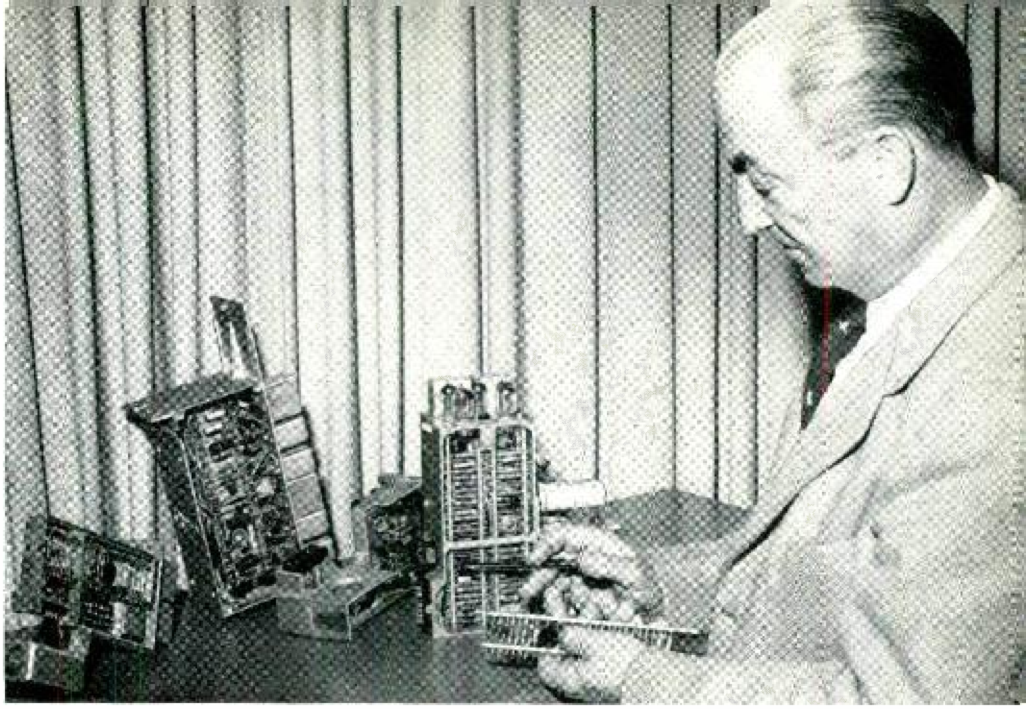
Minaplas—Miniature Apparatus in Plastic



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In electronic equipment, small parts are generally mounted on insulating cards with their wire being wrapped around soldering lugs or terminals. The cards must first be punched from insulating material and the terminals clamped or riveted on; then the parts are mounted by hand. Connection to a circuit requires further hand wrapping and soldering operations. In Minaplas assemblies, most of these hand operations are eliminated by mounting small parts on plastic rails, the pigtails serving for both mounting and connecting purposes

Five thousand years ago, when swarms of manual laborers were building the Pyramids in Egypt, the prodigal use of time in completing a job was probably considered unavoidable. However, during these succeeding 5,000 years, many generations of men have been working incessantly on the problem of conservation of man-hours. A recent step in this endless process of doing things better and faster is the development of a process and a machine for mounting electronic parts on a pair of plastic rails. This process is in line with present trends toward eliminating more and more manual operations by mechanization.

Each of the hundreds of individual components in modern electronic devices must be properly positioned, mounted, and connected into its circuit. Previous arrangements of small parts required special mountings as well as soldering lugs for external connections. Early in the development of type-N carrier, a joint committee of Bell Laboratories and Western Electric engineers was assigned as a task force to develop better mounting and wiring techniques. One of the Western Electric engineers perfected a simple and practical method for mounting small parts on plastic rails by the application of heat to the apparatus pigtails. Subsequently, a machine was developed and built that automatically mounts a group of small parts in a single eight-second cycle. "Minaplas" assemblies use the pigtail lead wires of miniature parts for both mounting and connecting, thus eliminating soldering lugs and specially fabricated mountings.

Above — H. G. Jordan points out a potentiometer mounted by pigtails in a type-O carrier sub-assembly. He holds a duplicate Minaplas assembly.

Fig. 1 — W. T. Westaway compares a Minaplas assembly for A4 channel banks with the previous terminal cards.

Fig. 2 — Parts are positioned in the jig by metal combs. Just-finished assemblies are cool enough to handle; the finger-stops are only to prevent the possibility of an operator being pricked by the pigtail ends.

Figure 1 (left) shows fiber apparatus cards with riveted studs, commonly used to support apparatus and provide terminals for soldering. In contrast, the Minaplas counterpart has double the number of components, each providing its own soldering lugs. The cost of a Minaplas assembly is half that of its predecessor, partly because of material and volume reduction, but mainly because of its adaptability to machine assembly.

The positioning of parts is semi-automatic – special aligning combs hold the parts during assembly. A manually loaded jig full of parts is inserted into a special machine; the mechanical assembly is then completed by one cycle of the machine in about eight seconds. Upon removal from the machine, the assembly can be handled immediately as an integral unit. The plastic rails furnish mechanical rigidity for the parts, hold them in position, and insulate them, all at the same time.

In searching for the ideal thermoplastic to use in such assemblies, design engineers had to consider the following basic requirements:

(a) Flow point low enough to result in rapid softening during assembly.
(b) Flow point high enough to prevent softening during soldering operations.
(c) High kindling temperature.
(d) Low toxic content when vaporized.

The material best fulfilling these requirements is cellulose acetobutyrate, more commonly known as Tenite II. This plastic is transparent, and in early production was used in this state, even though the smooth transparent surface sometimes reflected glaring highlights. Later, yellow-dyed Tenite was introduced to provide an opaque background with less glare, on which stenciled markings are easier to read.

Present assemblies are limited to lengths of 10 inches, more than adequate for the usual electronic assembly. As seen in Figure 2, two Tenite strips form the side rails of a "ladder" configuration, with various apparatus components as the rungs. A jig, Figures 2 and 5, is fitted with metal combs alongside and projecting above two side pieces; these combs hold the various parts in position during the assembly operation. A soft packing material in the bottom of the jig prevents transverse sliding of parts during handling before insertion into the machine. When a different arrangement of apparatus is desired, new combs are all that must be provided to make the changeover.

Steps in the assembly process may be followed

Fig. 3 — Chester Grzyb makes Minaplas assemblies at Western Electric's Kearny Works. Ordinarily, two operators feed assemblies into the machine from alternate sides. The safety cover was removed to show details of the press.

in Figures 2 and 3. Apparatus is assembled in the jig with the pigtail leads positioned by notches in the combs. The parts are stored in bins in front of the operator, so arranged that he merely takes a part from each bin in order; the parts are in the correct order for that particular assembly. The Tenite strips are placed on edge resting on the pigtails, and are held in this position by slots at the end of the jig. A cover is then fitted over the jig and the whole thing – jigs, parts, and Tenite strips – is placed in the specially designed hydraulic press.

The working portion of the press is shown in Figure 4. Heating elements attached to the metal shear plates supply enough heat to the plates to soften the plastic rails in the vicinity of each pigtail contact, and then the press forces the rails down over the pigtails. As each pigtail is pressed into the plastic, the softened material re-forms behind it, nearly closing the slot behind the embedded wire. This results in a strong anchor for each pigtail, holding the part rigid. At the same time the wire is being embedded, a shearing knife trims the pigtails to a 3/16 inch length; these stub ends of wire are then ready to serve as terminals suitable for wire-wrapping tools. A finished assembly as it leaves the press is shown in Figure 2.

An important advantage of Minaplas construction is that automatic wire-wrapping tools* may be used for making connections to the various parts. This wire-wrapping technique, developed in conjunction with the wire spring relay,† provides rapid, tight, compact connections to round terminals such as the projecting pigtail stubs. Further developments may include coining or shaping the pigtail stubs so that automatically-wrapped solderless connections‡ can be used. Of course, manual operations are at present necessary in strapping the components into the desired circuit combinations, but even these manual operations have been minimized by improved procedures involving the extensive use of wrapping tools.

Nonsymmetrical items such as potentiometers may also be included in Minaplas assemblies if they are first fitted with pigtails. Bare wires are sometimes used in Minaplas assemblies as mounting

* Record, *July*, 1951, *page* 307. † Record, *November*, 1953, *page* 417. ‡ Record, *February*, 1954, *page* 41.

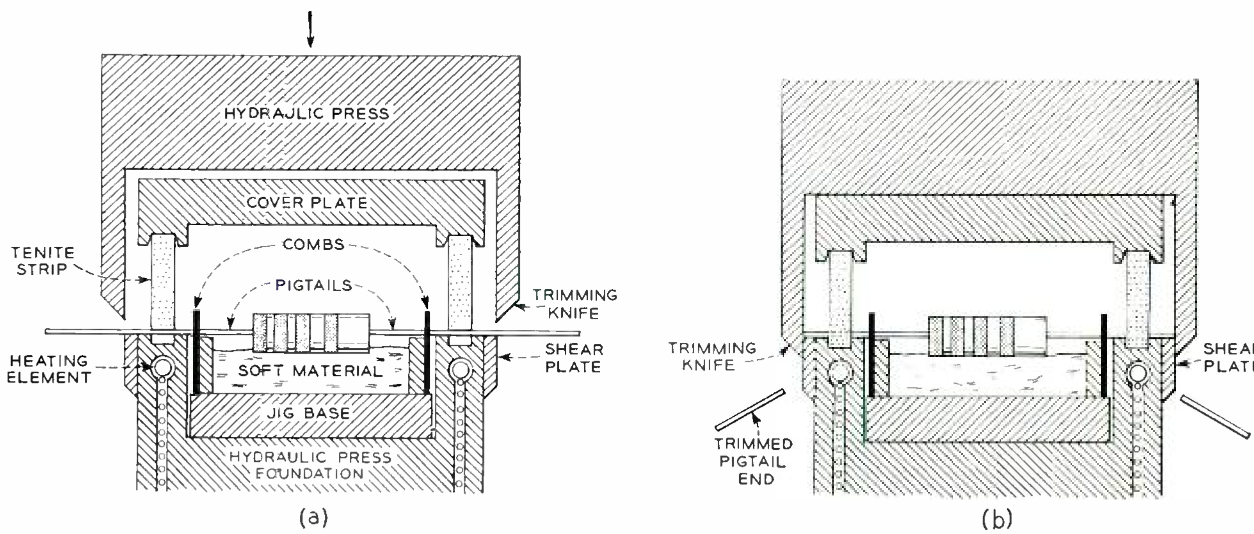


Fig. 4 — At the left, a jig with parts and plastic strips is in the machine just before it operates; at the right, the press has forced the heated strips down over the wires and trimmed the wires to length.

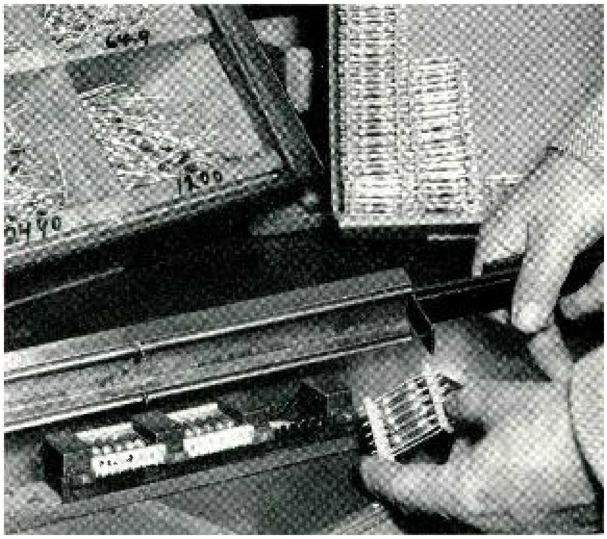


Fig. 5 — Several small assemblies can be made at one time in a jig like this.

supports for such nonsymmetrical parts. Bare wires are also useful in transferring terminations from one side of an assembly to another, to provide a new termination in a location more favorable to easy external wiring. These bare wires provide additional mechanical support for an assembly, and they have also been used in a limited way as shields between circuit elements to reduce crosstalk.

Complete equipment assemblies can be simplified and miniaturized by the use of Minaplas assemblies, resulting in smaller and less expensive units. At the same time, maintenance is simplified because defective parts may be manually removed and replaced with only a soldering iron to soften the plastic; no screw drivers or wrenches are needed to change a defective part.

Along with this development, equipment design drawings have been simplified by using a tabular form for all data on each component; only the generic designation is shown at each component location and the table supplies all remaining information. This improvement in the presentation of design information eliminates searching over a large and complicated drawing to find the pertinent information about a given part.

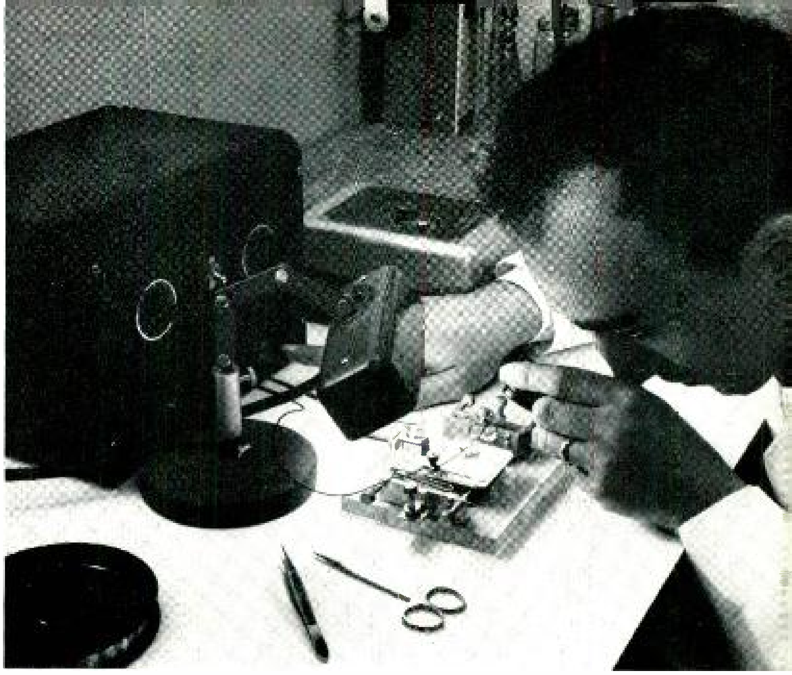
The advantages of decreased size, lower cost, and easier maintenance may be immediately realized through the use of Minaplas assemblies. For the future, Minaplas offers the potential of readily lending itself to automatic processing and may be a prominent factor in achieving the ultimate objective of completely automatic production.

