card, it can be prepared to serve a double function. By appropriate coding of the class, trunk block, trunk block connector, group start, group end, and other groups of holes, PRINCIPAL CITY routing can be obtained. Then, if no six-digit card is available, the three-digit card will again be selected and will compete the call to Oakland, the PRINCIPAL CITY for the 415 area.

There are, of course, many other switching problems encompassed by the information entered on translator cards. In fact the card is closely associated with almost all 4A switching functions. The few general aspects expressed here, however, illustrate the key role played by the card in 4A nationwide direct-distance dialing.

THE AUTHOR

D. A. JAMES received an S.B. degree in Electrical Engineering from the Massachusetts Institute of Technology in 1942, and for the succeeding two years held a position with the Western Electric Company. After two years in the United States Navy, during which he worked on infra-red signaling, he returned in 1946 to the Western Electric Company where he was engaged in the design of test equipment for toll crossbar circuits. He joined the Technical Staff of Bell Telephone Laboratories in 1948. He first was concerned with testing 4A senders and decoders and later designed a card translator test circuit and a 4A CAMA automatic trunk-test circuit. More recently he has been concerned with the mechanization of the TWX system.

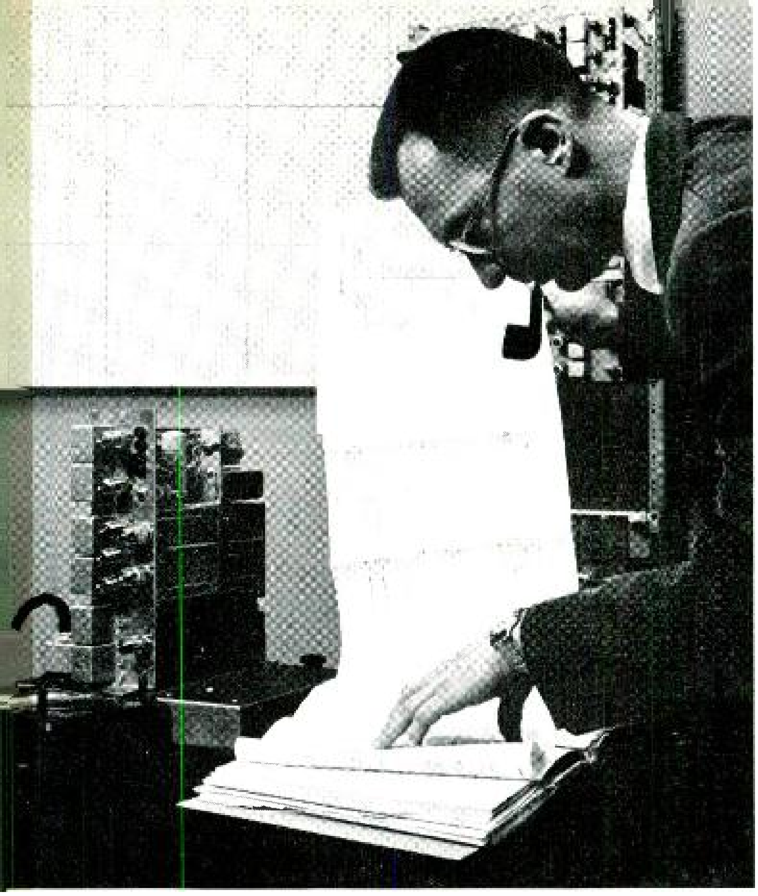
Atlantic Telephone Cable Laying Started

Laying of the world's first transoceanic telephone cable – to span the Atlantic between Newfoundland and Scotland – began June 22, the Long Lines Department of the American Telephone and Telegraph Company announced recently.

The transatlantic voiceways are to be extended 300 miles westward from Newfoundland to the eastern tip of Nova Scotia via another submarine cable, and from there to the United States over a 575-mile radio relay system.

The project is a joint undertaking of A. T. & T. Co., the British Post Office and Canadian Overseas Telecommunication Corp., and will cost about $40,000,000. Service will be established late in 1956.

Henry T. Killingsworth, Vice President of A. T. & T., said the first cable of a twin cable system would be spun out across 2,000 miles of ocean bottom by summer's end. Summer is the only time the Atlantic is calm enough to permit such an undertaking. Laying operations will start at Clarenville, Newfoundland, and be completed at Oban, which is on the west coast of Scotland, about 60 miles from Glasgow. The second cable is to be laid from Scotland to Newfoundland in the summer of 1956.



Improved Testing Instructions for Type-O Carrier

C. L. L. CRONBURG, Jr.
Transmission Systems Development I

Carrier systems such as type-O are becoming more and more complex as their usefulness increases, and this makes the problem of maintenance more difficult. To simplify and speed up the maintenance of these systems in the field, a radically new type of Bell System Practice has been developed. This B.S.P. uses a single multi-folded page to display in a simple, easy-to-read manner the same information that previously required many closely-spaced printed pages.

The Bell System is constantly seeking simpler procedures and better equipment for servicing its increasingly complex systems. To this end, new concepts have been introduced that have greatly improved maintenance methods. Some of these new concepts have been included in type-O carrier,* a system in which low cost is a requirement. New features were incorporated not only into the system but also into the Bell System Practices that provide instructions for servicing.

The use of plug-in assemblies and subassemblies was borrowed from type-N carrier† to facilitate replacement of any units that become defective while in service. Faulty units are cleared of trouble at a centrally located servicing center.‡ Some of the type-N subassemblies were used in type-O with practically no changes.

When such "unitized" equipment is mounted in bays at a terminal, important test-points and controls are inaccessible from the front or rear of the bay. This condition occurs with the channel units used in N and O carrier,§ so a special "Channel Unit Test Stand," above, was developed to give access to the internal test points and controls. A channel unit is unplugged from its position in a terminal and plugged into the test stand, from which a 10-foot extension cord connects to the bay so that the unit under test works normally while in the stand. Jacks on the test stand are used to connect test tones and supervisory or dialing signals to the channel unit, and a selector switch gives a choice of test conditions. While intended for use with channel units, the test stand can also be used with some other

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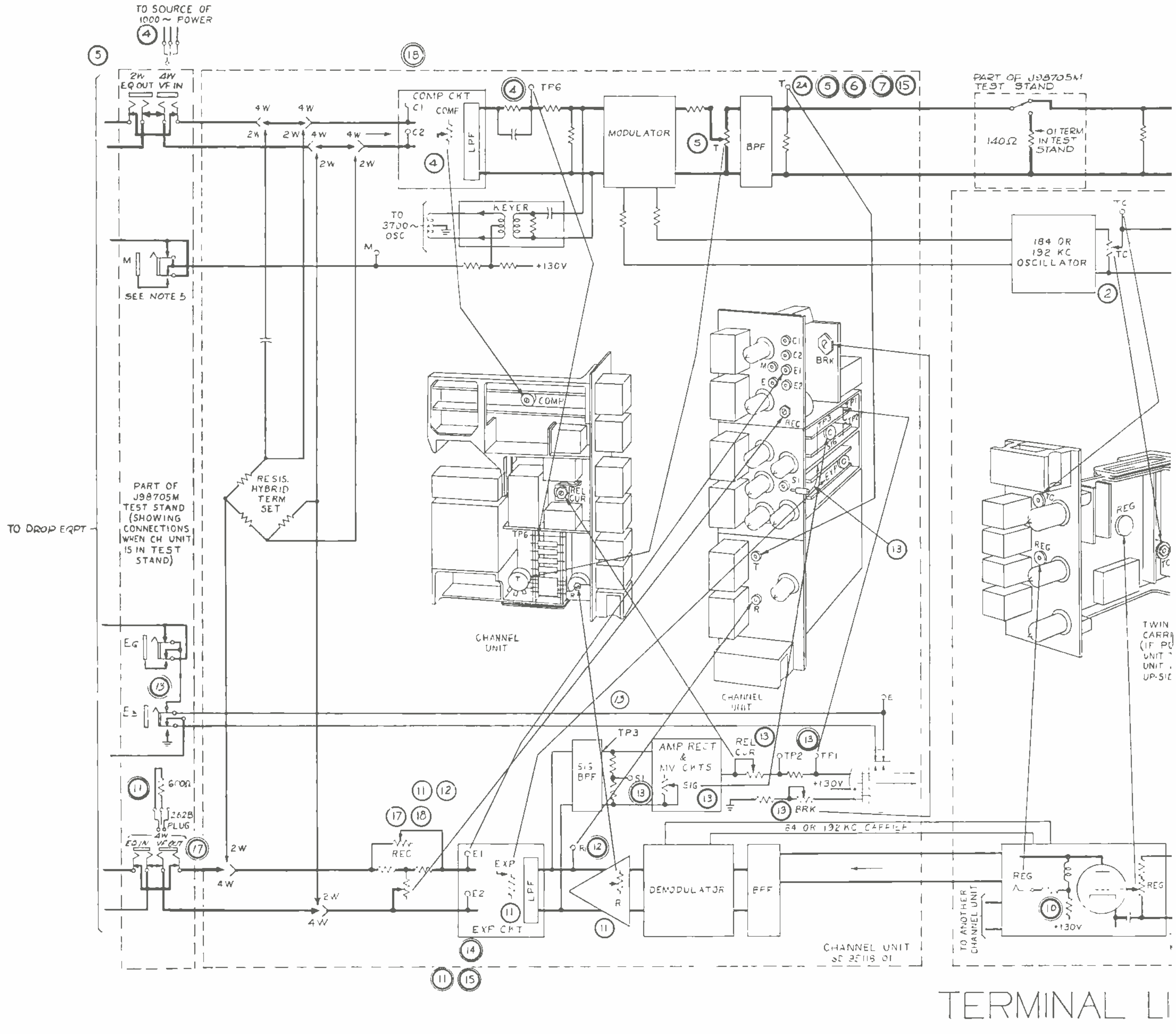
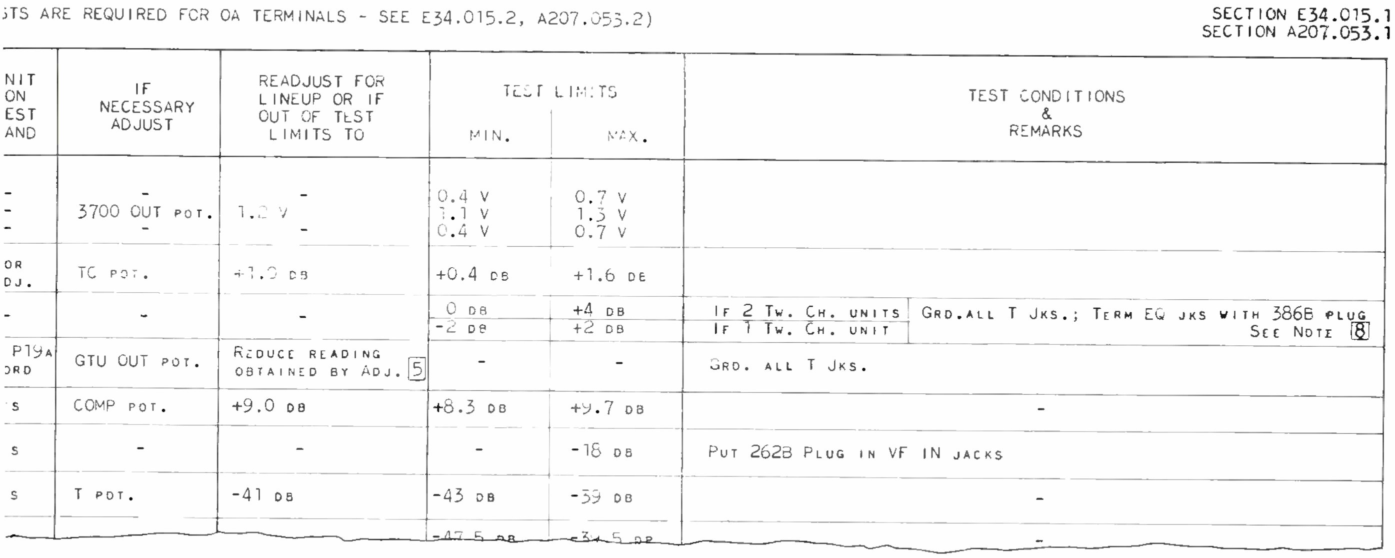
* Record, *June*, 1954, *page* 215. † Record, *July*, 1952, *page* 277. ‡ Record, *July*, 1955, *page* 264. § Record, *October* 1952, *page* 381 and *September*, 1954, *page* 341.