THE AUTHORS

Homer G. Jordan joined Western Electric Company at Hawthorne in 1917, and entered military service in World War I the same year. Following the war he returned to Hawthorne. In 1928 he transferred to Kearny and later to the A. T. & T. Co., and became a member of the Laboratories in 1934. From 1921 to 1931 he was concerned with engineering of central office equipment, mostly in a supervisory capacity. For the next ten years he worked on voice frequency and carrier transmission regulation and carrier system development. During World War II he was engaged in the development of secrecy systems, vacuum tube test sets, and methods of laying telephone wire from airplanes. Since then he has been engaged in the development of power line carrier, and radio control terminals for transoceanic radio, in addition to N-type carrier order-wire and alarm systems and O-type field trials. Mr. Jordan attended Northwestern University from 1919-21 and Purdue University from 1921 to 1922.

W. T. Westaway graduated from Nova Scotia Technical College in 1950 with a Bachelor of Engineering (Elec.) degree and joined the Engineer of Manufacture organization of the Western Electric Company in 1951. Since then Mr. Westaway has been associated with the development of carrier production techniques for several of the newer carrier systems such as L3, N and O. Mr. Westaway saw active service with the Royal Canadian Navy during World War II. Currently he is engaged in manufacturing engineering activities to develop production techniques for a new type all transistorized carrier system for rural subscribers.

Electronic Conductors



K. K. DARROW *Physical Research*

The advent of the transistor has resulted in the need for a review of our theories of electrical conduction. In doing this, we return to an original investigation 75 years old — that of the American physicist, Edwin H. Hall, who discovered a phenomenon named the "Hall effect" in his honor. His studies on electrical conductors in magnetic fields have laid the groundwork for our present conceptions of the motions of what we now speak of so glibly as "holes" and "electrons."

Nothing looks more placid and inert than a length of copper wire. Yet if it be regarded as a physicist regards it, the length of copper wire is a scene of furious activity. The atoms are vibrating to and fro, shivering with heat if not with cold. This will concern us later. What concerns us first is that the copper is traversed by electrons, darting to and fro in all directions with speeds of the order of many miles per second, bouncing off from the atoms and from the surface of the wire. These we call the "free" electrons, to distinguish them from others that do not take part in conduction.

The motion of these free electrons resembles that of the molecules of a gas. The resemblance is not perfect; no resemblance ever is; it is close enough to justify us in saying that the free electrons form an electron-gas, or an electron atmosphere. One of the features of our atmosphere is that now and again it becomes a wind. Even when the wind-speed seems terrific to us, it is small compared to the zigzag speeds of the darting molecules. To convert an electron-atmosphere into an electron-wind, we simply apply an electric field to the copper wire. The atmosphere will then blow through the wire with a wind-speed which is relatively small compared to the speeds of the darting electrons.

In such a conductor as copper, the electric current is the electron-wind. There are other types of conductors for which this is not true. I do not speak of them here, but the fact that they exist obliges us to coin a word for the conductors in which the electric current is an electron-wind. They are called the "electronic conductors."

Electronic conductors form a very large class consisting of two sub-classes. These are the metals and the semiconductors. Copper is an example of the former, and germanium mixed with a small quantity of arsenic may be taken as an example of the latter. Loosely one may say that metals are very much more conductive than semiconductors: the ratio between the conductivity of copper, and that of a germanium crystal in which one in ten million of the germanium atoms is replaced by an arsenic atom, is of the order of ten million.

If one measures the current in an electronic conductor, one is measuring the product of the wind-speed by the density of flowing or blowing charge. It would be very instructive if we could measure each factor of this product separately. Very fortunately this is possible, owing to a remarkable experiment called the "Hall experiment." One of the remarkable things about this experiment is that it was first performed in 1879 in the United States. There were few discoveries in physics in the United States before the end of the nineteenth century: this was one of the few. Edwin H. Hall, who first made it, was a graduate student at the time. He won his doctorate by the experiment, and might have won the Nobel Prize but that this was not established for another twenty years.

To visualize the "Hall effect," imagine a wire carrying a current and stretched crosswise to a magnetic field. If the wire is free to move, it will be pushed sidewise. This is the principle underlying the electric motor, and is well known to all physicists and engineers. But suppose the wire is *not* free to move: what then? According to Hall's intuition, the flowing charges will be pressed against the side of the wire. To test his intuition, Hall provided a bypath for the mobile charge, in the form of a circuit bridged between opposite points A and B of the ribbon and passing through a galvanometer G (Figure 1). I have substituted the word "ribbon" for the word "wire," because in Hall's first successful experiment he used a ribbon of gold leaf, and the use of thin ribbons is customary to this day. When the magnetic field was applied, a current flowed through the bypath.

The Hall effect is capable of giving us the *sign*, the *wind-speed* and the *density* of the flowing charge. It seems remarkable that one experiment can give us all three, but this is not too difficult to prove. To begin with the question of sign: the mobile charge, be it positive or negative, will always be pressed against the edge of the ribbon which faces in the direction in which the ribbon would be pushed if it were free to move. In Figure 1, if the magnetic field at right angles to the plane of the paper is pointing away from the onlooker, this edge will be the bottom edge. If the charges are positive, the direction of the current through the galvanometer will be from B to A. If the mobile charges are negative, they too will flow through the galvanometer from B to A, but the direction of the current as technically defined will be from A to B. The galvanometer can distinguish between these two cases. For gold-leaf the sign of the current indicates that the mobile charges are negative, which accords with our belief that in gold the current is a wind of negative electrons.

To understand how the Hall effect gives us the wind-speed and the density of flowing charge, consider the forces acting upon the mobile charge in a unit length of the ribbon. There is the force due to the field that drives the current along the ribbon: this is proportional to q, the amount of mobile charge in a unit length of ribbon. There is the force due to the magnetic field: this is proportional to the current, therefore to q times the wind-speed v. When the ratio of the forces is evaluated, the factor q drops out and we are left with the desired quantity v. To determine q we divide v into the current-strength i.

To see how the ratio of forces is measured, imagine that into the bypath there is inserted a battery of adjustable voltage, which is adjusted until

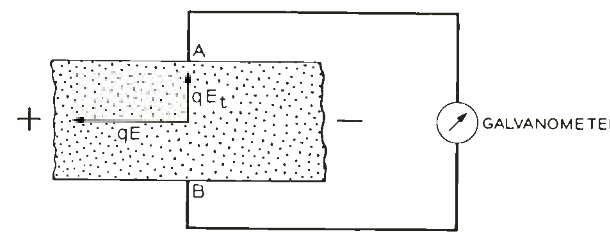


Fig. 1 — Schematic representation to show the Hall effect. Distribution of mobile charges in a ribbon placed in a magnetic field is distorted by the field.

the current in the bypath becomes zero. Denote by V_0 the value of voltage in this situation. Realize now that this is exactly the situation that exists when there is no bypath at all. Between the edges of the ribbon there is a voltage V_0 arising from the fact that there is an excess of mobile charge near the bottom edge of the ribbon and a deficit of mobile charge near the top. Corresponding to this voltage there is a transverse electric field E_t. In equilibrium, E_t is such that the force qE_t, exerted by this field upon the mobile charges in a unit length of wire, is equal and opposite to the force exerted upon these same charges by the magnetic field. I now write the expression for this latter force: it is qvH/c: here H is the strength of the magnetic field and c is a factor depending upon the system of units that is employed. Thus for the vertical force due to E_t we have qvH/c, and for the horizontal force that drives the current along the ribbon and is produced by the electric field E we have qE. It follows that $E_t/E = vH/Ec$. This is the fundamental equation of the Hall effect.

At this point we may begin to consider either what the Hall effect says about the wind-speed v or what it says about the density of mobile charge q. I will begin with the former, but give the lion's share of the remaining space to the latter.

The wind-speed, except in very unusual cases, is proportional to the fieldstrength E. The ratio v/E is therefore a constant. We call it "mobility," and talk about the mobility rather than about the wind-speed.

Experiment shows that the mobility is likely to obey one law in metals and another in semiconductors. In semiconductors it varies about as the (—3/2) power of the absolute temperatures; in metals about as the power —1. This is far from being accurately true in all cases, but the theorists are not particularly disconcerted, for they justly consider that the first business of theory is to explain the first approximation to the facts.

What the theorists infer from these laws is that the darting free electrons bounce off the elastic waves that constitute the thermal agitation of the quivering solid. The warmer the substance the more vigorous the waves; the more vigorous the waves, the more frequent the bounces; the more frequent the bounces, the lower the mobility. The bounces are in fact what prevent the electrons from running away, and constrain them to drift with the low wind-speed.

To prove that this assumption leads to the T^{-1} law for metals and to the $T^{-3/2}$ law for semiconductors is no easy matter, and will not be attempted in this article. I may at least say why the same assumption leads to different laws in the two cases: it is because the density of free electrons in metals is enormously greater than in semiconductors, and from this it follows that the mean zigzag speed of the darting electrons is much greater in the former than in the latter.

To close this too-cursory account of the mobility, I mention that in certain impure semiconductors there is a narrow range of temperatures in which mobility rises with rising temperature. This is because of a factor peculiar to such substances, to wit, the presence of impurity-atoms which are electrically charged. The faster the electrons, and therefore the higher the temperature, the less the mobility of the charge carriers.

Now we turn to q, the density of mobile charge. I will replace q by Ne: here N stands for the number of free electrons per unit volume, and e for the electron-charge. The attentive reader will note that I have made a change in the definition of q, which originally meant the amount of mobile charge in unit length of the ribbon: the alteration should not be troublesome.

In metals such as copper, silver, gold and sodium, the Hall effect testifies that the number of free electrons is of the same order of magnitude as the number of atoms. The number N does not vary much with temperature. More cannot safely be said. Unfortunately the data for metals are mostly old, which is not to say that they are bad; more unfortunately, they are scanty, and there are few if any cases of a sequence of measurements extending over a wide range of closely-spaced temperatures. History shows that of late years there has been a great revival of interest in the Hall effect, but this revival has affected the semiconductors almost entirely. Thus we are in the extraordinary situation — extraordinary it would indeed have seemed, twenty years ago — in which the quantity N is better surveyed and better understood in semiconductors than it is in metals.

As an example of a semiconductor I will take germanium mixed with arsenic — only, let me leave out the arsenic at first. Pure germanium is an element with a tetrahedral structure. This means that each atom has four nearest neighbors. The number "four" figures in another feature of germanium. The germanium atom has four outer electrons, in addition to 28 inner electrons which I mention this once and ignore henceforward. These two "fours" are correlated, and in fact one of them is responsible for the other.

Think of a single germanium atom in the crystal: denote it by A: denote its four nearest neighbors by B,C,D,E. Near the line AB is one of the four outer electrons of the atom A, and with it one of the four of the atom B. Near the line AC is another of the four belonging to A, and with it one belonging to C. Near the line AD is another of the four belonging to A, and with it one belonging to D. Similarly the line AE has a pair of electrons near it; and every atom of the crystal is surrounded by four pairs of electrons wedged into the crystal structure. Unlike the free electrons of our previous illustrations, these wedged-in electrons will not readily move. One infers that absolutely pure germanium at the absolute zero of temperature would be a perfect nonconductor. This is almost surely true. No one has been to the absolute zero and no one has produced absolutely pure germanium: but so closely have both ideals been approached, that it would be a very distrustful person who would doubt the extrapolation.

But now let the arsenic be introduced, say N atoms per unit volume replacing as many of germanium: N should be very small compared with the total number of germanium atoms, say one in ten million. The arsenic atom has five outer electrons instead of four. It is plausible to suppose that of these five electrons, four fit themselves in where the four electrons of a germanium atom would be, while the fifth is left metaphorically out in the cold, but actually free to ramble in the solid. In Greek mythology there was a character called Procrustes, who fitted his house guests to his bed by stretching them on the rack or amputating their extremities, as the case might be. The germanium

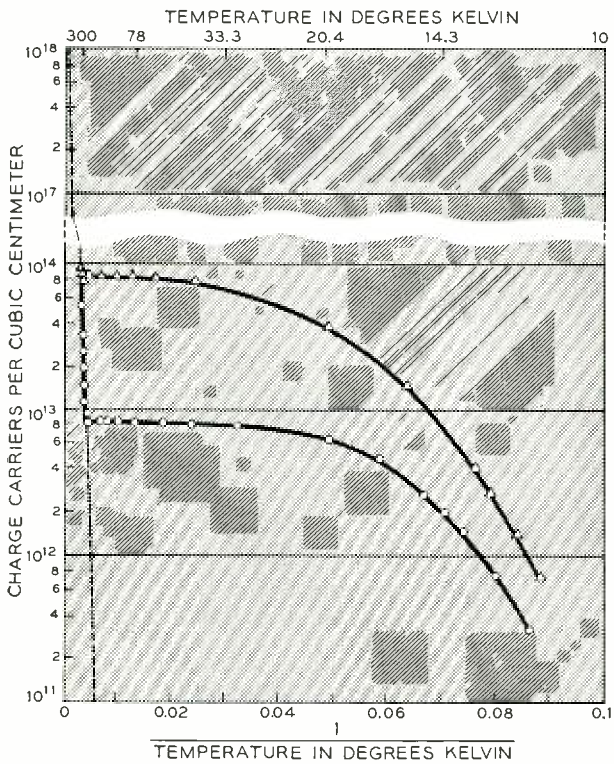


Fig. 2 — Effect of thermal agitation on two samples of germanium mixed with different proportions of arsenic, less arsenic for the lower curve and more for the upper curve.

structure appears to be a bed of Procrustes for the arsenic atom, whose fifth electron is lopped off to fit it to its bed.

If this is correct, the Hall effect should testify that there are N free electrons per unit volume in the substance. And this it does testify, but with an instructive limitation. The number of free electrons is equal to the number of arsenic atoms at fairly high temperatures. If however the substance is very cold, the free electrons are few. Their number rises with the temperature, and N is a limit which it approaches. What this means is that the "fifth electrons" do after all adhere a little to the texture of the solid, quite probably to the very atoms which so to speak brought them; and they must therefore be jarred loose by thermal agitation in the crystal.

One wonders next whether thermal agitation might rise to such a pitch as to jar loose the electrons which are wedged into the germanium structure, so that even pure germanium would become a conductor. This, in fact, does happen. The temperature at which it begins to be appreciable is 300 degrees absolute in germanium. At this temperature, the number of such charge carriers is 2×10^{13} electrons per cubic centimeter.

What has been said in the last two paragraphs is portrayed in Figure 2. The two curves relate to two samples of germanium mixed with different proportions of arsenic, less for the lower curve and more for the upper. The reader will certainly be perplexed if he fails to note that the abscissa is the *reciprocal* of the absolute temperature; temperatures rise from right to left, the cool side is the right. One sees how with rising temperature each curve rises from a low value toward or to a limit in the intermediate range of temperatures, those which I called "fairly high." This is the limit which is equal to the number of arsenic atoms per unit volume. One sees also how this limit is suddenly transgressed, the curves for the two samples merging as the electrons jarred loose from the germanium become so numerous that those detached from the arsenic are lost in the crowd.