PROCEDURE FOR OA, OB, OC, AND OD TERMINALS (ADDITIONA

LINEUP TESTS IN NUMERICAL SEQUENCE [2]		PURPOSE OF TEST	NO. OF TESTS PER TERM. [1]	1000-CYCLE INPUT 4W AT VF IN JK. OR C1 & C2 JKS. [3]	SIGNALING SET CONDITION IN CHANNEL UNDER TEST [4]		MEASURING EQUIPMENT REQUIRED AT		MEASURE TEST POINT TO GRD. OR BETWEEN TEST POINTS
					TSTG. END	DIST. END	TSTG. END	DIST. END	
ANSMITTING TESTS AT EACH TERMINAL	1	Grp. Osc. Unit Tests Carr. H Osc. Output 3700 Osc. Output Carr. L Osc. Output	 1 1 1	 - - -	 - - -	 - - -	 A A A	 - - -	 Carr H jk. 3700 jk. Carr L jk.
	2	Trans. Carr. from Tw. Ch. Carr. Units	2	-	-	-	A	-	TC jk.
	2A	Terminal Output	1	-	-	-	A + 4P + L	-	EQ BRDG jk.
	3	Coordination Adj. (If Req'd. See 4.07)	1	-	-	-	A + 4P	-	GTU OUT jk.
	4	Compressor Output	Channels 1 2 3 4	-16 dbm at tstg. end	Off Hk	-	A + (C + R) + Q	-	TP 6
	4A	Noise at Compressor Output	↓ ↓ ↓ ↓ 1 2 3 4	None	Off Hk	-	A + (C + R) + L	-	TP 6
	5	Ch. Unit Output (Message)	↓ ↓ ↓ ↓ 1 2 3 4	-16 dbm at tstg. end	Off Hk	-	A + (C + R) + Q	-	T jk.
	6	Ch. Unit Output	↓ ↓ ↓ ↓ 1 2 3 4						



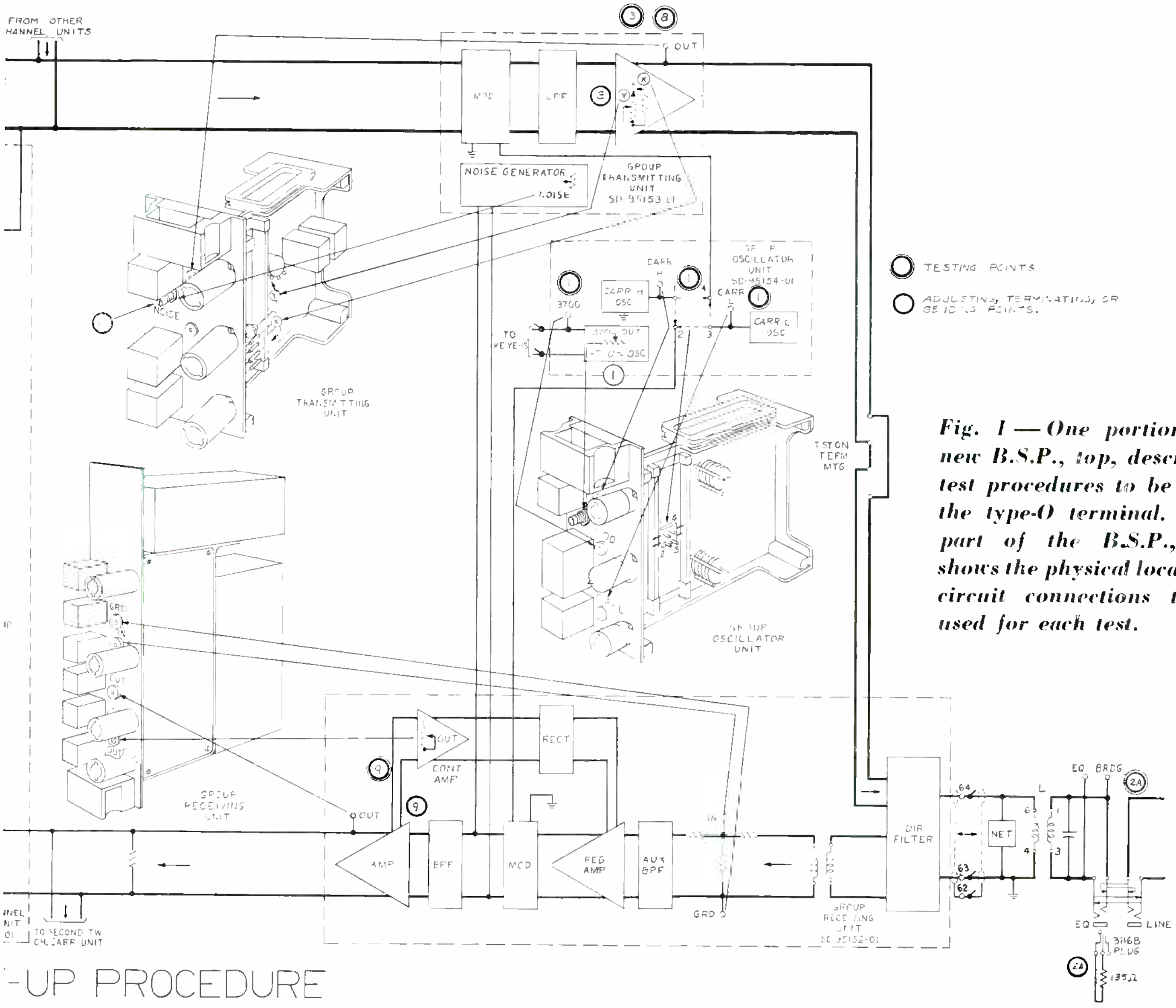
TERMINAL LI



STS ARE REQUIRED FOR OA TERMINALS - SEE E34.015.2, A207.053.2)

SECTION E34.015.1
SECTION A207.053.1

NIT ON EST AND	IF NECESSARY ADJUST	READJUST FOR LINEUP OR IF OUT OF TEST LIMITS TO	TEST LIMITS		TEST CONDITIONS & REMARKS	
			MIN.	MAX.		
- - -	- 3700 OUT POT. -	- 1.2 V -	0.4 V 1.1 V 0.4 V	0.7 V 1.3 V 0.7 V		
OR DJ.	TC POT.	+1.0 DB	+0.4 DB	+1.6 DB		
-	-	-	0 DB -2 DB	+4 DB +2 DB	IF 2 TW. CH. UNITS IF 1 TW. CH. UNIT	GRD. ALL T JKS.; TERM EQ JKS WITH 386B PLUG SEE NOTE 8
P19A ORD	GTU OUT POT.	REDUCE READING OBTAINED BY ADJ. 5	-	-	GRD. ALL T JKS.	
S	COMP POT.	+9.0 DB	+8.3 DB	+9.7 DB	-	
S	-	-	-	-18 DB	PUT 262B PLUG IN VF IN JACKS	
S	T POT.	-41 DB	-43 DB	-39 DB	-	
			-47.5 DB	-34.5 DB	-	



-UP PROCEDURE

Fig. 1 — One portion of the new B.S.P., top, describes the test procedures to be used on the type-O terminal. Another part of the B.S.P., below, shows the physical location and circuit connections that are used for each test.

type-O plug-in equipment, notably the twin-channel unit.

To enable telephone maintenance personnel in the field to keep the equipment performing properly, complete information is available as to tests and procedures to be used. This information is published in loose-leaf form, known as Bell System Practices, or B.S.P.'s. A typical B.S.P., like one of those used with type-N carrier, for example, describes testing procedures in numbered paragraphs of text. Usually, many pages are needed to describe the tests adequately.

For type-O carrier, a new presentation of test information has been worked out. Sill available as a regular B.S.P., the major part of the system line-up and maintenance information has been reduced to tabular form on folded sheets, instead of many pages of text. For the type-O terminal, for example, the B.S.P. section unfolds to give a single wide sheet containing data necessary for most of the transmission tests required at a type-O terminal. The headpiece shows C. W. Schweiger going over a test for the type-O channel unit on the test stand.

This new format uses only four separate divisions:

1. A paragraph or two describing the purposes of the tests and the specific test methods to be used. These are indicated by numbered boxes.
2. A table of the test equipment required, with a coded index letter to identify each piece of test equipment.
3. A drawing, Figure 1, showing the actual physical appearance of the various plug-in units, together with a simplified block diagram of the transmission circuit. All controls, test positions, and test points are identified, on the actual units and in the block diagram.
4. A table of detailed procedures, in which each horizontal row covers the testing of one particular item. Vertical columns tell the name of the test, the test equipment to be used, where to connect it, the results to be expected, and what to do if the expected result is not obtained. A part of this B.S.P. is shown in Figure 1.

The versatility of the new presentation can be appreciated by examining the procedure table. Test 2, required for system "line-up", can be found on line 2 of the table. It is identified as "Trans. carr, from tw. ch. carr. units" – meaning "transmitted carrier from twin channel carrier units." Reading across this row from left to right, we find that:

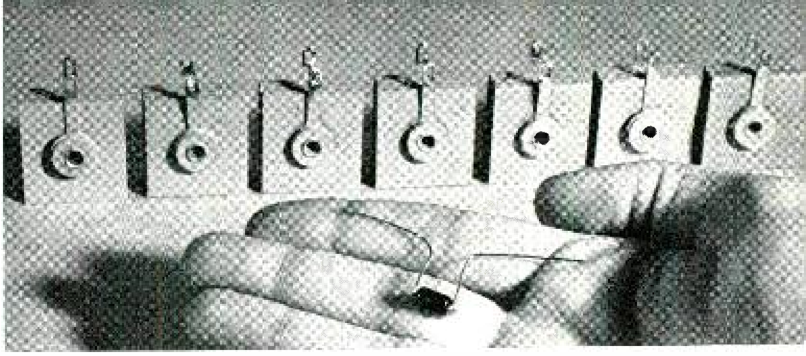
1. Two such tests are required per terminal.
2. 1,000-cycle test tone and signaling test set inputs are not required.
3. Test equipment A is needed at the sending end. Reference to the list of test equipment, not shown in Figure 1, identifies this as a 400C vacuum-tube voltmeter plus a W2DW test cord.
4. No test equiment is needed at the distant end of the system.
5. The vacuum-tube voltmeter is connected between jack TC and ground with the test cord; subsequent columns give the nominal voltmeter reading and tolerable limits, and tell the testman to adjust potentiometer TC if the reading is not within these limits. Since this potentiometer is not accessible when the twin-channel unit is in the bay, the unit must be mounted on the test stand for adjustment, as indicated in the table. The TC test jack and TC potentiometer are shown on the associated drawing, identified by a number 2 for test 2.

This new approach to the presentation of test information in the Bell System Practices for type-O carrier has been favorably received by the Operating Companies, and has already been extended to portions of the N, ON, and L1 carrier systems and the new A2A video transmission system. It is expected that still further uses for the new presentation will be found in the future.