Now let us start afresh with pure germanium, and replace a very small number of its atoms – one in ten million, for example – by atoms of gallium. An atom of gallium has three outer electrons instead of four. What happens when this electron-poor atom is forced into the bed of Procrustes provided by the germanium texture?

Up to a certain point, the result is the same as when the intruders are atoms of arsenic. Again the current is proportional to the electric field, and this implies that there is an atmosphere of mobile charges converted by the field into a wind. Again there is a Hall effect. If we interpret it as heretofore and assume that the mobile particles have the same charge as the electron, we can evaluate the number P of mobile charges per unit volume. If we plot P against the reciprocal of the absolute temperature we find just such curves as were seen in Figure 2. The rising parts of the curves, on the right, show that the charges must be jarred loose by heat, but do not require strong heat. The limiting value of P at the fairly high temperatures is equal to the number of gallium atoms per unit volume. Everything would be commonplace, but for something else that the Hall effect says. *The*

Hall effect says that the mobile charges are positive.

The Hall effect, I repeat, says that the atmosphere and the wind are an atmosphere and a wind of mobile positive charges. One could avoid a lot of trouble by saying that the gallium atoms contribute mobile positive electrons to the germanium texture. But one would then infer that heat or light would cause positive electrons to flow out of the substance into the open like thermionic electrons or photoelectrons, and no such thing has ever been reported. The theorists aver that what we here observe is an elaborate and successful illusion, put on by the negative electrons in the germanium texture masquerading as an atmosphere of positive electrons.

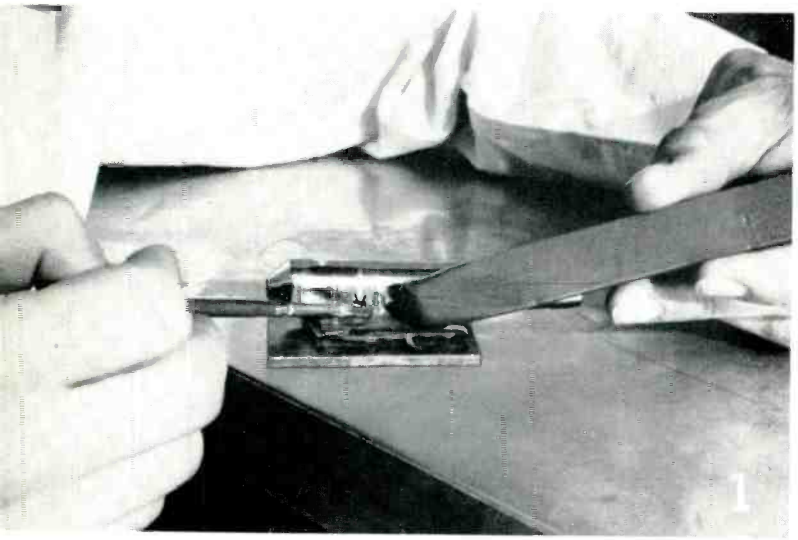
This is a hard saying. It ranks with the hard sayings which have troubled so many minds struggling with the theory of relativity, or trying to understand how a beam of light may show both the properties of corpuscles and the properties of waves. I shall not attempt to justify it here, but will describe the facts in the language recommended by the theory. What the gallium atom contributes to the germanium texture is absence-of-an-electron. Instead of saying "absence-of-an-electron" we say "hole" for short. What P gallium atoms per unit volume contribute to the germanium texture is P holes per unit volume. These holes, at fairly high temperatures, simulate with great success the particles of an atmosphere made up of mobile positive charges. We speak of an atmosphere of holes, of a wind of holes, and of hole-conduction.

At high temperatures, to repeat, pure germanium itself becomes a conductor. It must be inferred that here an electron-atmosphere and a hole-atmosphere exist together, equally dense. When the electric field is applied they blow in opposite directions. One might conclude that they must produce equal and opposite Hall effects which annul one another by symmetry. This would be a just conclusion, were it not that their mobilities differ: that of holes is less than that of electrons. This in turn is interpreted by saying that holes must be more massive than electrons. Since theory asserts and experiment confirms that electrons themselves may have one value of mass inside a solid and another when out in the open, it should not be a cause of surprise that holes may have a mass that differs from both.

I may have given the impression that conduction by holes was discovered when gallium was introduced into germanium. If so, this is a flaw in the method of presentation. The discoverer of hole-conduction was Hall himself. Indeed it was chance (and the malleability of gold) that led Hall to make his first successful experiments on a metal with an electron-atmosphere. Not a year elapsed before he found a metal in which, as we now say, conduction is pre-eminently by holes. This was iron. He guessed, quite naturally, that he had hit upon a peculiarity of ferromagnetics, and his next experiment was on nickel. The guess was wrong, for nickel displayed a Hall effect of the same sign as gold. However, other metals soon were found, of which the Hall effect proclaims that they are hole-conductors. Conduction by holes, in fact, is neither exceptional nor rare. If it seems so, this is because it is not displayed by the elements of the first column of the Periodic Table: and these are precisely the metals which are the favorites of the theorist because their theories are comparatively simple, and the favorites of the engineer because their conductivities are high.

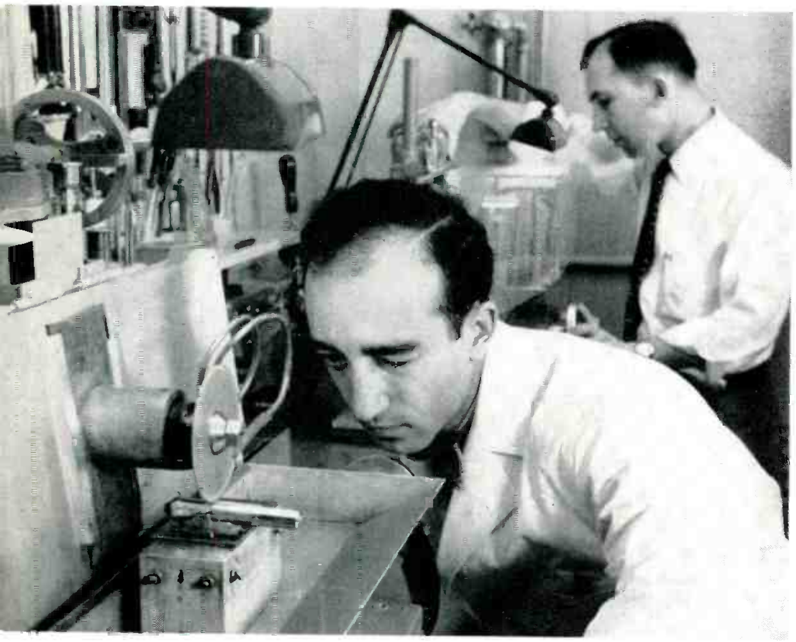
THE AUTHOR

KARL K. DARROW received the B.S. degree from the University of Chicago in 1911. During 1911 and 1912 he studied at the Universities of Paris and Berlin. Returning to Chicago, he received his Ph.D. degree there in 1917, having specialized in mathematics and physics. The same year, he joined the Laboratories, where his work has included study, correlation, and representation of scientific information for his colleagues to keep them informed of current advances made by workers in fields related to their own activities. As a corollary to this work, Dr. Darrow is an accomplished lecturer on current topics in physics and related sciences. He is the author of several books, among which are *Introduction to Contemporary Physics; The Renaissance of Physics; Electrical Phenomena in Gases;* and *Atomic Energy;* and a large number of articles for Bell System publications and other journals. Dr. Darrow was awarded the decoration of the French Legion of Honor, with the rank of Chevalier, and the honorary doctorate of science from the University of Lyons. Since 1941 he has been Secretary of the American Physical Society.



A Research Study of Germanium

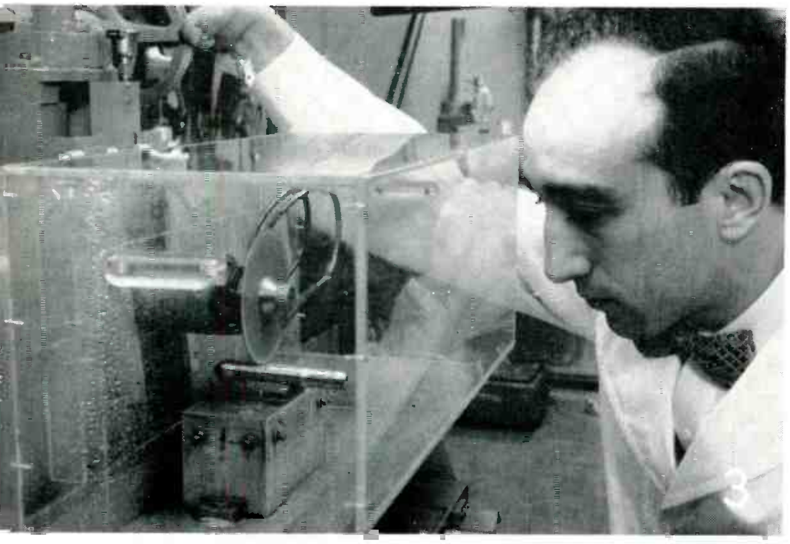
In addition to their widespread use in transistors and other devices, semiconducting materials are used extensively at Bell Telephone Laboratories in the investigation of fundamental properties of matter and electricity. The accompanying sequence of photographs illustrates one such investigation dealing with the measurement of electrical conductivity in germanium at absolute temperatures ranging from 10 to 1,000 degrees, and the Hall effect, discussed in the preceding article. This research is being carried out at the Murray Hill Laboratory under the direction of F. J. Morin, assisted by J. P. Maita, both of the Chemical Physics Department.

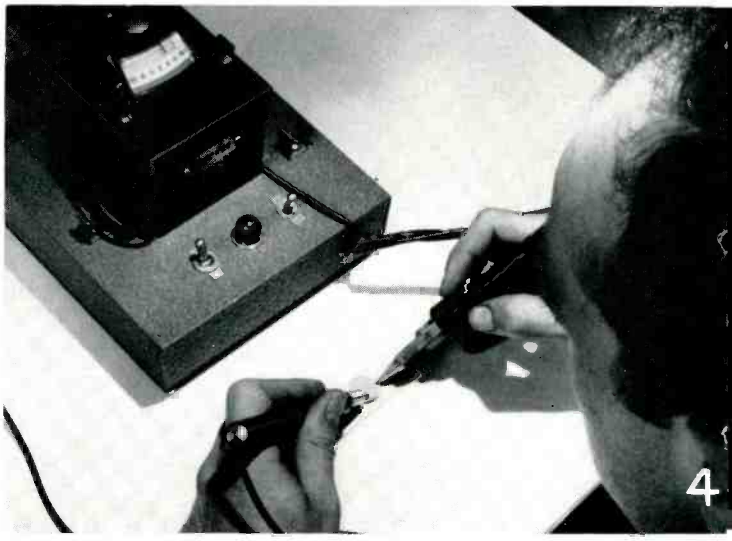


The initial step in an investigation of this type consists of mounting a single crystal of germanium, grown by either the metallurgical group or the crystal growing group of the Chemical Physics Department. As shown in Figure 1, the crystal is mounted with banker's wax on a glass and metal plate to facilitate cutting it into thin slices.

The mounted germanium crystal is carefully aligned in a cutting machine by J. P. Maita as shown in Figure 2. B. J. Wyluda, in the background, is using an identical machine to cut another germanium crystal.

Actual cutting is done by a wheel consisting of diamond abrasive embedded in the edge of a brass disc. As shown in Figure 3, the wheel is cooled and lubricated by a stream of water during the cutting





Conductivity

operation. The transparent plastic cover protects the operator while cutting is in progress.

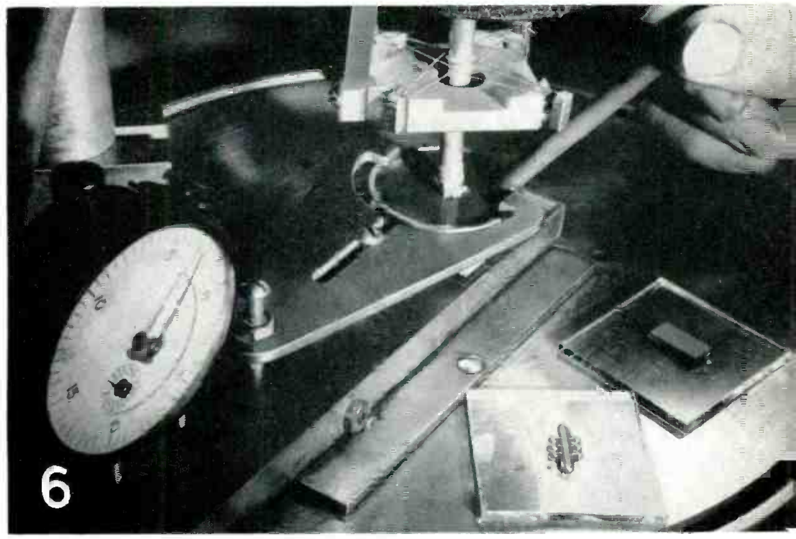
After cutting, thermoelectric probes, Figure 4, are used to investigate the germanium slices to determine whether the material is p- or n-type, and to insure that no junctions are present. In this way, unusable slices of the germanium crystal can be discarded before the process is continued.

The usable germanium slices, Figure 5, cut in rectangular plates and mounted on a brass lapping die, are lapped with a mixture of silicon carbide abrasive and water to give them uniform dimensions.

A magneto-striction machine, designed by W. L. Bond of the Laboratories and illustrated in Figure 6, is used to cut various configurations from slices of germanium and other brittle solids. An uncut slice is shown in the right foreground, and a cut bridge-form designed for Hall effect measurements, at the left. This bridge configuration provides contact areas located at some distance from the body of the sample being investigated. In this way, the effects of contact troubles on the measurements are minimized.

After the bridges are formed, the contact areas are cleaned by sand-blasting as shown in Figure 7.