THE AUTHOR

C. I. L. Cronburg, Jr., became a member of the Bell System in 1929 when he joined the Western Electric Company Installation Department. After receiving a B. S. degree from Fenn College in Cleveland in 1936, he transferred to the Laboratories where he became engaged in pulsing studies of panel and crossbar senders. From 1942 to 1945 Mr. Cronburg helped in the development of radar and proximity fuse equipment for the military, and since 1945 has been concerned with carrier telephone and video transmission systems. In 1946 he received the degree of M. S. from Stevens Institute of Technology.

New Silicon Power Rectifier Announced



The tiny device shown on the hand is one of Bell Telephone Laboratories' new silicon power rectifiers, Lined up are seven selenium rectifiers such as might be used in a television set or a private telephone switchboard. The one silicon rectifier does the job of the seven others shown. The active element is a silicon wafer smaller than the head of a pin.

A tiny new electronic device made of extremely pure silicon that shows promise of reducing costs on a large scale in many industries using electric power was announced last month at Bell Telephone Laboratories.

The simple device – a silicon power rectifier – converts alternating current into direct current, an essential step in the operation of telephone systems. Industries and homes also depend upon rectifiers to convert standard ac to dc current for such diverse purposes as running machinery and operating television sets.

Despite a trend in recent years toward smaller and more efficient components, power rectifiers have remained large, limited in efficiency and in need of bulky cooling equipment to prevent overheating. Bell scientists believe that the new power rectifier will far surpass any yet made of silicon or other material. They expect it may have an almost unlimited life span, and will be capable of operating continuously at temperatures up to 400° F.

These advantages are expected to open up many new uses in telecommunication, heavy industry and in military applications. The rectifier's efficiency – more than 98 per cent of the theoretical limit – was made possible by recent work of M. B. Prince.

Two of the new rectifiers, when made about the size of peas, linked together and mounted on a cooling fin, will furnish more than 20 amperes of direct current at 100 volts. This amounts to 2,000 watts – with only 20 watts lost through heat.

Only one ampere or less is needed to run a radio or television set, or to operate a group of telephone switching relays. To charge storage batteries used in automobiles and telephone central offices or to operate electric motors, from 10 to more than 100 amperes may be needed.

Highly purified silicon is a costly material when bought in pound quantities, but such minute amounts are used in the new rectifier that the material becomes relatively inexpensive to use. A rectifier the size of a pea, for example, contains a silicon wafer only five one-thousandths of an inch thick and one-tenth of an inch square. Even smaller rectifiers have been made and will be desirable for use in the telephone system and in electronic computers.

Larger rectifiers are necessary for other uses where greater amounts of power must be handled. The size of the wafer would vary, just as the size of a copper wire ranges from thin to heavy depending upon the current that must be carried.

The new silicon rectifiers provide 5,000 times more current than conventional rectifiers of the same size, thus permitting miniature operating units. Even so, the newest techniques may be applied to large sizes and thereby provide entirely new current and power possibilities for industry.

The silicon power rectifier grew out of the same broad research program at the Laboratories which produced the transistor – a tiny, long-lived amplifying device – and the Bell Solar Battery – first device to convert sunlight directly into substantial amounts of electricity.

The techniques created at the Laboratories for producing this silicon device involve the controlled introduction of impurity elements into the layers near the surface of a thin slice of silicon.

Treatment with vapors at high temperatures causes a minute trace of the impurities to enter the crystalline structure of the silicon. Before this process begins the silicon must first be so pure that there is less than one impurity atom per billion silicon atoms.

The controlled introduction of impurity atoms forms in the silicon a p-n (positive-negative) junction, which is the heart of the transistor. C. S. Fuller and G. L. Pearson announced the application of the techniques to power rectifiers more than a year ago.

Development of these techniques as applied to a wide variety of silicon devices is being pursued by K. D. Smith, C. J. Frosch and their associates.

Production plans for the new silicon power rectifier are being worked out with the Western Electric Company. Production will start soon for both Bell System and military uses.

New Supervisory Control System

C. A. DAHLBOM *Special Systems Engineering*

Supplying electric power to a large number of customers requires that power companies maintain vast sub-transmission networks. Should trouble occur in any branch of a network, that branch must be disconnected to maintain unaffected service on the rest of the network while the trouble is cleared. To accomplish this, power switches are located at strategic points throughout the network, opening and closing the high-voltage circuits as required. The Laboratories has developed a new supervisory control system that permits remote control of such switches over Bell System facilities. In addition, continuous monitoring by the control system keeps the control station advised as to the condition of all switches in the network.

One of the services offered by the Bell System is that of leasing telephone lines and facilities to industry for remote-control purposes. Gas and oil pipe-line companies, for example, must supervise and control the valves throughout their pipe-line networks. Electric power companies have power switches at various points in their sub-transmission networks, and these too must be supervised and controlled. Companies not having such remote control systems find it necessary to dispatch repairmen to remote locations to operate valves or switches.

The Bell System has studied the requirements of suitable supervisory and control equipment for such service so that, in the future, Bell System Operating Companies can furnish not only the line facilities, but also the control equipment required for a particular service. An SC1 supervisory control system, developed for this purpose by the Laboratories, has been undergoing field trials for some months in cooperation with the Philadelphia Electric Company, which serves Philadelphia and its suburbs.

A complete SC1 system comprises a control station, where all control is centralized, and controlled stations to handle up to a maximum of fifty controlled devices. As set up for the field trial, Figure 1, the control station provides supervision and control of six actual power switches and three dummy switches used for test purposes. A display panel provides three lamps and three nonlocking push-button switches for each power switch to be controlled. A power switch is shown to be open or closed by a green or red lamp respectively. An

The illustration at the top of this page shows P. J. Gayet of the Laboratories assisting in the installation of a controlled station in the trial. The two power switches being controlled are on the poles.

amber lamp indicates that there was no answer from the switch when last asked about its condition by the control system. Immediately above the display panel is a group of master control buttons and alarm and busy lamps.

At power switch locations in the trial, controlled stations are pole-mounted in white metal cabinets, Figure 2. These are the same cabinets as used for pole-mounting N1 carrier repeaters,* and the internal temperature is held relatively constant by a thermostatically-controlled damper. Since terminal equipment for as many as ten switches may be mounted in each cabinet, it was not necessary to design special cabinets for the trial.

Standard telephone pairs are used for the transmission network. A single pair connects the control station with a convenient telephone central office, where dc pulse repeaters may be inserted in the line as required. Since several controlled stations may be located relatively close together, a central office also acts as a hub from which lines radiate to the controlled stations. DC pulse repeaters are provided at the Swarthmore, Media, and Valley Brook central offices, Figure 3, for the Philadelphia trial.

An order signal is transmitted from the control station to all controlled stations in the network, but only one switch at a single controlled station responds to an order. Only the control station receives the answer from the interrogated station, all others being held busy for a fixed time interval. Should an alarm occur while the network is in use, it is stored on relays at the controlled station and is transmitted to the control station when the system becomes free.

Power companies, like the Bell System, must provide their service around the clock. A control system for such service must therefore be highly reliable. Should the control system fail, arrangements have been made for "fail-safe" operation; that is, the failure leaves the power system in "status quo", and does not introduce any conditions that might be dangerous to either men or equipment. To make the control system economically attractive, the line facilities used may be the simplest possible.

Reliability of the control system is assured by the use of the self-checking feature of the "two-out-of-five" code* used in multifrequency signaling and automatic message accounting. In this code, two and only two of five possible signals must be received to indicate a decimal digit. In the SC1 control system, each signal consists of long and short pulses – two long and three short. The position of the two long pulses in the series of five determines the digit value represented. Since each of the fifty switches that can be controlled by the SC1 system requires both a "close" and a "trip" code, a total of 100 basic codes is necessary. This requirement is met by using

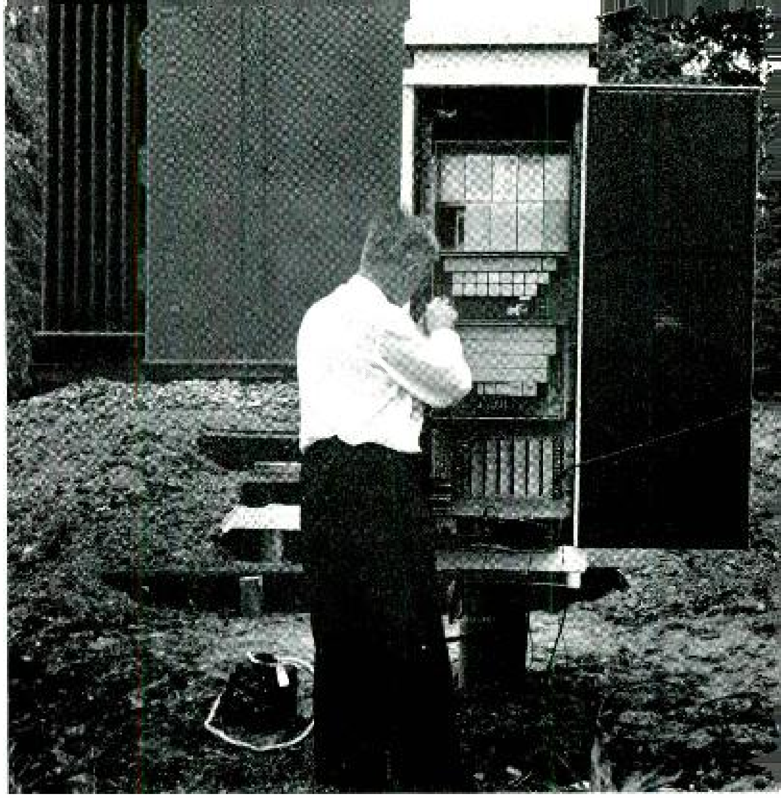
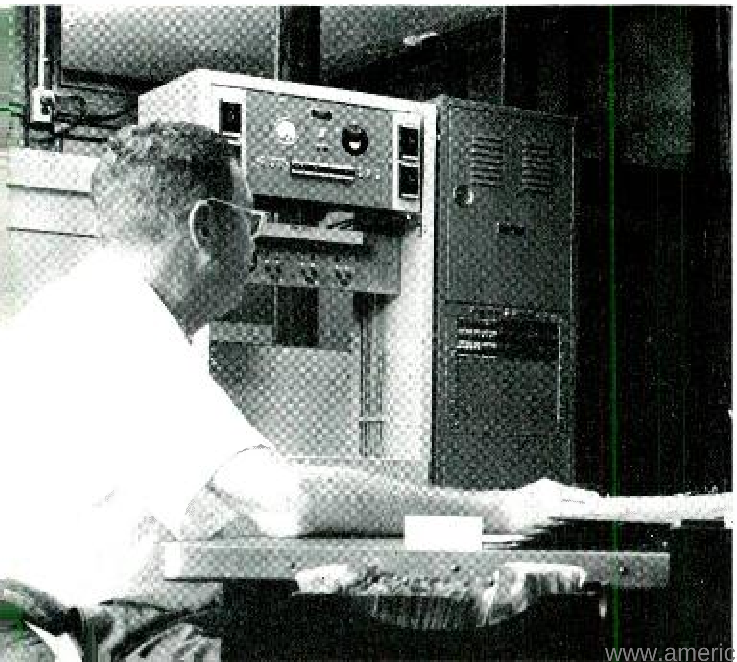


Fig. 2 — A controlled station is checked before operation by G. R. Driesbach of the Bell Telephone Company of Pennsylvania. Mr. Driesbach was loaned to the Laboratories to assist in the development of the SC1 system.

Fig. 1 — B. L. Rodgers of the Philadelphia Electric Company at the control station. The controlled station behind Mr. Rodgers controls three dummy switches in the center rack. The main control unit is on the right.



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* Record, *October*, 1953, *page* 397.

*Record, *January*, 1952, *page* 9.

a two-digit code. To permit the use of low-cost line facilities, the pulsing is dc, at a rate of about ten pulses per second.

Relay windings terminate each line at both ends, and no current flows during the idle condition. When either an order or inquiry is originated at the control station, a long "prepare" pulse is sent out before the signal pulses, to arrange for the establishment of a transmission path. The advantage of a normal "no-current" condition on the line is that any line faults such as opens or crosses on any single line will not disable the entire network. To check on the continuity of all line facilities, the control station initiates a periodic roll-call of all controlled power switches. This verifies to the attendant at the control station that the lamps show the true condition of all switches and also that the system is in working order.

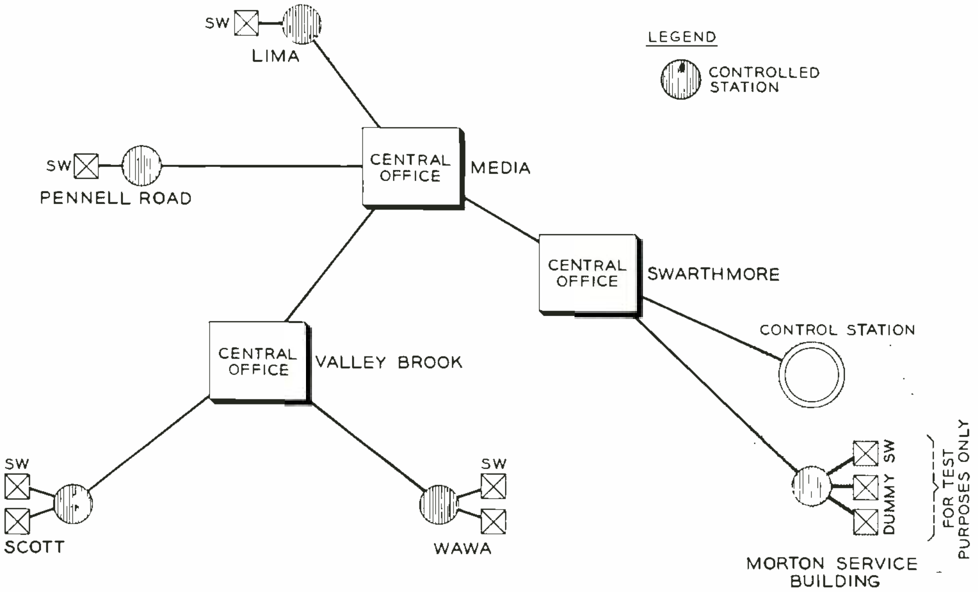


Fig. 3 — Three telephone central offices provide dc pulse repeaters and serve as hubs for the connecting lines in the test.

Associated with each red lamp is a "close" button; with each green lamp is a "trip" or open button, and with each amber lamp is an "inquiry" button, Figure 4. To verify the condition of a particular switch, the attendant merely presses the proper inquiry button. In answer to his inquiry, the system will cause one of the three lamps to light, indicating the condition existing at that switch. Pressing the button initiates a sequence of pulses – a long prepare pulse followed by ten signal pulses representing two digits, Figure 5. Should the attendant desire to close a power switch, he operates both the close button associated with the particular switch and the "master-operate" button just above the panel. This sends the same pulses as for an inquiry, but sends them twice – a prepare pulse, two digits, another prepare pulse (this time called an order pulse), and the same two digits. Receiving equipment at the controlled station compares the two sets of digits and the switch will not close unless they match.

Should the attendant wish to trip, or open, a closed switch, he presses the proper trip button together with the "master-operate" button. This again sends two sequences, but the digits to be matched

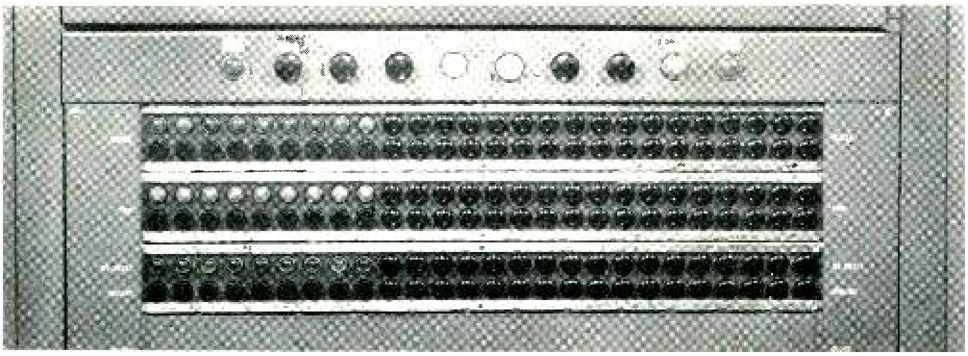


Fig. 4 — All necessary control buttons and lamps are mounted on the control panel.

are those telling the controlled station to open the switch rather than to close it. Pressing a telemeter button (not provided for in the Philadelphia trial) will set up a telemetering channel for transmission of any pertinent electrical information desired from the substation. The code used for telemeter is one half of a trip order code.

All signals from the control station, whether order, inquiry, or telemeter, are polar signals. All pulses are sent as current of one polarity, the spaces between pulses being current of the opposite polarity. Should the control system fail and no current of either polarity be received at a controlled station, nothing would operate and the power system would remain unaffected.

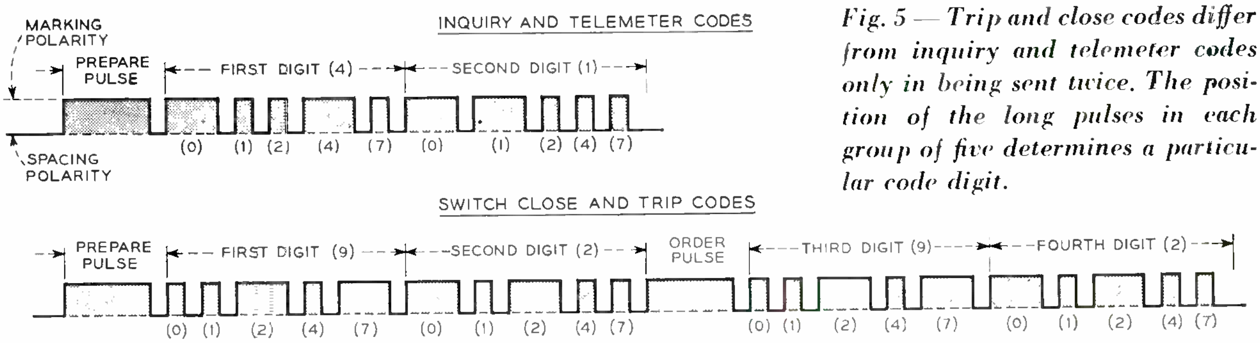


Fig. 5 — Trip and close codes differ from inquiry and telemeter codes only in being sent twice. The position of the long pulses in each group of five determines a particular code digit.

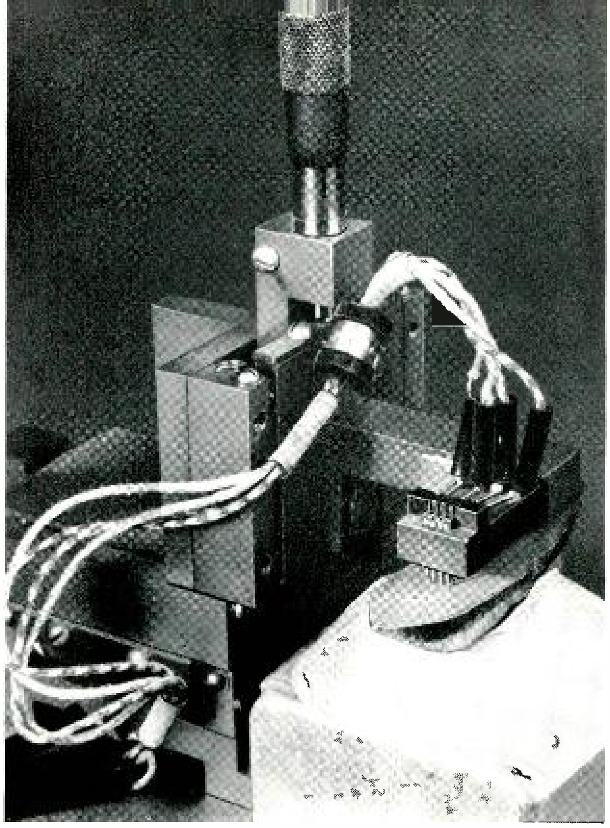
Signals from a controlled station are simple dc pulses of one polarity. A short (100 milliseconds) or long (400 milliseconds) pulse represents an open or closed switch respectively. Controlled stations can therefore use fairly simple equipment, resulting in substantial economies. Any unordered closing or tripping of a power switch automatically sends a single pulse to the control station. Since no order had been sent, the pulse represents an uninvited signal and means trouble somewhere in the network; the received signal therefore initiates a roll-call of the entire network. When the switch that is in an unordered condition is found by the roll-call, a gong sounds and the "close" or "trip" lamp associated with that switch flashes on and off. Should two switches close simultaneously, the appropriate lamps associated with both switches will flash. The alarm and flashing lamps may be retired by pressing the proper buttons above the panel.

Equipment panels at all stations are designed for rapid replacement by the use of plug-in connectors. Maintenance personnel can quickly restore the control system to operation by replacing a unit, should trouble develop. The defective unit is then returned to a Bell System maintenance center for repair.

Results from the Philadelphia field trial are being evaluated and improvements indicated will be incorporated in the control system. Requirements of other power and pipeline companies and railroads are being studied to determine desirable features. It is intended that converters be designed to permit ac transmission of the coded signals over long-haul voice frequency and carrier systems, since such arrangements would be required if the SC1 system were used, for example, to control valves on long pipe-line installations. This new control system will be offered to interested customers with the usual assurance of Bell System reliability.

THE AUTHOR

Carl A. Dahlbom joined the Laboratories in 1930, subsequently receiving the degree of B.E.E. from Brooklyn Polytechnic Institute in 1941. He engaged in transmission and circuit development of dc, carrier, and switching circuits for the Telegraph Department, and during World War II was engaged in the development of carrier telegraph systems for the Signal Corps, multiplex transmission for speech secrecy systems, and tube modulators for radar systems. Since the war, Mr. Dahlbom has done development work on single- and multi-frequency signaling systems, and design of supervisory control circuits. For a time he was assigned to a military project and is now in the Systems Engineering Department in charge of a group responsible for the formulation of signaling requirements for message service.



Before transistors with precisely specified operating characteristics can be built, certain properties of the semiconducting material must be accurately measured. Resistivity and lifetime are currently the two most distinguishing quantities in germanium and silicon crystals, and these are being measured by apparatus adaptable both to experimental work and to production methods.

L. B. VALDES *Transistor Development*

Semiconductors — Resistivity and Lifetime Measurements

During the past few months readers of the RECORD have had an opportunity to become acquainted with several different types of transistors and with the techniques used for producing transistor materials.* It is now appropriate to ask how a development engineer selects and specifies those crystals that will produce good transistors. It might also be asked how a research physicist knows that a given crystal has the properties that are desired for a particular experiment.

The answers to both of these questions require knowledge of at least two properties of single-crystal semiconductor materials — *resistivity* and *lifetime*. (The expression "lifetime" will be defined later, but it should be mentioned that the word is not used here in its usual sense.) These properties determine to a large extent such characteristics of semiconductors as their ability to rectify or amplify signals. In fact, for a given transistor structure, the performance can usually be predicted from a knowledge of resistivity and lifetime throughout the entire volume of the semiconductor element. Alternatively, by proper choice of structure and of materials having appropriate resistivities and lifetimes, the designer can produce transistors having desired characteristics.