The contact areas of the bridge are gold plated to provide a low resistance at the contacts, and to aid in bonding gold contact wires onto those areas as shown in Figure 8.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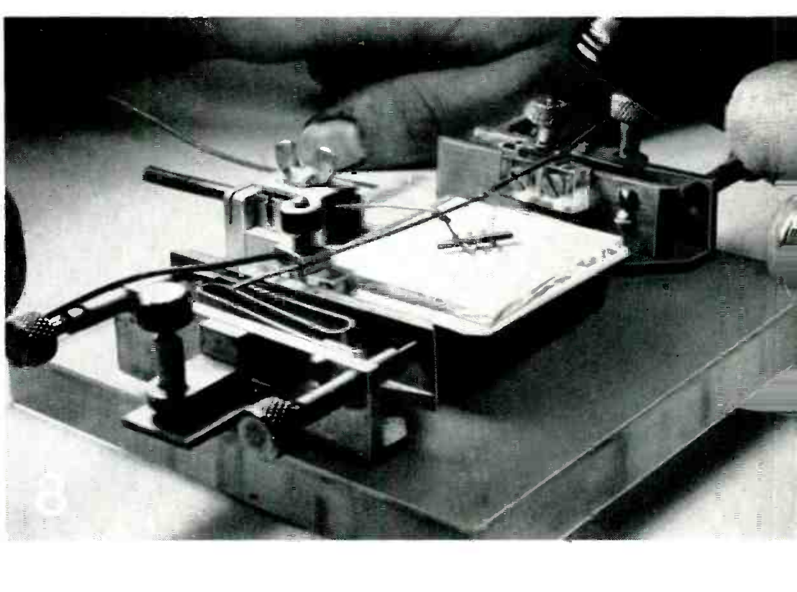
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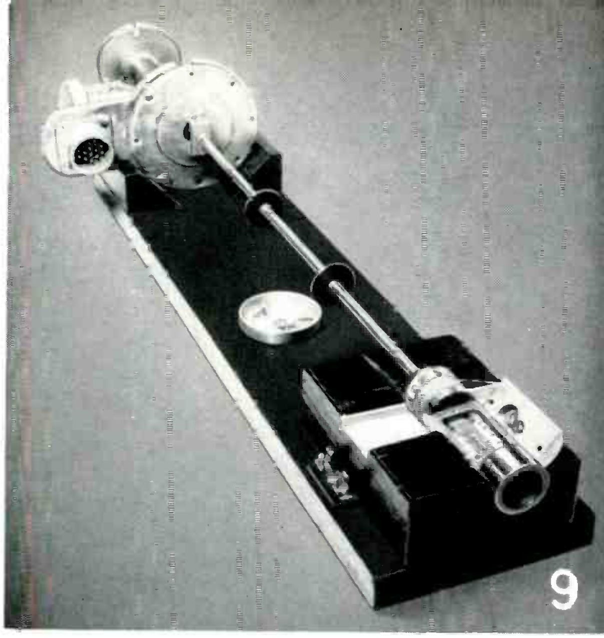
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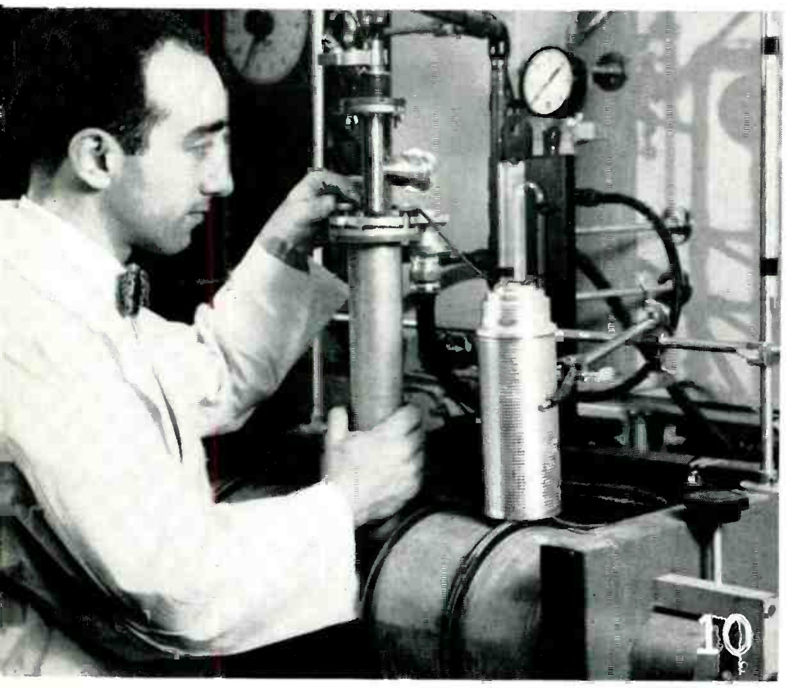
After the bridge is completed, it is mounted in a sample holder, Figure 9. The bridge with the gold contact wires in place, can be seen in the cavity near the end of the holder at the lower right-hand corner of the photograph. The bridge and holder are then placed in low-temperature apparatus for Hall effect and conductivity measurements.

The holder assembly is screwed into place between the poles of an electro-magnet as illustrated near the bottom of Figure 10. The apparatus is then cooled with liquid hydrogen. This electro-magnet is used to provide the magnetic field perpendicular to the plane of the sample as required to provide Hall effect currents at right angles to the direction of normal flow as described in the preceding article in this issue of the RECORD.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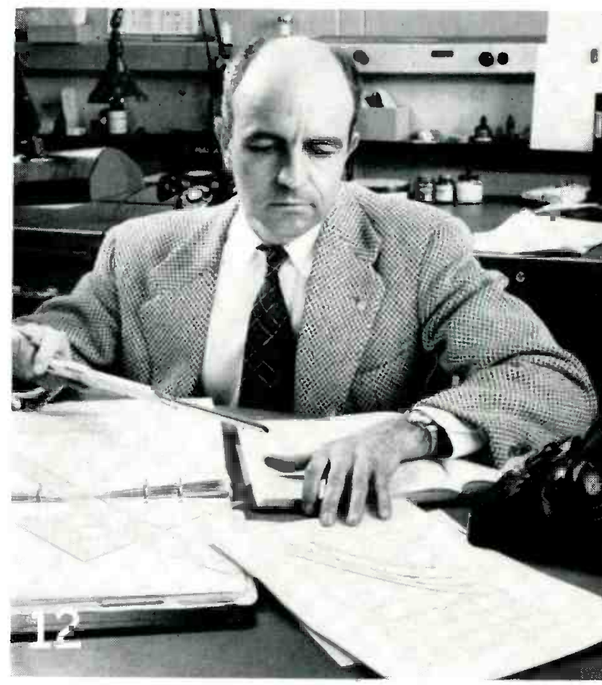
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In Figure 11. Mr. Maita is shown obtaining data including measurements of the temperature of a germanium bridge made with a resistance thermometer. Hall effect currents and conventional currents are also measured and recorded at this stage of the investigation. The sample holder assembly can be seen above the magnet pole-piece in the right foreground of Figure 11.

Data obtained in measurements, including those illustrated in Figure 11, are used in studying some of the fundamental properties of germanium. Graphs, such as those shown in Figure 12, are plotted by Mr. Morin as an aid in these investigations. The graph shown in the foreground of this photograph is a plot of electron concentration in the germanium bridge versus absolute temperature.

Operation of the Card Translator

P. MALLERY *Switching Systems Development II*

Translation is a part of all modern, high-speed telephone systems, since dialed information must be converted to a language that switching equipment can use to determine the routing of calls. In the 4A toll crossbar system, metal cards register the necessary information and provide a versatile means of translation. By helping to control the complex 4A switching processes, the card translator is an important factor in the growth of direct distance dialing of telephone calls.

An important feature in nationwide dialing is the automatic determination of the routing for calls. This determination must be made at each of the control switching points through which the call passes. It requires converting the digits dialed into routing information, and for this purpose a translator of some sort is needed. In earlier crossbar systems the translator was part of the marker; however, in the new 4A toll crossbar system the routing information is so complex that the translators used in the past appeared to be uneconomical. Therefore a radically new type of translator, called the card translator, was developed.

As its name implies, the card translator has the routing information registered on cards. When a new routing is required, a card may be prepared and then added or substituted in the translator as if it were an ordinary card file. Since the code registered on the card is the full information for the translation, it is possible to check thoroughly the new code before it is placed into the translator. This is a distinct advantage over translators which require the running of cross-connections to establish the output information for each input code.

A typical card is shown in Figure 1. It is made of steel, and is plated first with nickel and then with chromium. The 118 holes in the face of each card represent the various possible bits of routing information. The particular information required is registered on the card by enlarging the corresponding holes. The tabs along the lower edge represent the digits for which this card provides the routing information. As shown in the figure, all tabs, except those for which the card is coded, are cut away. The remaining tabs are used by the translator to select the card.

In the translator the cards stand in a vertical position resting on their tabs. The holes form horizontal tunnels, called channels, through the entire stack of cards. There may be as many as 1,200 cards in the stack. Figure 2 shows an end view of the stack with all cards in their normal position; this also is the appearance of an uncoded card. Under

Above — The author of this article inserting a single card into a card translator.

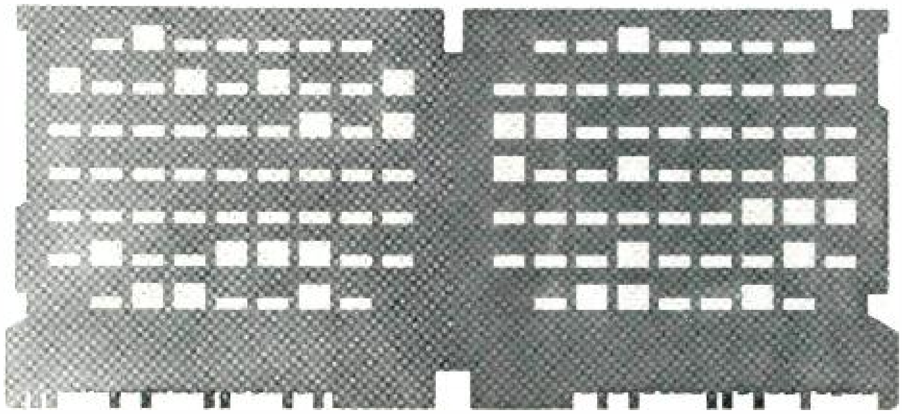


Fig. 1 — Typical metal translator card, with required pattern of holes enlarged.

each tab, running horizontally the entire length of the stack of cards, are the code bars. These bars support the cards in their normal position.

To select a card, the code bars corresponding to the digits received from the operator or customer are lowered. This will remove all support under the card to be selected, which will then drop a distance slightly greater than the height of an unenlarged hole. All other cards will find support under at least one tab and will not drop.

When the selected card has dropped, it will block all channels except those for which holes have been enlarged. The clear channels form a pattern which represents the routing information. Such a pattern is shown in Figure 3. The routing information is determined by directing a light beam through each channel and detecting the presence or absence of light at the far end by means of a phototransistor. The output of the phototransistor is coupled to a transistor amplifier which in turn operates a cold cathode gas tube. The gas tube then operates a relay in the associated equipment. These channel circuits are the first large-scale application of transistors in the Bell System, and a future RECORD article will describe them in detail.

Figure 4 is a simplified sketch of the translator showing only the major parts used in making a translation. As shown, all cards are in their normal position so that all channels are clear. Light originates (at the right in Figure 4) from an arrangement of a lamp, modulating device, mirrors, and lenses. As indicated in Figure 2, light falls upon all phototransistors when the cards are in their normal position. Figure 5 shows in simplified form an end view of the card bin, with one card dropped onto the pull-down magnet.

The following paragraphs describe a complete cycle of operations of the cards, magnets, code bars and other parts identified in Figures 4 and 5. Basically, this cycle will be seen to consist of three consecutive operations: all the cards are first raised from their normal position; they are then restored and the one card selected is dropped; and third, all cards are again raised above the normal

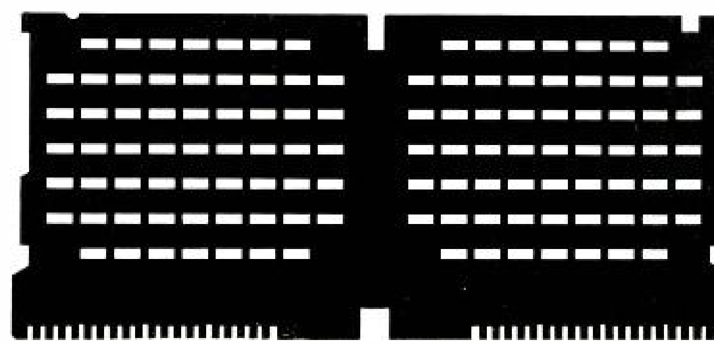


Fig. 2 — Shadowgraph end view of card stack, all cards in normal positions and all light-channels clear.

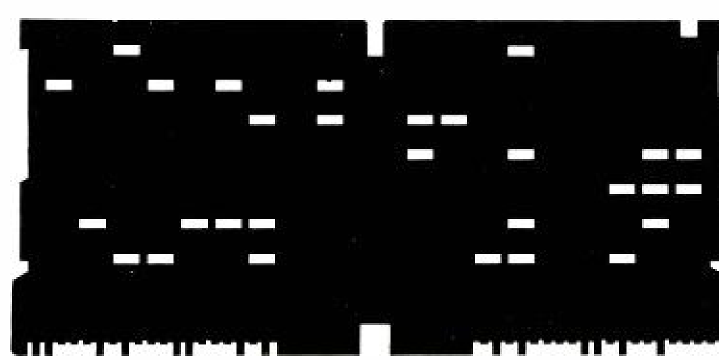


Fig. 3 — Shadowgraph end view of card stack with one card dropped, all channels blocked except those corresponding to enlarged holes.

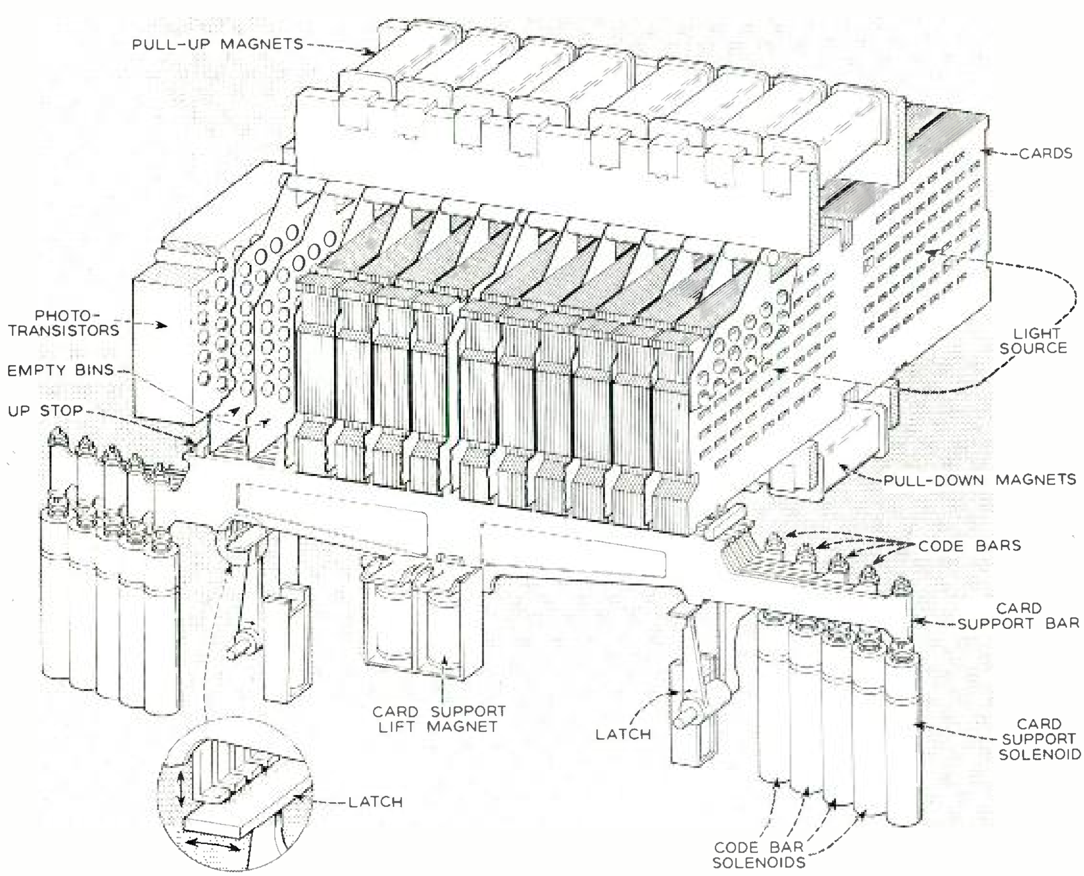
position. Although apparently complex in the number and manner of individual actions, the complete translation is rapid, and requires only about one-third of a second.