Both resistivity and lifetime can be measured by reasonably straightforward methods, and these methods will be the chief subject of this article. It will be useful, however, to begin by reviewing briefly these two concepts as they apply to transistor electronics. Resistivity is a physical property which can be measured in practically all kinds of materials, including insulators, semiconductors and metals. For variously shaped specimens of a given material, we know that electrical resistance (R) increases with length (L) but decreases with cross-sectional area (A). Resistance is therefore proportional to L/A, and resistivity (ρ) is merely the constant of pro-

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* RECORD, *June* 1954, *pages* 201 *and* 203; *August*, 1954, *page* 285; *February*, 1955, *page* 41; *April*, 1955, *page* 121; *May*, 1955, *page* 167; *June*, 1955, *page* 201.

portionality in the formula $R=\rho L/A$. To give a value of resistance in ohms, the units of resistivity are seen to be ohm-centimeters.

By contrast with resistivity, lifetime is a property that is characteristic of semiconductors, and to understand its significance we must consider the basic theory of current flow in a semiconductor material. Current is carried both by the movement of electrons and by the movement of "holes" (vacant spaces that remain when valence electrons leave their normal positions). The numbers of these "current carriers" found in a given semiconductor are determined by several factors. "Doping" a crystal with a suitable impurity will cause a major change in its current-carrying properties – in the case of a crystal which has been doped with an n-type (negative) impurity, for example, the number of electrons is increased and the number of holes is decreased. Also, vibration of the atoms, even at room temperature, creates equal numbers of additional electrons and holes that are available for conduction of electricity. Simultaneously with this thermal generation process, and at an equal rate, holes and electrons are recombined or neutralized. By these thermal generation and recombination processes, holes and electrons are thus constantly being produced and neutralized, but for a given volume of semiconductor in a state of equilibrium, the number of holes multiplied by the number of electrons is a constant. As an example, for one cubic centimeter of germanium at room temperature, this constant has a numerical value of about 6×10^{26}.

Lifetime can now be visualized as the time required for a disturbance of the hole-electron equilibrium in the crystal to disappear. We can disturb this equilibrium in the crystal by several means – one way is by shining light on the surface of the specimen. In the n-type crystal we have been considering, this light would produce excess holes and electrons. If we turn off the light, the excess holes then recombine with electrons to restore the original equilibrium. In simplified terms, lifetime is merely the time it takes for the excess holes to recombine with the electrons after the agency producing the disturbance has been removed. Mathematically, the process is an exponential one, involving a term e^{-t/τ_p}, where t is the time elapsed after the light source is turned off, and τ_p is the lifetime. These relationships are shown graphically in Figure 1, where the initial excess minority particle density at the instant of removal of the disturbance (D_0) decays exponentially with time. The curve is such that lifetime is determined at a point where the density has dropped to 38 percent of its initial value. A p or positive type crystal is of course analogous, and in this case lifetime is τ_n, or the length of time required for excess electrons to recombine with holes.

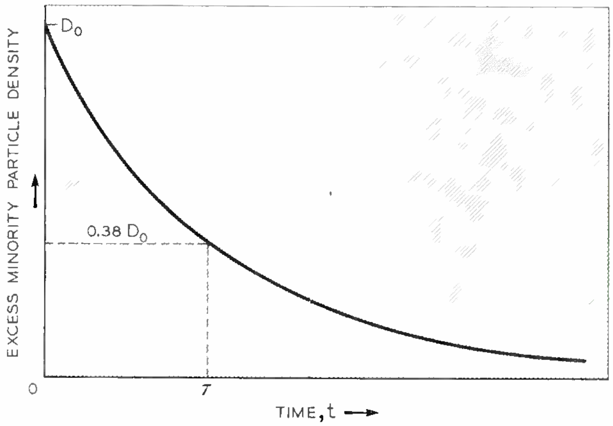


Fig. 1 — Decay shape of density of excess electrons or holes in semiconductor crystal.

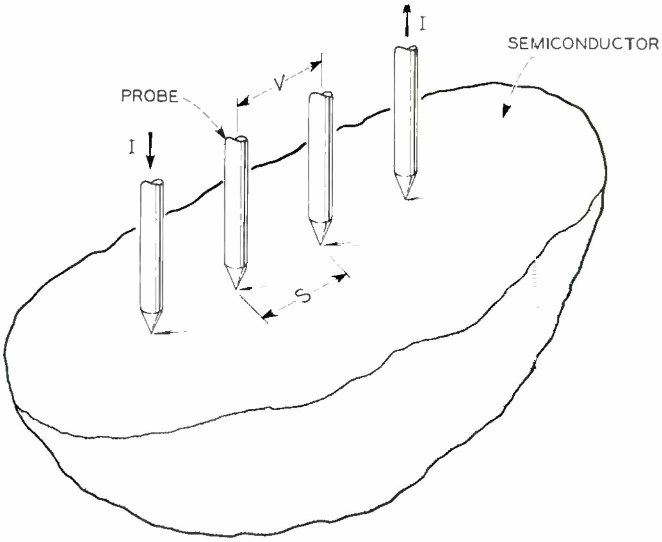


Fig. 2 — Arrangement of probes for resistivity measurements. Potential is measured across distance S between the inner pair of probes.

To return now to the measurement techniques, conventional methods for measuring resistivity cannot be used for semiconductors of reasonably high purity. If the metallic leads of our measuring instrument are connected to the semiconductor by the usual methods, it is difficult to achieve low resistance contact. The measured resistance would then include not only the resistance of the semiconductor but also that of the contacts. For germanium this difficulty is overcome by an arrangement illustrated in Figure 2. Four equally spaced probes are laid on

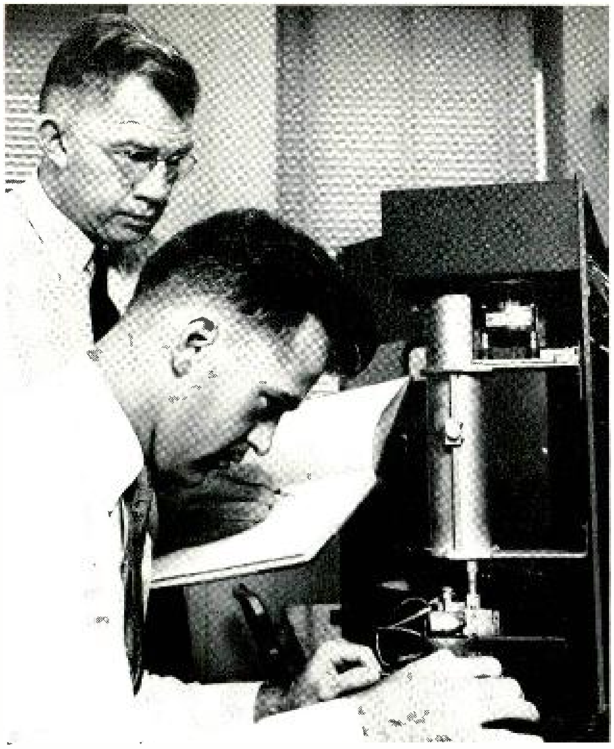


Fig. 7 — P. A. Byrnes (right) moves germanium specimen with respect to beam of light while G. P. Carey plots data for lifetime measurement.

tal is in the dark and a higher value when a portion of the crystal is illuminated by a pulse of light. Lifetime can then be determined from the length of time required for the current to decay to the unilluminated value.

In the discussion of these measurement methods, we have assumed only crystals of a single conductivity type. In crystals containing p-n junctions, however, the same methods are used to make measurements on both sides of the junction. In addition, it is also possible to measure lifetime in a crystal containing a single p-n junction by using the junction as the collector of minority carriers. These are straightforward extensions of the methods that are described in this article.

In this story it has been shown how modern techniques are brought to bear in the measurement of the important properties of transistor materials. The history of transistor development furnishes an excellent example of the generalization that in any technology the quality and reproducibility of a product can improve only with the development of means for measuring and controlling the properties of the starting materials.

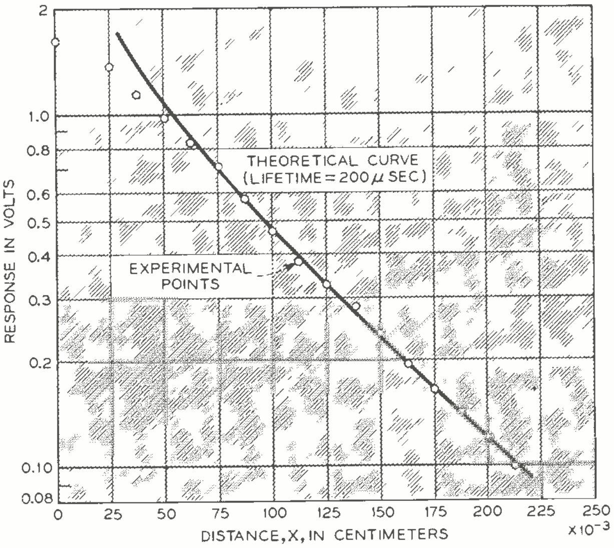
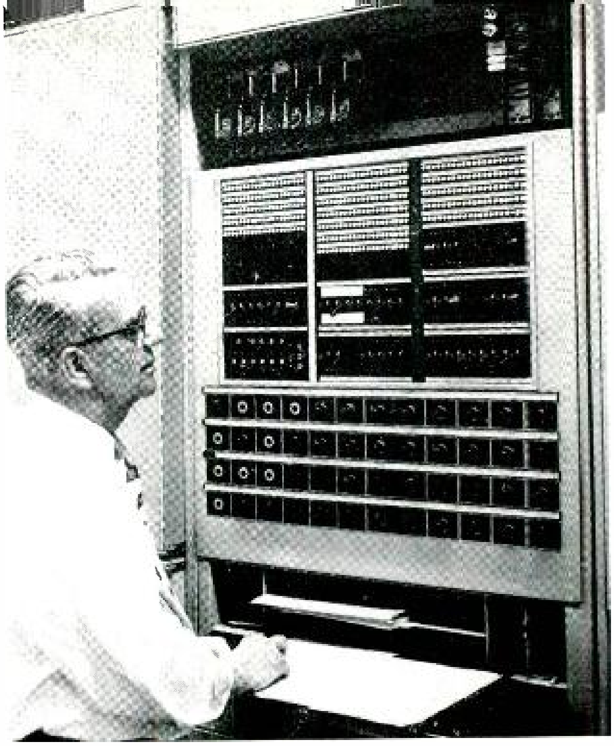


Fig. 8 — Curve reflecting decreasing concentrations of minority carriers at greater distances from illuminated area.

THE AUTHOR

L. B. Valdes received the B.E. degree in Electrical Engineering from Tulane University in 1946 and the M.S. degree in Electrical Engineering from Northwestern University in 1947. At Northwestern University he taught electrical communications from 1947 until 1949, when he became a member of the technical staff of Bell Telephone Laboratories. In the electronic apparatus development group he was concerned with the study of the physical properties of solid state devices, particularly the transistor. Later, with the device feasibility group of the Transistor Physics Research Department, he was concerned with silicon rate-grown transistors. Mr. Valdes presently holds a position with Pacific Semi-conductors, Inc. He is an associate of the I.R.E. and a member of Eta Kappa Nu and Sigma Xi.

CAMA — Sender Test Circuit



R. Y. SIMS *Switching Systems Development*

Centralized Automatic Message Accounting as described in a current series of RECORD articles, is the latest development by means of which customers can dial their own long distance calls. Like most modern switching systems, CAMA requires checking and testing circuits to insure proper operation and to help locate faults. A new sender test circuit performs a large portion of the necessary tests for both CAMA and non-CAMA tandem central offices.

Centralized Automatic Message Accounting at crossbar tandem offices * has required the parallel development of new test circuits. One of these circuits tests senders, operators' switchboard positions, and transverters. The name "Sender Test Circuit" is therefore descriptive only of its primary function.

The physical arrangement of the circuit involved follows latest crossbar tandem practices, using casings with hinged doors in front and removable rear covers. Two bays are required for mounting the apparatus, the auxiliary circuits are mounted on a separate connector frame. Manual selector switches allow the type of test and other information to be preset. The lever-type keys allow modification of major types of tests and also permit manual control of particular tests. Lamps above the lever keys show the progress of the test, the point of failure, the type of failure, and other information, such as the number of the sender under test and the value of the digit being checked.