The cards are supported by forty bars—thirty-eight code bars which rest on the latches, and two card-support bars which do not engage the latches. When a translation is to be made, the pull-up magnets are energized and they then lift the thousand or more cards off the code bars. At the same time the card-support lifts are energized, thereby clamping the card-support bars against the up-stops (Figure 5), thus holding any cards which may not have been picked up by the pull-up magnets. This initial pull-up action takes the weight of the cards off the latches, and the latches and code bars are now free for the subsequent operations.

The latches are then withdrawn and the code bars corresponding to the dialed-code digits are pulled down by the code-bar solenoids. Next, the latches are again restored to a position to support the code bars, which in turn will support the cards, and the pull-up and card-support lift magnets are released. The cards drop onto the code bars, and all cards except the one selected will find an unoperated code bar under at least one of its tabs and so will stop in the normal position. The selected card will find no support, however, and will drop farther, following the card-support bars as they are pulled down by their solenoids, until the card rests on the pull-down magnet pole faces. This situation can be seen in Figure 5, where the dropped card has now blocked off the light from all channels except those for which the holes have been enlarged.

The pattern of the remaining beams of light is detected by the transistor channel circuits, and these circuits then permit the determination of routing information by the decoder and marker. After this is accomplished, the pull-down magnets

Fig. 4 — Simplified sketch of translator, showing major working parts.



are cut off and the pull-up magnets are again energized. This lifts the stack of cards, freeing the latches. The latches are now withdrawn again, and the card-support bars and depressed code bars are released. These bars drive the selected card back up into the stack. After the code bars have restored to normal, the latches are released. At the same time, the card support lift magnets are energized to guarantee that any cards which may not have been picked up by the pull-up magnets cannot depress the code bars sufficiently to cause the latches to bind as they restore to normal.

With the cards supported by the pull-up magnets and with the latches withdrawn, the translator is ready to select another card. It is held in this position for a fraction of a second so that during the busy hour the time of energizing the pull-up magnets and withdrawing the latches will be saved for a following call. If a succeeding call does not engage the translator within this overlap period, the latches will restore and the pull-up magnets will release.

To permit normal maintenance and to provide a stand-by, an emergency translator is provided in each office. It may be substituted for any other translator by transferring the cards from the regular translator into the emergency apparatus.

The technique of translation by means of a card gives great flexibility to the 4A toll crossbar system. It also made necessary new devices and procedures. A device for coding the card had to be designed, and methods of adding, removing and transferring cards had to be developed. One of the particular problems was to transfer the entire stack of cards from a regular translator to the emergency translator and back again. To facilitate this operation a bulk removal tool was designed. With it, all the cards in one bin of the twelve bins making up the stack can be removed at a time. A "tea wagon" provided with the portable translator test set is equipped with compartments for carrying the cards. The cards are transferred from the translator and reinserted, using the same bulk card tool. The photograph of Figure 6 shows the transfer of cards

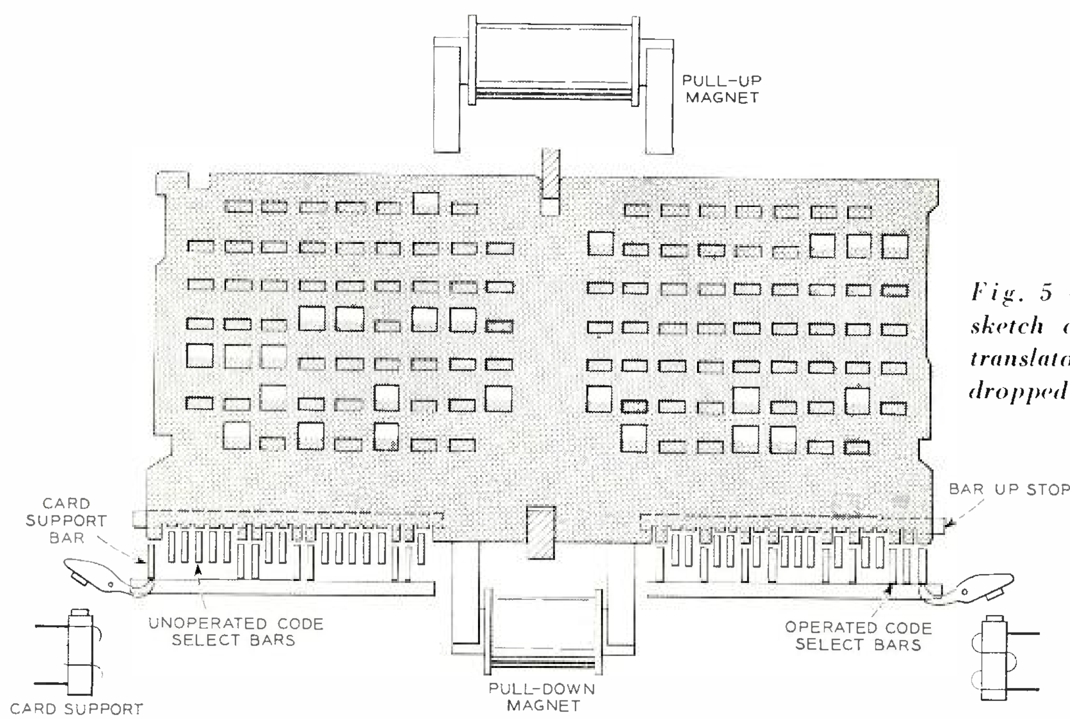


Fig. 5 — Simplified sketch of end view of translator. one card in dropped position.

This translator is a versatile device and could be used in many ways and applications. In the 4A toll crossbar system, as mentioned before, its input code is determined by the digits dialed by the operator or customer. The number of input and output codes is sufficient for present and future growth.

from a translator to the tea wagon. To prepare the translator for card removal, either the portable test set shown or the decoder-marker test frame can be used.

In bulk card removal it is unnecessary to identify particular cards, but if a single card is to be removed or substituted, such identification is necessary. All cards appear the same from the edge, and therefore a means of selection other than visual is employed. By using either the tea wagon test set or test frame, the desired card is selected and dropped as for a normal translation, except that in this case it remains dropped. Its location may then be determined by inspection and a suitable identification marker inserted in the stack. The card is then restored and removed.

Cards can be added to any bin not loaded with a maximum number of cards, and it makes no difference in the operation of the translator where any particular card is located. However, in actual practice, records are usually maintained as to the bin location of each card to facilitate card removal and replacement. The photograph at the head of this article shows how a tool is used for insertion of a card.

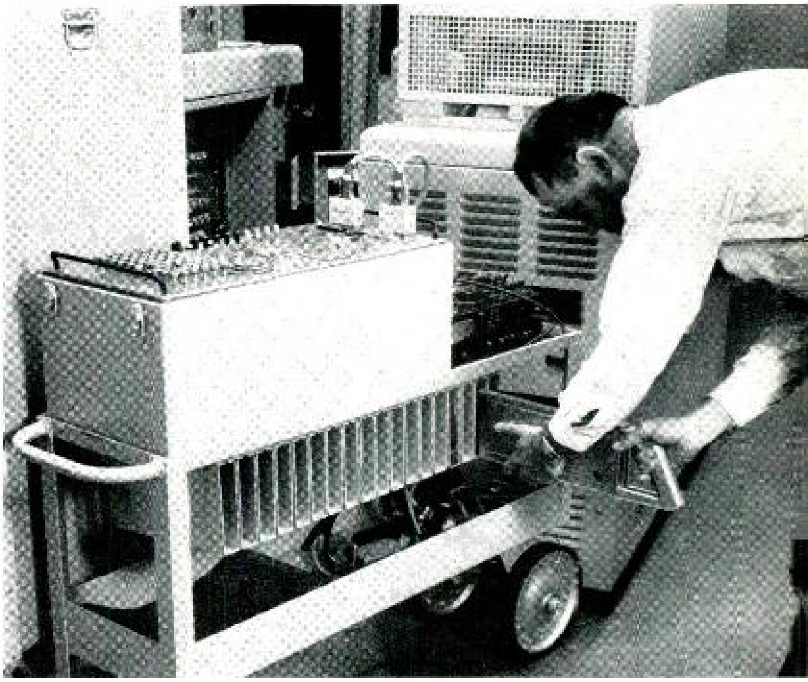


Fig. 6 — D. A. James using bulk removal tool to transfer cards in one bin of the translator to the "tea wagon" test set.

The tea wagon test set and the decoder-marker test frame are also arranged to make operational tests. The various parts of the translator can be checked and operating times determined. With the test frame, all the transistor channel circuits can be tested for operation under marginal conditions in a single mass test. The output code of any particular card can be verified. In addition, troubles that develop on either a service or test call will cause a punched-card record to be made, which will show the type of trouble and identify the translator involved.

THE AUTHOR

P. Mallery joined Bell Telephone Laboratories in 1941 following his graduation from Ohio State University where he obtained a B.E.E. degree. He was concerned with toll systems testing before entering the U. S. Army in 1942 where he served as a radio and radar repair officer in the Southwest Pacific. Remaining in the Army Reserves he is now Chief of Public Facilities of a military government group, the section which controls civilian telephone operation. Following World War II he worked on sender circuit development for manual toll and then on the card translator. He was concerned with the CAMA project for No. 4A toll and is now engaged in the program to develop an automatic switching system for TWX. He is the author of approximately one hundred technical articles and currently has an electrical handbook being published.

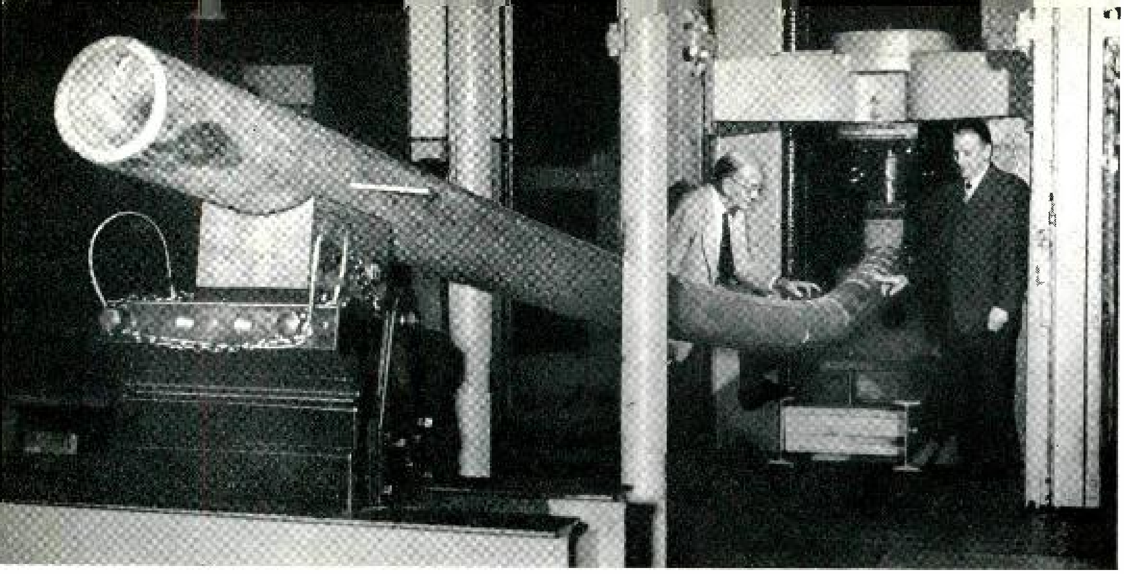


Fig. 1 — Untreated western larch pole under test in the million-pound testing machine at the U. S. Government Forest Products Laboratory, Madison, Wisconsin. Pole is near ultimate load. Left to right: R. P. A. Johnson and L. J. Markwardt, Forest Products Laboratory.

Bell System Participation in ASTM Pole Research

The Bell System, through the Laboratories, is participating in a cooperative wood pole research program being carried out under a fund contributed by pole users, suppliers and treaters, and the United States Forest Products Laboratory. The two-year program is being sponsored by the American Society For Testing Materials and will cost an estimated $160,000. This program was conceived over five years ago, following the evaluation of all existing data relative to the establishment of standard fiber stresses for wood poles. It was thought at that time that additional data were needed, especially on several of the more recently introduced pole timber species. Although several years were necessary to plan the work and to raise funds, the program became a reality with the actual testing of a 30-foot western larch pole at the Forest Products Laboratory in Madison, Wisconsin, on February 4, 1954.

Plans call for static bending break tests on over 500 full sized poles of five different species – southern pine, Douglas fir, western red cedar, lodgepole pine, and western larch. In addition, several thousand small, clear specimens taken from the poles under test will also be broken. These clear specimens are selected to be free from knots and other strength-reducing defects.

The principal objectives of the tests are:

1. To compare the reliability of two ASTM standard methods of test now used for full-sized poles and to correlate the results obtained by each method of testing.

2. To determine the relationship between the results of tests of small, clear specimens taken from poles with the results of tests on full-sized poles.

3. To obtain reliable data on the strength of full-sized poles in order to provide an accurate design basis for the five major pole species.

4. To ascertain the effects of knots, spiral grain, checks and splits, and other defects on the strength of poles, as a basis for improving the requirement for specifications.

5. To determine the effect of the accepted preservation processes on the strength of full-sized poles.

All tests are being made at the Forest Products Laboratories by the ASTM group, of which a Laboratories representative is a member.

Fig. 2 — Southern pine pole just after test. L. J. Markwardt of the Forest Products Laboratory describes the break to (left to right) G. Q. Lumsden, Bell Telephone Laboratories; Harold Armfield and Walter Hecker of Wisconsin Telephone Co.; Dorwin E. Kennedy, Canadian Forest Products Laboratory; O. A. Hanna, Bell Telephone Laboratories; and I. V. Anderson, U. S. Forest Service.

The tests have been divided into three series. Series I consists of static bending tests to provide a comparison of the machine and crib methods of testing. Untreated southern pine poles will be used. About fifty Class 6 (medium size) poles 30 feet long, about twenty Class 1 (large size) poles 60 feet long, and about twenty Class 9 (small size) poles 25 feet long will be tested, half by the machine method, and half by the crib method. In the machine method (Figures 1 and 2), the pole is supported near each end in a trunion-mounted saddle and is subjected to a bending load. In the crib or cantilever method of test (Figure 3), the butt of the pole is fastened securely in a fixture built into a concrete pier. A line is attached to the pole two feet from the top, and is connected to pulling gear to apply the load.

Series II of the tests will provide relative strength data on untreated poles of the five standard species. About thirty-five medium-sized poles of each species will be used — twenty-five of average specific gravity, five of maximum specific gravity, and five of minimum specific gravity. In addition, five small poles and five large poles will also be tested to study size effects.

Since some strength loss results from the application of preservative treatments, Series III tests are being conducted to provide data on poles treated with creosote using standard treatment processes. All treatments will be applied in accordance with the standard American Wood-Preservers' Association specifications. It has been agreed that the treatments will be on the severe side so that the results can be accepted as representing standard treatments under conditions set to bring about the current maximum strength reductions. For each species, twenty-five Class 6 poles of average specific gravity, five of minimum and five of maximum specific gravity will be tested. As in Series II, five small poles and five large poles will also be included for each species.

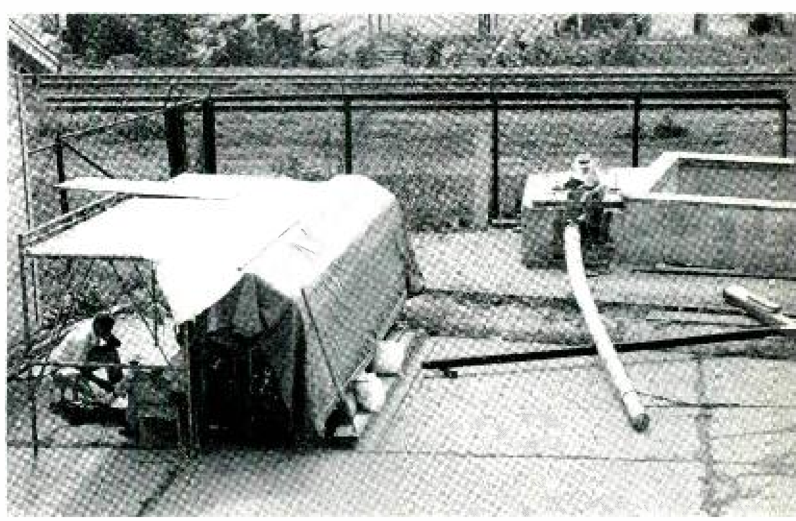
Poles are sometimes re-treated because of inadequacies of penetration or absorption in the original treatment. To determine the effect of re-treatment on these poles, five samples of each species will be treated and then re-treated prior to testing.

Tests of small, clear specimens will accompany the tests on most full-sized poles. To provide material for static bending, compression parallel to the grain, surface hardness, and toughness tests, all poles in Series I and II have been cut with an extra 5-foot butt section from which the small matching specimens are to be taken. In the case of Series III poles, an extra 10 feet is required for the small, clear specimens; 5 feet is removed before treatment and 5 feet just prior to test.

The test poles are selected for the most part in the woods by representatives of the U. S. Forest Service and the U. S. Forest Products Laboratory. After careful woods selection, with careful identification, an inspection is made by a Western Electric inspector to insure conformance to specifications. Many of the green poles needed in Series I and II already have been shipped to Madison, Wisconsin. The Series III poles are being treated at conveniently located wood preserving plants and will be shipped to the test site at Madison.

Upon arrival, the poles are held at a high moisture content until tested. This is done since the strength of wood changes markedly when moisture content drops below the fiber saturation point, about 30 per cent. No satisfactory method is known today for the adjustment of strength data on large round timbers when tested below fiber saturation. Except for a few of the initial poles tested (which were covered with wet tarpaulins) all poles both treated and untreated will be kept fully submerged in a special soaking tank. They are removed a few at a time and kept wet until just prior to test.

Fig. 3 — Southern pine pole being tested by crib method.



Existing data on small, clear specimens indicate that the present permissible fiber stress values of the American Standards Association might safely be raised 10 to 15 per cent. The pole research test program in progress will establish whether such an increase is justified.

O. A. Hanna
Outside Plant Development

Service Features of the No. 2 Telegraph Serviceboard

M. R. PURVIS *Telegraph Switching Engineering*

The rapidly increasing use of teletypewriters has resulted in vastly more complex telegraph networks. These networks, composed of line and loop facilities, are normally administered at telegraph testboards where the facilities are interconnected in series. Network changes require loop current and repeater poling adjustments that cannot be made at the testboards, but must be made at the repeaters. A new electronic "hub" circuit has been included in the No. 2 serviceboard, eliminating these adjustments and concentrating the work load at the serviceboard. This greatly simplifies the work of the attendants and permits it to be done by a much smaller force.

It may be surprising to many people to learn that Bell System telegraph services are provided almost exclusively by teletypewriters and not by Morse keys and sounders. In many cases the words "telegraph" and "teletypewriter" are used interchangeably. As an illustration, serviceboards are designated as "telegraph," but the associated circuits and equipment have been developed almost exclusively for use with teletypewriters.

The term "teletypewriter facilities" includes all equipment such as repeaters and coupling units associated with the switchboard. Those terminating in telegraph serviceboards are primarily for private-wire services (also called leased-wire services). Line facilities for intercity trunk circuits in Bell System teletypewriter exchange (TWX) service also appear in serviceboards for testing and patching purposes. In TWX service, teletypewriters at customers' stations are connected to manual and automatic switching centers by customer line circuits in much the same manner as are telephones. TWX customer lines are not connected to serviceboards.

The No. 2 serviceboard is designed to perform two main functions. The first is to provide interconnections between various telegraph facilities to form the networks employed by private-line services. There are two general types of facilities (also called legs) – line and loop. A line facility is equivalent in some respects to a telephone trunk circuit and includes the actual trunk line plus a repeater at each end. A loop facility includes the

Above — The five service positions at West 50th Street, New York City.

conductors to a customer's station and generally a loop repeater located at the serviceboard office.

The second serviceboard function involves the testing of lines and loops to locate faults, and the manual switching or substituting of facilities to clear trouble. This is done at the board, using test equipment and patching cords at each position.

Some private-line telegraph networks are simple point-to-point circuits as in Figure 1; more often they are complex. The fairly complex network of Figure 2 is typical of the circuits commonly employed by government agencies, news services, air lines, financial institutions and industrial organizations. Several customer stations may be controlled at each city; the numbers in Figure 2 indicate how many stations are controlled at each point. In most networks, only one station can send at a time and the message is received by all other stations in the network. Some stations are arranged for "receive only" operation when the customer considers it unlikely that important information will originate at these points.

In a simple network, troubles occur infrequently and are easily located and cleared. When trouble is located, the particular facility involved (line or loop) is removed from service and replaced. This substitution is done at a serviceboard located at A, B, or both in the circuit of Figure 1. In a complex network, troubles can occur more frequently and even a momentary false pulse or "hit" is likely to affect transmission on the entire network. Since trouble may occur in any branch, or leg, it is often difficult to locate. The No. 2 serviceboard was designed to expedite the work of locating and eliminating troubles in the more complex networks.

At present, most telegraph facilities terminate in existing telegraph testboards where customer loops and line repeater equipment are connected in series. With testboards, then, it is necessary to readjust the over-all loop current whenever a facility is added or removed from a network. The No. 2 serviceboard uses an improved interconnecting arrangement known as an electronic "hub" circuit. The various lines and loops terminate in repeaters; these connect directly, or indirectly through electronic adapters, to the hub circuit somewhat as spokes

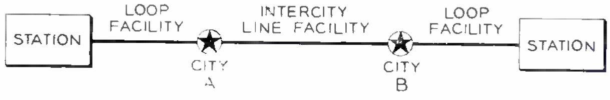


Fig. 1 — In this simple telegraph circuit, a customer loop is connected to the line at each city.

to the hub of a wheel. Since the line and loop currents are independent of the hub-circuit current, it is possible to add or remove facilities from the hub without current adjustments. Telegraph legs that are interconnected by a hub circuit form what is known as a "concentration group."

At present about 60 per cent of the telegraph circuits, including TWX trunks, involve the interconnection at a serviceboard of only two legs such as a line and a loop. In such cases it is more economical to interconnect these legs directly and thereby eliminate the hub circuit and associated electronic adapters. This type of connection provides direct-leg or D-L operation.

At the serviceboard, D-L and hub circuits are segregated and served by two different positions. A "facility" position, Figure 3, serves all D-L cir-

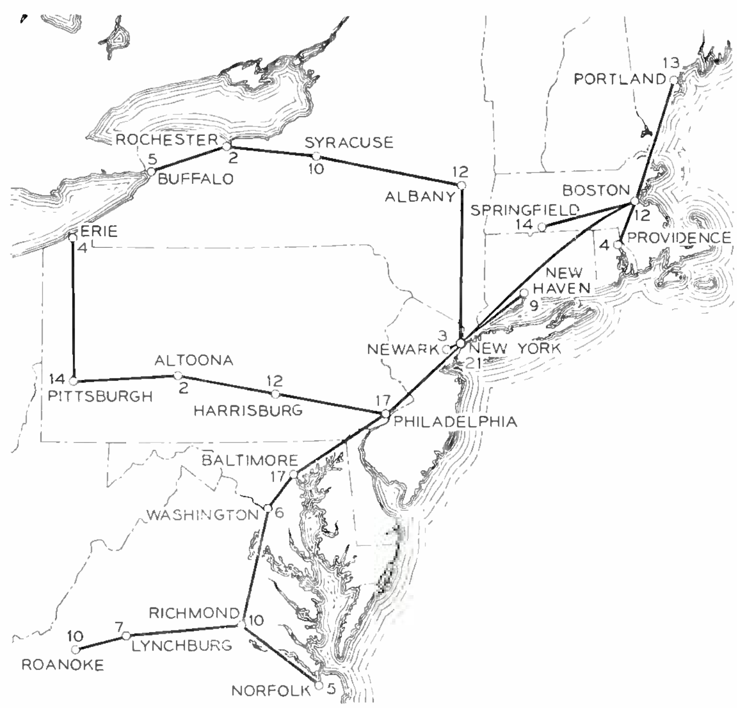


Fig. 2 — A typical complex telegraph network. The number of stations controlled at each city is indicated.

cuits and most line and loop facilities appear at this position. Those facilities assigned to hub operation are cross-connected to a "service" position provided exclusively for hub circuits.

A simple hub circuit is shown in Figure 4. In such a network, the facilities that form the "spokes" of the hub are interconnected in parallel rather than in series. A hub includes a send lead SH and a receive lead RH, and each spoke or leg is connected to both leads through either an electronic coupling unit or an electronic loop repeater.

The operating voltage between the RH lead and ground is supplied by a high-impedance potentiometer circuit. This parallel arrangement simplifies the addition or removal of a leg from the hub, since the hub current is not affected by such alterations in the circuit.

A hub network appears in the face of the service position as a group of jacks – one for the hub itself and a concentration jack for each leg. A neon lamp associated with each concentration jack flashes in response to signals from its leg, simplifying the location of trouble. Line and loop facilities appear at the service position in leg jacks, from which they may be patched to a concentration group as required. Idle legs are indicated by lamps associated with the leg jacks. When a leg encounters trouble, it may be replaced by patching a spare to its concentration jack. This removes the assigned leg from the hub circuit and causes it to appear as a spare at its leg jack. Most patching is done with leg patching cords and it is possible with these cords to build up a complete new hub circuit. Permanent assignments to a hub are cross-connected; cords are normally used only for temporary connections.

Twelve or more legs can be accommodated by a single hub, depending on the ratio of coupling units to loop repeaters used, the distributed capacity between the SH and RH leads, and whether regeneration is provided. If a concentration group involves more than the permissible number of legs, two or more hubs can be connected together through concentration-group repeaters.

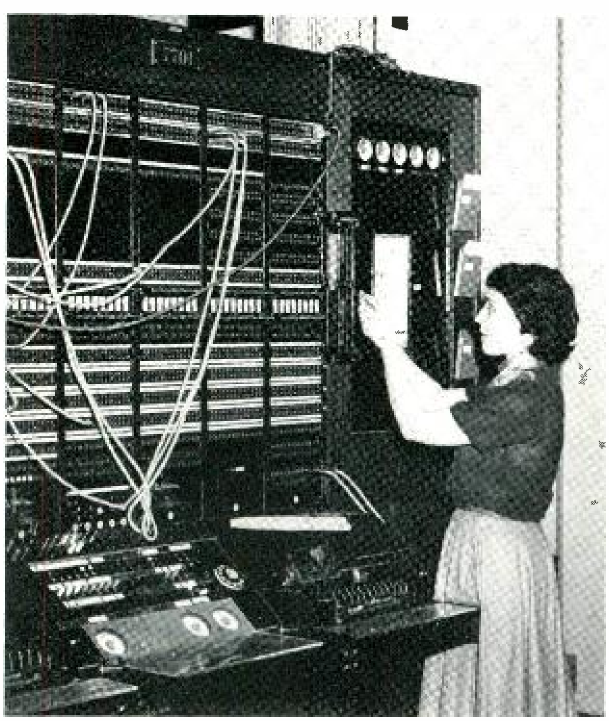


Fig. 3 — Mrs. Constance Kirkpatrick makes changes in the facility position bulletin at the 50th Street office in New York City.

A further advantage of hub-circuit operation is the ease with which regeneration may be applied. In telegraph parlance, regeneration is the process of restoring the wave-shape and time sequence of the signal elements of each teletypewriter character to their original condition. Telegraph signals, when transmitted over long distances without regeneration, may become sufficiently distorted that errors are introduced in the received message. With hub operation, a single regenerative repeater serves an entire hub as shown in Figure 4, option A. The repeater is connected to both the SH and RH leads and all signals are regenerated before being re-transmitted to the SH lead. This is called "multiway regeneration." Older telegraph circuits usually employ a regenerative repeater for each line facility requiring regeneration. Approximately 25 per cent of telegraph private-line networks require regeneration at some point. When regeneration is not desired, option B is utilized and the two hub leads are strapped together.