Before going into detail on the functions of this test circuit, it is useful to review the operation of a crossbar tandem office and how it is affected by the addition of CAMA. The method of switching a non-CAMA call through a crossbar tandem office can be followed with reference to Figure 2. An originating central office selects an incoming tandem trunk and requests a sender. When an idle sender is found, the originating office begins to pulse forward the called telephone number. After the office-code digits have been registered, a marker establishes a connection to the terminating office and tells the sender what type of outpulsing to use. The numerical digits of the called number are then pulsed to the terminating office, and the sender releases.

The action on calls originating on CAMA trunks is quite similar, but in addition, after the originating office completes the pulsing of the called number, an operator is connected by means of the position link circuit. She asks the calling customer what the calling telephone number is and keys it into the sender. The sender then transfers the calling number, the called number, and other information to a transverter which, in association with the billing indexer and recorder, punches an AMA tape. If the tape is punched satisfactorily, the sender is allowed to com-

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* RECORD, *July*, 1954, *page* 241, and *October*, 1954, *page* 371.

Fig. 1 — The author (left) and J. M. Repholz, switchman, New York Telephone Company, discuss a sender under test by the test circuit, New York City CAMA installation.

plete the pulsing of the called number to the terminating office and to release from the connection.

In testing certain of these switching operations, the new test circuit has four broad functions: (1) selection of and connection to a particular circuit; (2) a removal of this circuit from service; (3) simulation of service conditions; and (4) observation of the reactions of the circuit under test to the simulated conditions. On a sender test, for example, the "PCI pulser" simulates an actual pulser at an originating office, and one of the "receivers" simulates an actual receiver in a terminating office.

The test circuit has been divided into eleven functional blocks as numbered in Figure 2. These blocks or sections are useful in an explanation of the operation of the test circuit, and they also approximate its actual physical layout. To simplify engineering and maintenance, each section has been designed to operate as independently as possible.

The first of these sections is the test connector, which connects the sender link and the sender to the test circuit. Its principal function is to provide the actual electrical paths from the test circuit to the circuit to be tested. All of the usual test connector functions are provided: automatic progression from the test of one sender to the test of the next, means for automatically passing busy senders, methods for skipping part of a test procedure under control of the switchman operating the test panel, and means for the switchman to select a particular circuit for test. After the switchman selects the desired type of test, the operation of the start key will cause the circuit to select automatically the circuit to be tested.

This selection, however, is only a preliminary operation. The function of removing a circuit from service without interference to customers is performed by the group test circuit. After a particular sender has been selected, other calls must not be permitted to get service from the group of five in which the desired sender is located. All calls will instead be diverted to other senders by the sender link circuit. Enough time is then allowed to elapse to insure that any seizure in progress in the group will have occurred and thereby will have made the associated sender busy. The test circuit can then determine if the desired sender in the group is idle, seize it, and make it busy to other calls. This technique insures that customer calls are given preference and that double connections do not occur. If the desired sender is found to be busy, the test circuit can pass it by or wait until it becomes idle.

The group test section also simulates the sender link, which passes data relating to the trunk to be used for a call. In addition, the group test circuit signals the sender that it is being tested, so that the sender will not "time out" if trouble is encountered during a test. On a service call the sender will "time out," free itself, and go on to serve another call if trouble is encountered. By preventing this timing-out on test calls, the "test call" signal allows the progress of the call up to the point of failure to be maintained on the lamps in the key and lamp panel.

The third section of the test circuit generates the called number in the form of Panel Call Indicator (PCI)* pulses, in accordance with the setting of the control-panel switches. On actual telephone calls, these pulses come from panel or crossbar originating offices, some of which may be as many as twenty miles distant from the tandem office. The test circuit must therefore generate very accurate pulses. Eight lever-type keys on the control panel allow operate, non-operate, and release tests to be made on the PCI receiving relays of the sender under conditions that are as nearly like service conditions as possible.

After receiving the called-office code, the sender calls in a marker, and the fourth or marker-checking section is used. This circuit checks that the informa-

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* Record, *December,* 1929, *page* 171; *April,* 1940, *page* 236.

tion transmitted from the sender to the marker is in agreement with information passed to the sender by the group test section and the PCI pulse generator. The marker is informed that a test call is in progress and therefore does not attempt to establish a connection to a terminating office. Under test, it performs only its decoding function.

When senders are tested for CAMA operation, the calling number must be pulsed to the sender. In service, this information is keyed by an operator. On test calls, however, a calling number is established by control-panel settings, and the fifth or key pulsing section simulates the operator's position and causes the number to be registered in the sender. This section and number six, the transverter test circuit, require a somewhat more extended discussion, which will be delayed until the remaining parts of the test circuit are described.

Four sections (numbers seven to ten) are provided to check the different kinds of outpulsing from the sender: revertive, PCI, dial, and multifrequency pulsing. Each of these sections checks the accuracy of the digits that the sender outpulses by comparing the digits with the settings of switches mounted on the control panel.

The final or control section includes the keys and switches operated by the switchman handling the tests. This circuit has established the pattern of the call for all the test operations. Besides the normal service-call type of test, many others can be set up — for example, abandonments of calls by originating customers, simulation of open trunks to the terminating office, and failure to complete pulsing of the called number to the sender. In each case the control circuit prepares the individual sections to operate in a manner similar to the handling of a call under service conditions.

Figure 3 is a more detailed version of the key pulsing and position test section in Figure 2. Position tests are made manually and they fall into two classes — testing an operator's position alone by simulating a sender, and testing the position by using it with a sender and monitoring the signaling between the two. When the position is tested alone, the keying leads are connected to lamps in the sender-simulating circuit. These lamps light in accordance with the key depressed and thus provide a visual check of the accuracy of the keying operations. When the position is tested using a sender, the keyed number is recorded in the sender and is passed to the transverter as on a service call. Instead of connecting to a recorder, the transverter connects

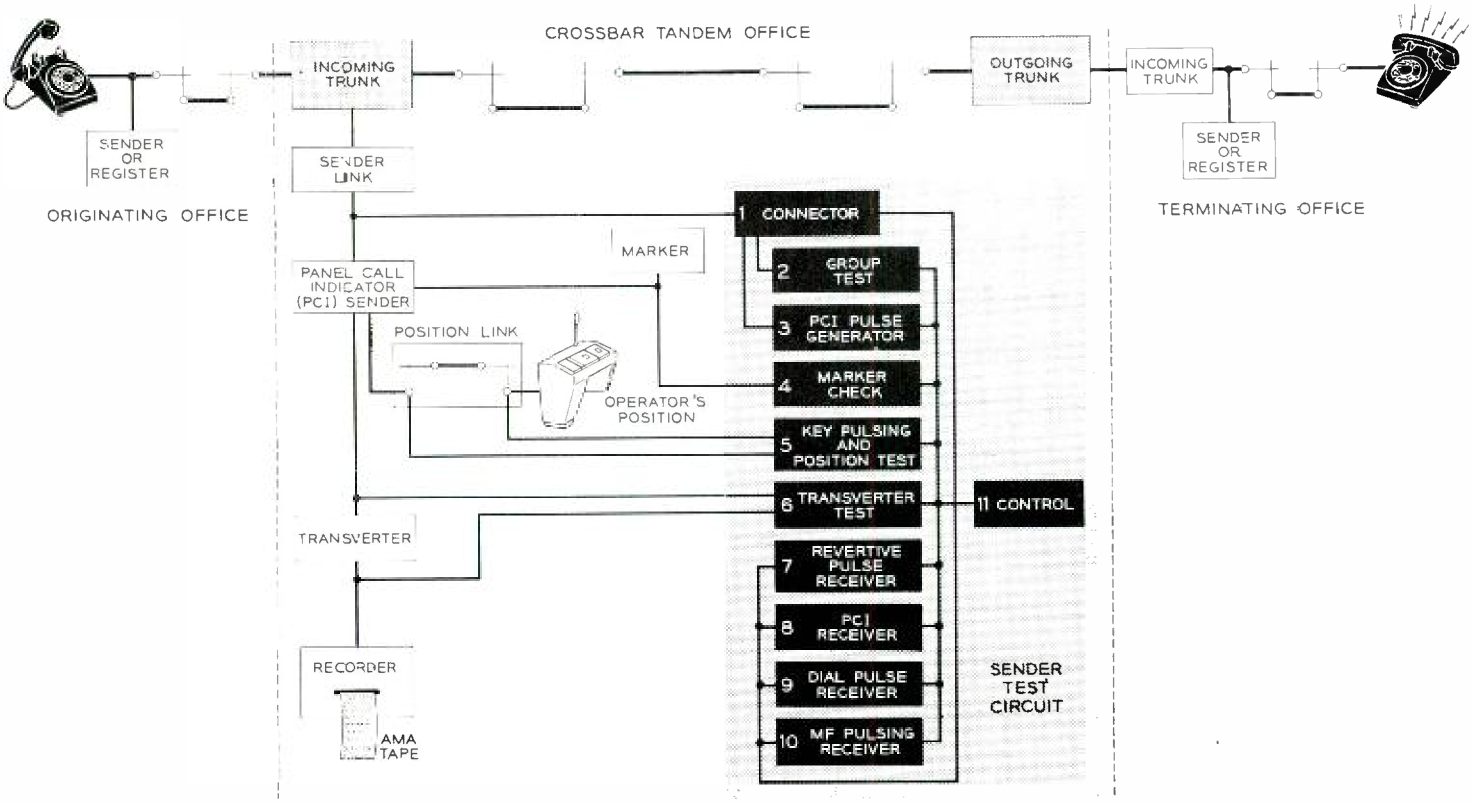
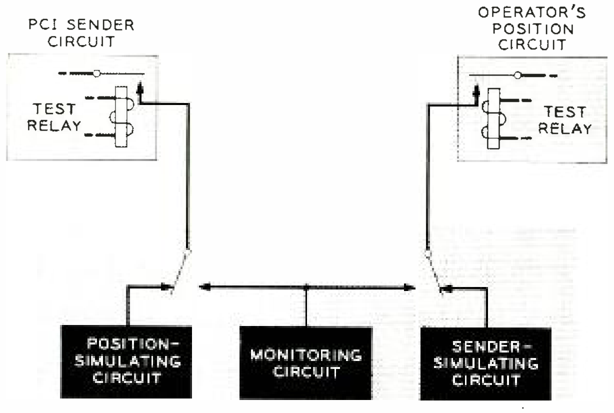


Fig. 2. — Block schematic of sender test circuits and crossbar tandem CAMA equipment.

to the transverter test section, number six in Figure 2. This section checks that the keyed information matches the preset calling number information.

Still another sender-position relationship is possible. This is called the "Any Position" test. Here, the position link selects an operator's position as for an actual call. When the operator asks for the calling number, the switchman performing the test gives a number that has been set up on the key panel. This enables the position link frame to be tested by calls originating in a particular sender.



NO. 5: KEY PULSING AND POSITION TEST SECTION

Fig. 3 — Block schematic showing subsections of key pulsing and position test section.

Transverter tests are automatic; they are made in conjunction with the sender, using a simulated recorder which is a part of the transverter-test section. Progression from the test of one transverter to the test of another, however, is not automatic, and must be controlled by use of a manually operated "particular transverter" selection switch. On regular tests of senders, the normal operation of a transverter is thoroughly checked. In addition, various troubles in recording can be simulated, and the transverter's actions both toward the sender and toward the recorder can be tested. On these calls, the control circuit will establish the test pattern that the sender is expected to follow on encountering trouble signals from the transverter. A single test of an individual sender and transverter generally requires about twelve seconds. A test cycle on all the senders and transverters in an office can be completed in an hour or two.