Telegraph line repeaters developed recently have terminations that are readily adaptable to serviceboards. For example, the 43A1 carrier channel terminal has optional hub and D-L connections that require no electronic adapter or coupling unit. If a line repeater other than a 43A1 channel terminal is used, a simple conversion repeater is required for D-L operation, to properly connect it to a loop. When a circuit requires regeneration, it is terminated in the service position where it becomes part of a regenerating hub circuit.

The series method of interconnecting line and loop facilities at telegraph testboards employs jacks mounted in relay-rack bays. The large number of singly-mounted jacks required per network makes it difficult to concentrate a suitable working load in one testboard position, and it is frequently necessary for an attendant to cover several positions by walking back and forth. The serviceboard uses small strip-mounted jacks to concentrate an attendant's working load in one position. All line and spare loop facilities are multipled and equipped with idle-indicator lamps, throughout the service positions. These features enable attendants to remain seated, and perform their work more efficiently.

Each position is equipped with a monitoring teletypewriter, and all test cords are located in the keyshelf. Telephone, manual telegraph, and teletypewriter cords are provided for communication over official and leased lines and with customer stations. Certain of these cords can be connected to a transmission measuring set and the characteristics of received teletypewriter signals can then be observed on meters in the keyshelf. Test signals for transmission to distant points can be connected to line and loop facilities and varying degrees of distortion can be introduced for test purposes. A volt-milliammeter permits voltage and current measurements to be made. Six trouble-indicator cords are available for trouble observation over long periods; these cords provide permanent trouble indications until cancelled. An attendant is thus provided with "locked-in" hit indications, eliminating the need for a continual watch of the hit-indicator lamp associated with a leg.

The increased operating efficiency possible with serviceboards is reflected in substantial economies even with their present limited use. Operations requiring close interoffice cooperation, such as the substitution of line facilities, may be delayed if all offices involved in clearing a trouble are not equipped with serviceboards. Thus a system-wide application of serviceboards is essential to realize maximum operating economies.

At present, No. 2 serviceboards are in use at Portland, Ore., Oakland, Calif., and the Stewart and West 50th Street offices at Chicago and New York, respectively. Orders have now been placed for serviceboards to replace testboard equipment in the main centers at New York and Chicago, and a number of other offices are presently being surveyed and engineered for serviceboards.

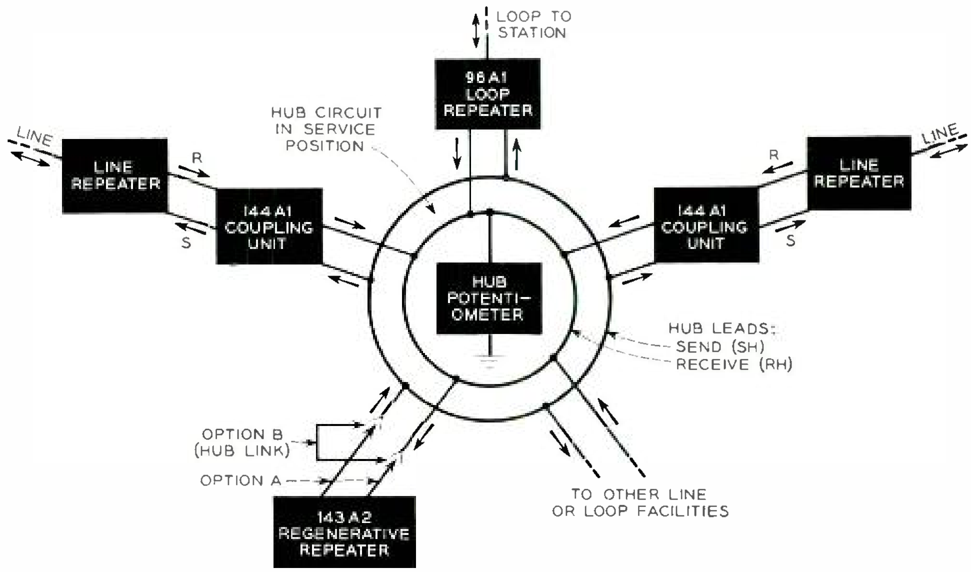


Fig. 4 — A simple hub circuit of a station loop, two lines, and a regenerative repeater.

THE AUTHOR

MATTHEW R. PURVIS received the B.E. degree from Johns Hopkins University in 1926 and went to work the same year for the American Telephone and Telegraph Company. He joined the Laboratories in 1934. Mr. Purvis was concerned with the development of telephone central office apparatus from 1926 to 1930. Then he was assigned to the development of dc telegraph repeaters and polar telegraph relays from 1930 to 1939. He also worked on the development of dc and electronic hub circuits and equipment in conjunction with telegraph serviceboards. From 1940 to 1950 Mr. Purvis was concerned with the development of telegraph regenerative repeaters for teletypewriter communication. More recently he has worked on problems in connection with telegraph switching engineering. Mr. Purvis holds several patents pertaining to electronic telegraph hub circuits, and methods of terminating and interconnecting interoffice telegraph communications circuits.

Dislocations in Germanium Crystals

F. L. VOGEL, Jr. *Metallurgical Research*

In recent years, the Research Department at Bell Laboratories has been actively concerned with a type of imperfection in crystalline structure known as the "dislocation." By properly controlling these imperfections, it may be possible to create structural materials many times stronger than those in use today, but of particular interest at present is their effect on the electrical properties of semiconductors. A number of fundamental experiments have been performed, which have contributed extensively to the verification of dislocation theory.

Crystalline materials – which include all metals – are composed of atoms arranged in repetitive three-dimensional patterns known as lattices. Many different types of lattices exist, but for the purpose of illustration the cubic form shown in Figure 1(a) is the simplest. This lattice is perfect in the sense that every atom has its neighbors disposed about it in exactly the same way as every other atom.

One characteristic of crystals, especially metal crystals, is their ability to withstand plastic deformation. That is, a large and permanent change of external shape and dimensions can be made to take place without the occurrence of fracture. On a microscopic scale this process appears to result from a shearing or sliding motion of certain planes of atoms in the crystal over one another. Figure 1(b) is an illustration of a cubic crystal that has been sheared a unit distance along the plane A-B. This fundamental process is called slip, and the plane A-B in Figure 1(b) is called the slip plane. From the description given, it is evident that no basic change in the crystallinity of the material results from slip.

From a knowledge of the bonding forces which hold the atoms in their positions in the lattice, it is possible to calculate the stresses required to deform plastically a perfect crystal. These calculations of theoretical shear strength indicate that a perfect crystal should be many times – even thousands of times – stronger than actual crystals are observed to be. Therefore, the notion that crystals are perfect three-dimensional arrays of atoms becomes suspect, and the block-sliding picture of slip cannot be the true one.

Suppose now, instead of sliding the half crystal above A-B in Figure 1(b) bodily over the lower half, the shearing motion had been made to occur progressively. That is, the atoms above A-B take up their new positions by jumping in sequence, one unit distance to the right of their original positions.

This operation is equivalent to moving a single compression wave through the crystal above A-B while simultaneously below A-B a tension wave traverses the slip plane in the same direction. If the waves were stopped mid-way through the crystal, a defective configuration of atoms, represented

Above — The author measuring bend in germanium crystal as part of one experiment used to verify dislocation theory of plastic deformation.

by Figure 1(c), would result. In the center of this defective region the atoms do not have the customary "nearest-neighbor" relations; instead, an "extra" plane of atoms occurs above the slip plane. The "extra" plane of atoms terminates in the slip plane along a line which separates the slipped region of the crystal to the left from the unslipped region on the right. This line defect is termed an edge dislocation and is represented by an inverted "T" symbol as in Figure 1(c).

A crystal slips by one whole unit when a dislocation traverses it completely. For example, if the dislocation in Figure 1(c) were to move out of the crystal to the right, the lattice would be in the condition of Figure 1(b). Thus, the movement of dislocations through the lattice produces the same microscopic appearance as block sliding. Furthermore, the movement of dislocations requires far less force than block sliding. This fact explains why real crystals, which always contain a certain number of dislocations, are not so strong as the perfect ideal crystal.

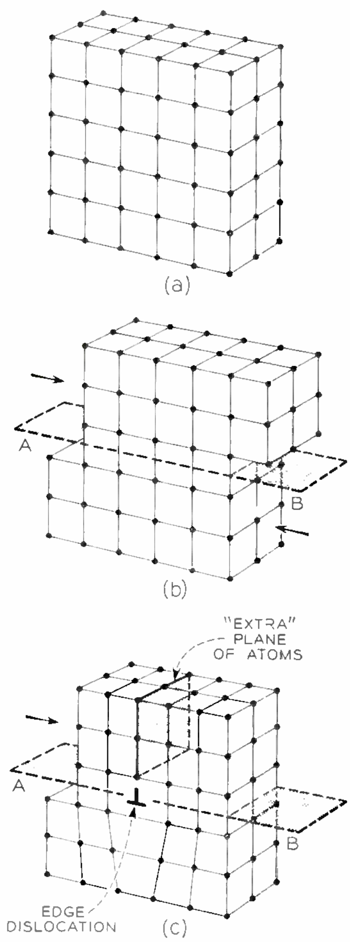


Fig. 1 — Representation of crystal lattices illustrating formation of edge dislocation by partial slip of plane of atoms.

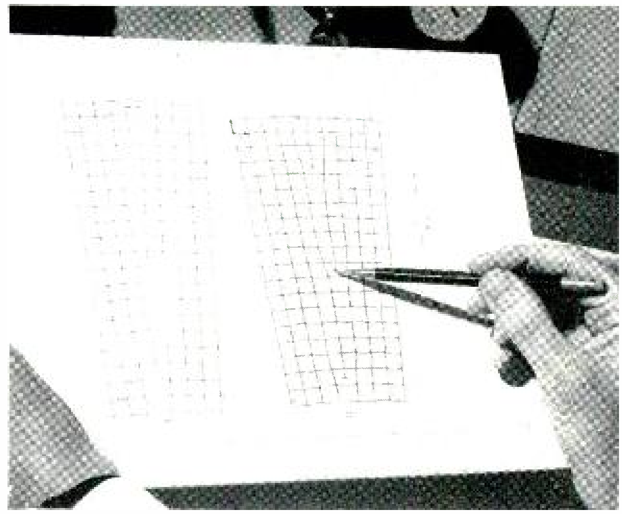


Fig. 2 — Representation of crystal lattices illustrating formation of edge dislocations along a tilt boundary between misoriented crystals.

A direct outgrowth of the early dislocation theory was a model, proposed by the Dutch physicist, J. M. Burgers, for the boundary zone between two crystals. If two adjacent crystals differ only slightly in orientation, they will join together with a minimum of distortion of the lattices in the boundary region. Figure 2 shows a pure "tilt boundary," a boundary between two crystals whose orientations are related by a small rotation about a common axis which is normal to the page. Notice that most of the boundary atoms occupy positions which satisfy the force requirements imposed by both lattices, but that occasionally a row of atoms terminates in the boundary. Thus, this type of boundary is simply a vertical array of edge dislocations. The spacing of the dislocations (D) is related to the angle of tilt (θ) and the lattice constant (b) by the equation $D = b/\theta$. The significance of this model will become more apparent later in the article where it is used to extend our knowledge of dislocations.

From the description already given, one can understand why dislocations are of interest. First, they are an important consideration in understanding the fundamental structure of solids. Second, they determine the strengths of our engineering materials, and proper control of them should yield benefits in higher strengths. After about a decade of development, dislocation theory had advanced to the point where it could explain many observed phenomena in solid state physics, but it lacked a sense of realism because there existed no simple and direct proof that dislocations actually were present in crystals or that they were behaving as predicted by theory. Then, several critical experiments were performed in our laboratories which removed all doubts about the existence of dislocations, and provided a firmer experimental basis for the theory of dislocations.

One of these experiments grew out of the transistor development program at Bell Telephone Laboratories. For this work, many zone-melted single crystals of germanium are produced, and these are given careful routine examination for imperfections of all sorts. One of the more common imperfections seen in single crystals is known as lineage – a slight misorientation of various regions of the crystal. As seen to the left in Figure 3, the boundary between such regions is optically visible after the surface has been properly polished and etched. Also, from the photomicrograph to the right in the figure, it is noticed that significant detail is revealed under magnification – the boundary is not a line, but a series of small pits of rather regular spacing. Observations on a characteristic type of "etch pit" in germanium single crystals by H. E. Corey, Jr., of the Transistor Development Department stimulated a detailed study of lineage boundaries that was made by the Metallurgical Research Department.

The fact that the regions on either side of the boundary are slightly misoriented led us to suspect that the "etch pits" occur at edge dislocations according to Burgers' model for a low-angle boundary. To prove this, the difference of orientation (θ) was measured by a sensitive X-ray technique, and on the same specimen the spacing of the pits in the boundary (D) was measured microscopically.

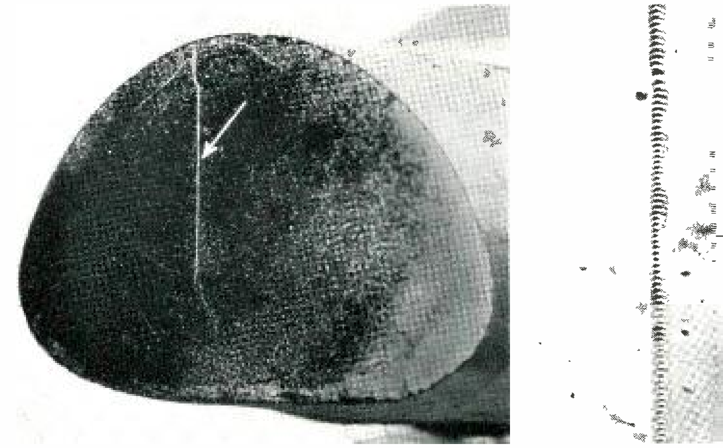


Fig. 3 — Lineage boundary in germanium single crystal; length of boundary line about one cm. Photograph at right shows boundary line under high magnification; length of section of line shown about one-hundredth cm.

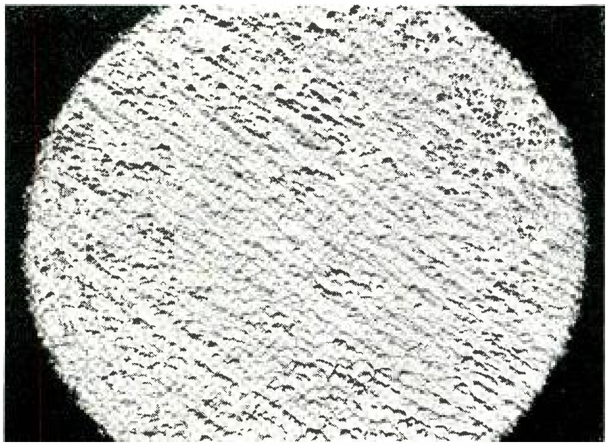


Fig. 4 — Photomicrograph of compressed germanium, showing etch pits. Width of area shown about two-hundredth cm.