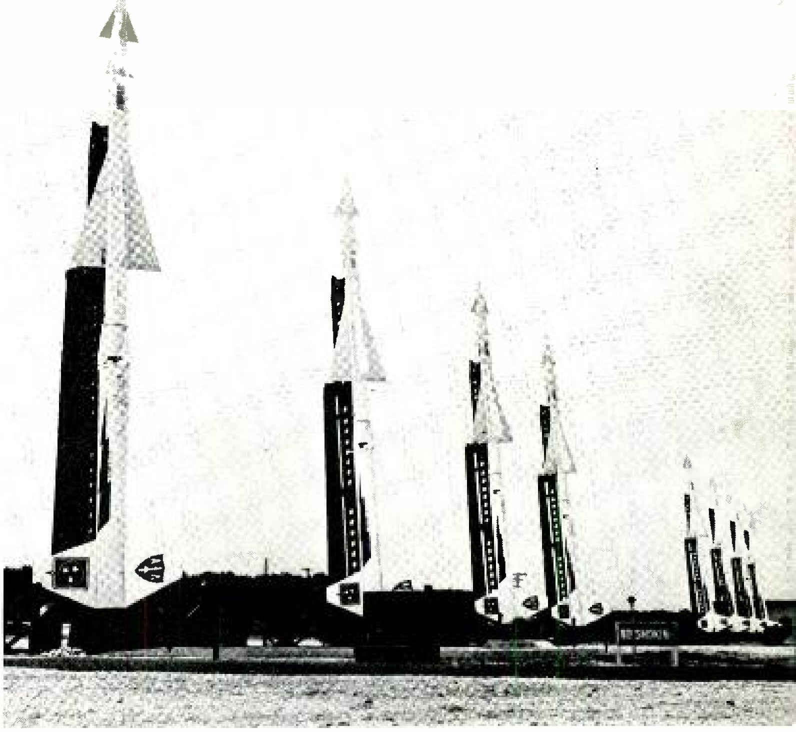
By performing routine and special tests on the senders, operator positions, and transverters, the test circuit helps insure trouble-free operation of CAMA equipment. In addition to its CAMA application, certain elements of this circuit are also used for sender testing alone in crossbar tandem offices not equipped for CAMA.

New CAMA developments will require other sections in addition to the eleven incorporated in the present circuit. For example, new pulse generators will be required for testing senders other than the PCI type. It is expected, however, that the basic test patterns established by the existing equipment will be retained, with only minor modifications in the control section.

THE AUTHOR

R. Y. Sims received his B.E.E. degree from Clemson A. & M. in 1942. After one year with the General Electric Company, he joined the United States Navy where his military experience had to do with an underwater weapons project, in cooperation with Bell Laboratories Engineers. In 1948 he joined the Technical Staff of the Laboratories and has since been concerned with switching development work. He first was engaged in No. 4 toll crossbar equipment development, after which he attended the Laboratories Communications Development Training Program and switching school. Later he was briefly associated with development work on circuits for automatic inter-toll trunk-testing and since 1950 he has been engaged in the testing phases of the application of CAMA to crossbar tandem.

Army Holds Press Show at Nike Installation



Eight Nike missiles point their noses skyward in launching position at battery site near Washington.

Nike, the new guided missile for the nation's defense against aerial attack, is becoming an integral part of the American scene. At a press show recently near Washington, the Army took off some of the security wraps that have shrouded this missile system during ten years of development and production work at the Laboratories, Douglas Aircraft and the Western Electric Company.

As the number of Nike sites grows steadily around American cities, the long nose of the Nike projectile and the antennas of the radar ground control equipment will be familiar sights both to motorists on suburban highways and farmers in rural areas.

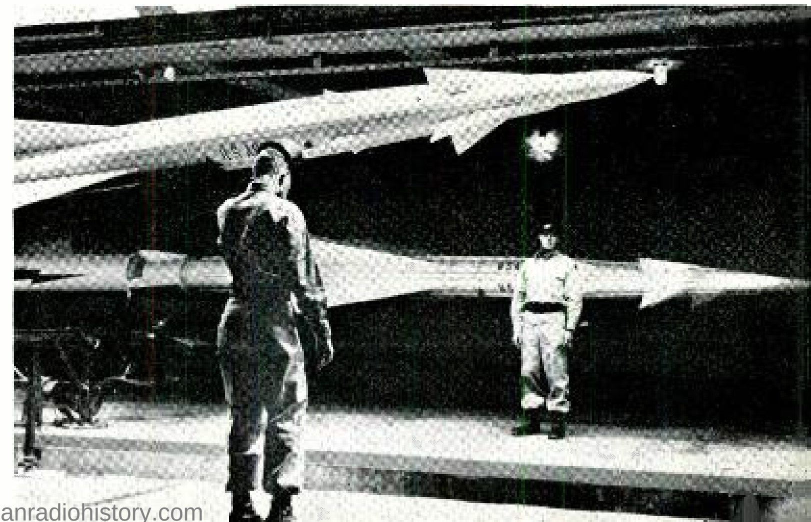
The Army is installing these Nike guided missile batteries on sites of 40 to 50 acres. The sites provide housing and underground storage areas, although the missile system itself is mobile. Each site is manned by six officers, two warrant officers and 101 enlisted men. The battery is ready to fire at a moment's notice, but the Army does not expect to fire from the operational sites except in the event of enemy attack. Personnel go to established firing ranges for regular annual practice.

A typical Nike engagement would proceed as folllows: one of three radars, the acquisition radar, searches the sky continuously for first contact with any approaching aircraft that might manage to slip through our outer ring of defenses. When contact is made, the second, or tracking radar takes over while the aircraft is still many miles distant, feeding information on its location and movement to the computer. In the meantime the missile tracking radar trains on a missile. At the right moment, the half-ton, 20-foot rocket speeds skyward from the launcher. With target and missile tracking radars working in unison, any evasive tactics taken by the target are detected and the missile's flight altered to meet it.

Although details of speed, range and altitude must remain secret, the Army has stated that the "kill" potential of Nike has far exceeded its expectations.

Liquid fuel gives the supersonic anti-aircraft missile its speed. Ground personnel, protected by elaborate safety suits, fuel Nike missile.

Nike missile rises on elevator in underground storage area toward surface, where it will be transferred to launching rack shown in the illustration at the top of the page.



Dr. Kelly Named to Board of Trustees of Stevens Institute

Dr. Mervin J. Kelly has been named to the Board of Trustees of Stevens Institute of Technology, Hoboken, New Jersey, according to a recent announcement by Willis H. Taylor Jr., chairman of the board.

Colleges Honor Laboratories Men

Walter H. Brattain of the Physical Research Department and John Bardeen, formerly of the Laboratories and now Professor of Physics and Electrical Engineering at the University of Illinois, received honorary Doctor of Science degrees from Union College at the 160th annual commencement exercises on June 12. The degrees were awarded in recognition of their joint invention of the point-contact transistor.

Dr. Brattain was also honored by his alma mater, Whitman College, Walla Walla, Wash., with an honorary Doctor of Science degree awarded at the college's commencement exercises on May 29.

William Shockley, Director of Transistor Physics Research of the Laboratories, received the honorary Doctor of Science degree from the University of Pennsylvania at its 199th annual commencement exercises in Philadelphia. He is now serving as Deputy Director and Director of Research of the Weapons Systems Evaluation Group of the Department of Defense.

Harold S. Black of Systems Research received the degree of honorary Doctor of Engineering on June 19, at the 87th commencement of Worcester Polytechnic Institute. The degree was awarded in recognition of his achievements in the field of transmission systems and amplifier circuit theory leading to the fundamental concept of negative feedback.

Talks by Members of the Laboratories

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

A.I.E.E. MAGNETISM AND MAGNETIC MATERIALS CONFERENCE, PITTSBURGH

Anderson, P. W., and Hasegawa, H. (of University of Tokyo), Some Considerations on Double Exchange.

Bommel, H. E., Ultrasonic Absorption in Superconducting Tin at Low Temperatures.

Nesbitt, E. A., and Williams, H. J., New Facts Concerning the Permanent Magnet Alloy – Alnico 5.

Owens, C. D., Stability Characteristics of Molybdenum Permalloy Powder Cores.

Van Uitert, L. G., High Resistivity Nickel Ferrites – The Effects of Minor Additions of Manganese or Cobalt.

Weisbaum, S., Recent Developments in Microwave Ferrite Devices.

Williams, H. J., see Nesbitt, E. A.

AMERICAN PHYSICAL SOCIETY, TORONTO, CANADA

Becker, J. A., The Effect of Adsorbed Hydrogen on the Field Emission Current from the 310 and 210 Planes of Tungsten.

Chynoweth, A. G., The Pyroelectric Effect in BaTiO$_3$.

Chynoweth, A. G., see McKay, K. G.

Geller, S., The Crystal Structure of Gadolinium Orthoferrite, GdFeO$_3$.

Gianola, U. F., Noise Characteristics of Silicon Photovoltaic Junctions.

Gilleo, M. A., Magnetic Properties of a Gadolinium Orthoferrite Crystal.

Harrower, G. A., Energy Spectra of Secondary Electrons from Mo and W for Low Primary Energies.

Haynes, J. R., New Intrinsic Recombination Radiation from Germanium.

Hughes, W. T., see Moore, G. E.

McKay, K. G., and Chynoweth, A. G., Optical Studies of Avalanche Breakdown in Silicon.

McKay, K. G., see Rose, D. J.

Moore, G. E., and Hughes, W. T., Dissociation of Solid Compounds by Electron Bombardment.

Rose, D. J., and McKay, K. G., Microplasmas in Silicon.

SEMICONDUCTOR DEVICE RESEARCH CONFERENCE, PHILADELPHIA

Barry, J. F., and Beveridge, J., Electrolytically Shaping Germanium.

Bennett, D. C., and Zuk, P., Lineage-Free Germanium Crystal.

Beveridge, J., see Barry, J. F.

Bridgers, H. E., Rate-Grown n-p-n Structures for High-Frequency Transistors.

Clark, M. A., Figures of Merit for Power Output Transistors.

Forster, J. H., New Surface Effects in Point Contact Transistors.

Fuller, C. S., see Tanenbaum, M.

Kleimack, J. J., see Wahl, A. J.

Lee, C. A., A New High Frequency p-n-p Transistor – Physical Description.

Miller, S. L., Alloyed Junction Avalanche Transistors.

Pfann, W. G., Electromagnetic Suspension of a Molten Zone.

Ross, I. M., A Semiconductor Stepping Device.

Tanenbaum, M., and Fuller, C. S., High-Frequency Silicon Transistors.

Thomas, D. E., A New High-Frequency p-n-p Transistor – Electrical Characterization.

Wahl, A. J., and Kleimack, J. J., Effect of Ambient Atmosphere on Alloy Junction Transistors.

Weinreich, G., The Diffusion Delay Diode.

Zuk, P., see Bennett, D. C.

ELECTRON TUBE RESEARCH CONFERENCE, EAST LANSING, MICH.

Collier, R. J., see Feinstein, J.

Cutler, C., and Tien, P. K., Overload Characteristics of Traveling Wave Amplifiers on Large C Conditions.

Elder, H. L., see McDowell, H. L.

Feinstein, J., A Theoretical and Experimental Study of Magnetron Electronics.

Feinstein, J., and Collier, R. J., A Coaxial Cavity Coupled Magnetron.

Hines, M. E., On the Thermal-Velocity Limitation to Current Density in Electron Guns.

Karp, A., Velocity-Spread Electron Beam in Crossed-Field Tubes.

McDowell, H. L., and Elder, H. L., Noise in a Medium Power Traveling-Wave Tube.

Olson, H. M., see Turrell, G. C.

Tien, P. K., see Cutler, C.

Turrell, G. C., and Olson, H. M., Investigation of Starting and Steady State Current Sources in the Pulsed Magnetron.

OTHER TALKS

Anderson, O. L., Reversible Density Changes in Glass Under Pressure, Fifth Annual Symposium of Crystal Chemistry as Applied to Ceramics, Pennsylvania State University, State College, Pa.

Baker, W. O., see Winslow, F. H.

Baldwin, M. W., Jr., and Nielsen, G., Jr., The Subjective Sharpness of Simulated Color Television Pictures, Image Evaluation Symposium, University of Rochester, N. Y.

Becker, J. A., Impact of Modern Techniques on the Theories of Adsorption, Gordon Research Conference, New London, N. H.

Bommel, H. E., see Mason, W. P.

Brattain, W. H., Transistor Physics, Physics Colloquium, University of Chicago.

Compton, K. G., and Mendizza, A., Galvanic Couple Corrosion Studies by Means of the Threaded Bolt and Wire Test, A.S.T.M., Atlantic City.

Crater, T. V., Some Highlights of Information Theory, Pennsylvania State University.

Darrow, K. K., Semiconductors, Canadian Association of Physicists, University of Toronto.

Dehn, J. W., and Hersey, R. E., Recent New Features for the No. 5 Crossbar Switching System, A.I.E.E. Summer General Meeting, Swampscott, Mass.

Ferrell, E. B., Electronic Switching, I.R.E. Greensboro (N. C.) Section.

Ferrell, E. B., Statistical Method in Engineering Design, Symposium on Statistics in Engineering and Engineering Education, American Society for Engineering Education, Pennsylvania State University.

Foster, F. G., The Metallograph's Unconventional Application, Armour Institute Symposium on Microscopy, Chicago.

Gohn, G. R., A Hardness Conversion Table for Copper-Beryllium Alloy Strip, A.S.T.M., Atlantic City.

Gohn, G. R., Guerard, J. P., and Freynik, H. S. (of Riverside Metal Company Division of H. K. Porter Company, Inc.), The Fatigue Properties of Wrought Phosphor Bronze Alloy, A.S.T.M., Atlantic City.

Guerard, J. P., see Gohn, G. R.

Grisdale, R. O., The Formation and Properties of Black Carbon, Petroleum Section, Gordon Research Conference, New London, N. H.

Hagstrum, H. D., The Mechanism of Electron Ejection by Positive Ions, International Symposium on Electrical Discharges in Gases, Delft, Netherlands.

Hagstrum, H. D., Auger Ejection of Electrons from Metals by Ions, Chalmers Institute of Technology, Gothenburg, Sweden; Technische Hochschule and University of Munich, Germany; University of Tübingen, Germany; University of Heidelberg, Germany; University of Marburg, Germany; and Max-Planck Institute for Chemistry, Mainz, Germany.

Hannay, N. B., Solid State Physics, Summer School for Chemical Engineering Teachers, Pennsylvania State University.

Herrmann, D. B., see Williams, J. C.

Hersey, R. E., see Dehn, J. W.

Inskip, L. S., Grounding in the National Electrical Code, Thomas Edison Club, Detroit.

Mason, W. P., Bommel, H. E., and Warner, A. W., Jr., Dislocation Relaxations and Anelasticity of Crystal Quartz at Low Temperatures, Acoustical Society of America, Pennsylvania State University.

McMillan, B., Mathematical Approaches to Information and Communications, Pennsylvania State University.

McSkimin, H. J., Measurement of Elastic Stiffness and Dissipation for Solids at Ultrasonic Frequencies, Acoustical Society of America, Pennsylvania State University.

Mendizza, A., see Compton, K. G.

Meyer, F. T., An Improved Detached-Contact Type of Schematic Circuit Drawing, A.I.E.E. Summer General Meeting, Swampscott, Mass.

Nielsen, G., Jr., see Baldwin, M. W.

Nossaman, R. J., New Materials in Telephony, Engineers' Club, Omaha.

Owens, C. D., Modern Magnetic Ferrites and Their Engineering Applications, A.I.E.E.-I.R.E. Electronic Materials and Components Symposium, Philadelphia.

Raisbeck, G., Electric Power from the Sun, Naval Research Company 4-1, Princeton, N. J.

Sears, R. W., A Regenerative Binary Storage Tube, Electronic Components Conference, Los Angeles.

Suhl, H., see Walker, L. R.

Terry, M. E., Applications of Statistics in the Electronics Field, Industrial Engineering Seminar, Cornell University.

Terry, M. E., Use of Statistics in Research, American Association for Engineering Education, Pennsylvania State University.

Tukey, J. W., Experimental Design in American Industry, Business Statistics Conference, Philadelphia.

Turner, E. H., Field Displacement Isolators at 55 KMC, U.R.S.I. Symposium, Ann Arbor, Mich.

Ulrich, W., see Yokelson, B. J.

Walker, L. R., and Suhl, H., Propagation in Circular Wave Guides Fitted With Gyromagnetic Material, U.R.S.I. Symposium, Ann Arbor, Mich.

Warner, A. W., Jr., see Mason, W. P.

Wilkinson, R. I., The Beginnings of Switching Theory in the United States; and Theories for Toll Traffic Engineering in the U.S.A., First International Congress on the Application of the Theory of Probability in Telephone Engineering and Administration, Copenhagen, Denmark.

Williams, J. C., and Herrmann, D. B., Surface Resistivity of Ceramic and Organic Materials at High Relative Humidity, A.I.E.E.-I.R.E. Electronic Materials and Components Symposium, Philadelphia.

Winslow, F. H., Baker, W. O., and Yager, W. A., The Structure and Properties of Some Pyrolized Polymers, Carbon Conference, University of Buffalo, N. Y.

Yager, W. A., see Winslow, F. H.

Yokelson, B. J., and Ulrich, W., Engineering Multi-Stage Diode Logic Circuits, A.I.E.E. Summer General Meeting, Swampscott, Mass.

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

Anderson, A. E. – *Transistor Trigger Circuit* – 2,708,720.

Chick, A. J., and Speck, L. J. – *Fabrication of Metal to Ceramic Seals* – 2,708,787.

Dehn, J. W. – *Pulse Counting and Registration System* – 2,709,771.

Kircher, R. J. – *Constant Voltage Semiconductor Devices* – 2,709,780.

Kircher, R. J. – *Semiconductor Signal Translating Device* – 2,709,787.

Locke, G. A. – *Telegraph Storage System* – Re 23,990 (reissue of 2,569,478).

McLean, D. A., and Wehe, H. G. – *Electrical Capacitors* – 2,709,663.

McSkimin, H. J. – *Testing Viscous Liquids* – 2,707,391.

Oliver, B. M. – *Pulse-Actuated Circuits* – 2,708,750.

Pierce, J. R. – *Electronic Amplifier* – 2,707,759.

Pierce, J. R. – *Microwave Amplifiers* – 2,708,236.

Quate, C. F. – *Helix Coupling Arrangements* – 2,708,727.

Rosene, V. E. – *Service Observing on Toll Cords and Trunks* – 2,709,722.

Speck, L. J., see Chick, A. J.

Straube, H. M. – *Code Conversion* – 2,708,748.

Wehe, H. G., see McLean, D. A.

Ziegler, A. W. – *Methods for Bonding Silica Bodies* – 2,709,147.

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, P. W., see Weiss, M. T.

Baker, W. O., see Winslow, F. H.

Bogert, B. P., Stereophonic Sound Reproduction Enhancement Utilizing the Haas Effect, S.M.P.T.E., **64**, pp. 308-309, June, 1955.

Boyle, W. S., Kisliuk, P., and Germer, L. H., Electrical Breakdown in High Vacuum, J. Appl. Phys., **26**, pp. 720-725, June, 1955.

Buehler, E., see Tanenbaum, M.

Cetlin, B. B., see Geller, S.

Clogston, A. M., Relaxation Phenomena in Ferrites, B.S.T.J., **34**, pp. 739-760, July, 1955.

Cook, J. S., Tapered Velocity Couplers, B.S.T.J., **34**, pp. 807-822, July, 1955.

Doba, S., Jr., and Kolding, A. R., A New Local Video Transmission System, B.S.T.J., **34**, pp. 677-712, July, 1955.

Ebers, J. J., and Miller, S. L., Design of Alloyed Junction Germanium Transistors for High-Speed Switching, B.S.T.J., **34**, pp. 761-782, July, 1955.

Fisher, J. R., and Potter, J. F., Significant Factors Affecting the Physical Structure of Dry Pressed Steatite, Bulletin J. Am. Ceramic Soc., **34**, pp. 177-181, June, 1955.

Fox, A. G., Wave Coupling by Warped Normal Modes, B.S.T.J., **34**, pp. 823-852, July, 1955.

Geballe, T. H., and Hull, G. W., The Seebeck Effect in Silicon, Phys. Rev., **98**, pp. 940-941, May 15, 1955.

Geller, S., and Cetlin, B. B., The Crystal Structure of RhSe$_2$, Acta Crys., **8**, pp. 272-274, May, 1955.

Geller, S., and Schawlow, A. L., Crystal Structure and Quadrupole Coupling of Cyanogen Bromide, BrCN, J. Chem. Phys., **23**, pp. 779-783, May, 1955.

Germer, L. H., see Boyle, W. S.

Hannay, N. B., see Tanenbaum, M.

Heidenreich, R. D., Thermionic Emission Miscroscopy of Metals – Part I. General, J. Appl. Phys., **26**, pp. 757-765, June, 1955.

Hull, G. W., see Geballe, T. H.

Hutson, A. R., Velocity Analysis of Thermionic Emission from Single-Crystal Tungsten, Phys. Rev., **98**, pp. 889-901, May 15, 1955.

Kisliuk, P., see Boyle, W. S.

Kohn, W., and Luttinger, J. M., Theory of Donor States in Silicon, Phys. Rev., **98**, pp. 915-922, May 15, 1955.

Kolding, A. R., see Doba, S., Jr.

Lakin, Miss C. L., see Rounds, P. W.

Louisell, W. H., Analysis of the Single Tapered Mode Coupler, B.S.T.J., **34**, pp. 853-870, July, 1955.

Lovell, C. A., McGuigan, J. H., and Murphy, O. J., An Experimental Polytonic Signaling System, B.S.T.J., **34**, pp. 738-806, July, 1955.

Luttinger, J. M., see Kohn, W.

Mason, W. P., Dislocation Relaxations at Low Temperatures and the Determination of the Limiting Shearing Stress of a Metal, Letter to the Editor, Phys. Rev., **98**, pp. 1136-1138, May 15, 1955.

Matreyek, W., see Winslow, F. H.

McGuigan, J. H., see Lovell, C. A.

Miller, S. L., see Ebers, J. J.

Murphy, O. J., see Lovell, C. A.

Pape, N. R., see Winslow, F. H.

Potter, J. F., see Fisher, J. R.

Robertson, S. D., The Ultra-Bandwidth Finline Coupler, Proc. I.R.E., **43**, pp. 739-741, June, 1955.

Rounds, P. W., and Lakin, Miss C. L., Equalization of Cables for Local Television Transmission, B.S.T.J., **34**, pp. 713-738, July, 1955.

Schawlow, A. L., see Geller, S.

Tanenbaum, M., Valdes, L. B., Buehler, E., and Hannay, N. B., Silicon n-p-n Crown Junction Transistors, J. Appl. Phys., **26**, pp. 686-692, June, 1955.

Valdes, L. B., see Tanenbaum, M.

Walker, L. R., Generalizations of Brillouin Flow, J. Appl. Phys., Letter to the Editor, **26**, pp. 780-781, June, 1955.

Weiss, M. T., and Anderson, P. W., Ferromagnetic Resonance in Ferroxdure, Phys. Rev., **98**, pp. 925-926, May 15, 1955.

Winslow, F. H., Baker, W. O., Pape, N. R., and Matreyek, W., Formation and Properties of Polymer Carbon, J. Polymer Sci., **16**, pp. 101-120, April, 1955.