This experiment was performed on many specimens having boundaries with varied angles of tilt. The angles of tilt (θ) and the dislocation spacings were found to be related exactly by the equation $D = b/\theta$, using the known value of b. Therefore, it was concluded that the boundary pits are dislocations and that Burgers' model for a low angle boundary is confirmed.

Another means had been used previously to confirm this model. W. T. Read, Jr. and W. Schockley, of Bell Telephone Laboratories, developed a theory of crystal boundary energies based on Burgers' model. The energy of a crystal boundary is a result of the local distortion of the lattice at the boundary, and, the theory predicts, it should increase with increasing angle of tilt (θ). The relative grain boundary energies can be determined by measuring the angles between the boundaries where three join together. This is analogous to the determination of the ratios of three static forces that meet in a point by measurement of the angles between them. Numerous experimental measurements of interfacial angles have confirmed the crystal boundary energy predictions of the theory. Thus, two completely unrelated lines of research led to the conclusion that Burgers' model represents a true picture of the structure of a crystal boundary.

The primary contribution of the etch-pit work was that it revealed individual edge dislocations. This could obviously be of value in the field of plastic deformation where, according to modern theory, dislocations play an essential role. Here-to ore, the intimate relation between slip and dislocations could not be proved because no way of revealing dislocations was available.

The first point of interest, then, is proof that a deformed single crystal does contain dislocations as a result of slip. Figure 4 is a photomicrograph of a compressed germanium crystal, which was etched in the same way that revealed the dislocations in the lineage boundaries. Dislocations are seen here to be aligned in the traces of the slip planes. However, plastic bending affords a more quantitative approach, since the theory predicts a certain density of dislocations depending on the

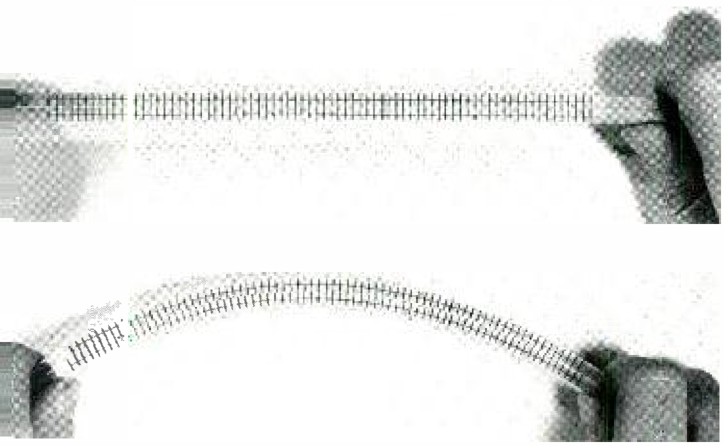


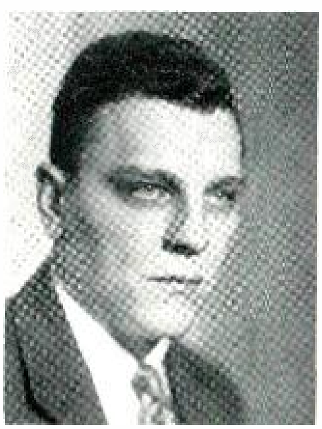
Fig. 5 — Flexible bars with ruled lines can be bent to illustrate production of dislocations by bending.

radius of the bend (r). Figure 5 illustrates how bending of the crystal lattice introduces dislocations. As before, a correlation was obtained — this time between the dislocation density and the radius of curvature of germanium crystals deformed by pure bending. Again, the agreement between theory and experiment indicated that dislocations are the agency by which plastic deformation occurs.

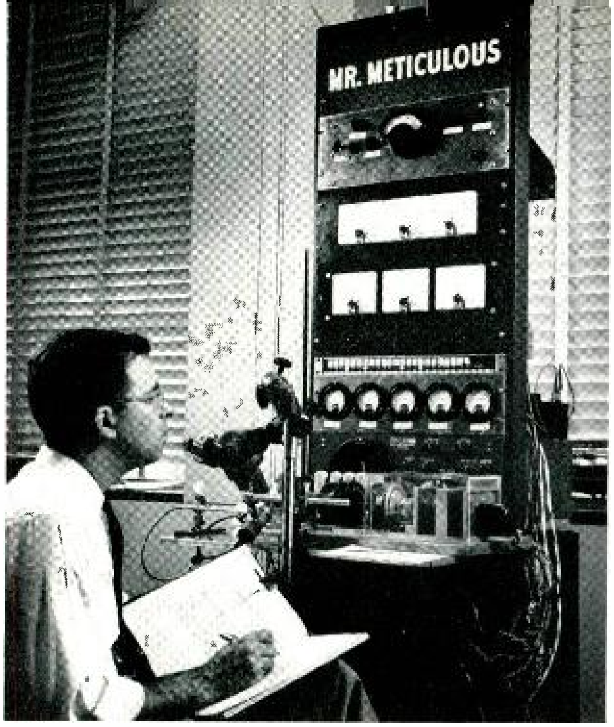
One of the most significant implications of these experiments is fairly obvious. Since dislocations have a very important influence on the strength of materials, it may be possible by proper control of dislocations to produce structural materials many times stronger than those presently available. Of especial interest to the telephone industry, however, is the effect of dislocations on the electrical characteristics of semiconducting devices like transistors. The unique electrical behavior of semiconductors is due largely to the type of bonding that exists between atoms. This bonding is such that most of the electrons are held in definite positions about each atom; only a few are free to migrate through the material. Along an edge dislocation the nearest-neighbor relationships of the atoms are distorted, since the atoms at the edge of the extra plane lack the normal electron bonds across the slip plane. The number of electrons that are free to migrate is thereby reduced, and in addition, the electrons that are able to migrate can readily fall into "traps" provided by the distorted regions around the dislocations. Consequently, one finds that the useful electrical properties are sensitive to the dislocation density of a particular sample. Proper control of the electrical properties of semiconductors, therefore, implies regulation of the dislocation content as well as the chemical composition of semiconductor materials.

Dislocation theory comprises a relatively new field which is just beginning to make contributions to the technology of engineering materials. However, a tremendous challenge is held out for the improvement of these materials and for a new understanding of crystalline solids. We may soon expect to see the consequences of the rapid advances currently being made in the theory.

THE AUTHOR



F. LINCOLN VOGEL, JR., is engaged in fundamental metallurgical research dealing with various phases of dislocation in semiconductors, particularly germanium. This has been his primary concern since joining the Laboratories in 1952. Mr. Vogel's first work at the Laboratories was on germanium boron alloys. He received his B.S. in 1948, M.S. in 1949, and Ph.D. in 1952 from the University of Pennsylvania. While there he was engaged in metallurgical research for the Atomic Energy Commission and the U. S. Air Force. He taught physical metallurgy at the University of Pennsylvania from 1950 to 1952. Mr. Vogel was in the U. S. Army Signal Corps from June 1943 to February 1946 and served in the South Pacific. He is a member of the American Institute of Mining and Metallurgical Engineers; the American Society for Metals; and the American Association for the Advancement of Science. Mr. Vogel is also a member of Alpha Chi Sigma, professional chemical fraternity.



The new Laboratories' machine for assembling experimental transistors in operation at Murray Hill under observation from R. P. Riesz.

New Machine for Transistor Assembly

A machine that can automatically carry out a series of more than fifteen intricate steps in making experimental transistors is now in an early stage of development, the Laboratories recently announced.

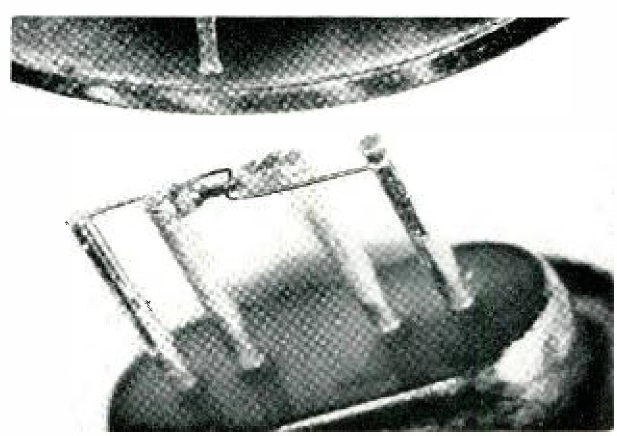
When fashioned by human hands over any extended period of time, some transistors are produced which are substandard and useless for research purposes. But the new machine, familiarly known as "Mr. Meticulous," never gets tired, never loses his precision or accuracy. His hand never shakes and his highly organized electronic "brain" rarely has mental lapses. The machine, originated by R. L. Wallace, Jr., may someday be a pilot model for industrial machines to be used in assembly-line transistor manufacture. At this stage, however, it is primarily a laboratory device designed to aid research on junction transistors.

The commonest form of the junction transistor, now in production at Western Electric's Allentown plant, is a three-layer "sandwich" of germanium sealed in a metal can a fraction of an inch in diameter. The two outside layers are of n-type (negative) germanium; the central layer is of p-type (positive) germanium. Wire leads connect to each of the three layers and extend outside the can. The new type of transistor that "Mr. Meticulous" is currently assembling (he can assemble other junction types as well) has a fourth wire which is attached to the central layer. For this reason it is called a "tetrode" or four-element junction transistor.

The machine operates this way: An operator places an n-p-n "sandwich" of germanium as short as a matchhead and only a little thicker than a human hair, into a clamp on the machine. The machine then presses a very thin strand of gold wire against the bar and the wire edges along the bar with minute steps of 1/20,000 of an inch; after each step the device takes a quick electrical look to see whether it has reached the thin (1/10,000 of an inch) central layer of germanium, to which it must bond the wire. As soon as the wire touches this layer, the machine starts measuring width until the wire reaches the far side of the layer. The machine then decides whether the bar is satisfactory; if it is not, it can be automatically rejected.

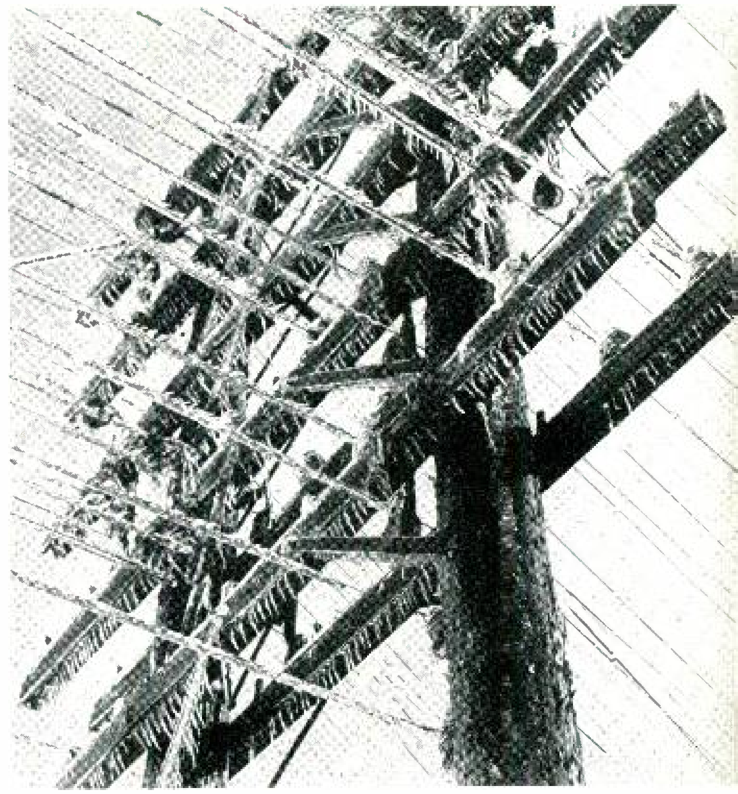
If the bar is acceptable, the machine retraces its steps to the other side of the central layer and counts forward a predetermined number of steps. At this point a shot of electric current is used to attach the wire to the germanium. The machine then attaches this wire to one of the four leads of the transistor itself. It then rotates the bar end over end and automatically goes through the same operations on the other side of the bar.

Finally the machine runs a series of electrical tests to determine whether the completed transistor has the proper operating characteristics for research purposes. If the transistor fails any of the tests, it can be automatically rejected. If it passes, "Mr. Meticulous" puts it aside as finished business and goes on to the next bar of transistor material. The entire process can be carried out in about one minute.



A completed tetrode transistor compared with the edge of a United States dime.

Type-O Carrier—Terminal Alarm Circuits



V. J. HAWKS
Transmission Systems Development I

As with all communication systems, the basic purpose of type-O carrier is to transmit information. Weather conditions, accidents, and many other things can affect open-wire lines and the carrier equipment, and cause impairment of transmission. When this happens, the particular channel encountering trouble must be taken out of service and then promptly restored to proper operation. In type-O, this is facilitated by alarm circuits which give warning when trouble occurs, automatically take the channels out of service, and provide the attendant with a means of testing the system.

As in other carrier systems developed for use by the Bell System, the new type-O carrier for short-haul open-wire lines includes alarm circuits. In this way, maintenance personnel are advised of trouble conditions or any impairment of transmission. Many things can happen to open wire lines—some accidental, as when an automobile crashes into a telephone pole; some the result of heavy winds, rain, or sleet. These and many other occurrences can impair transmission over such lines. In type-O carrier, alarm circuits are provided to give warning when transmission is absent or is reduced below a predetermined minimum.

Above — This not unusual sight graphically illustrates one of the problems encountered when open-wire lines are used. A sleet-covered line can cause serious attenuation of carrier telephone messages. When this happens with type-O carrier, the alarm system warns that transmission is being impaired.

Variations in line loss are compensated for by regulating circuits in carrier terminal and repeater equipment. These circuits determine, from the level of the received carrier, just how much gain is needed in the regulating amplifiers to hold the output constant. With a strong received carrier, the gain is held to a low value; when the received carrier is weak, the gain is raised accordingly. If trouble occurs in terminal or repeater equipment or on the line, succeeding regulators will adjust their gain to maximum in trying to compensate for the reduced carrier level.

This type of regulation is simple and inexpensive, but it has inherent difficulties from a signaling point of view. When there is line trouble, sufficient noise energy may fall into the signaling channel to cause false operation of signaling circuits in the carrier equipment, or of switching equipment connecting to the carrier system. If there happens to be more than one pair on the line equipped with type-O carrier, the increased amplifier gains may permit excessive crosstalk between carrier pairs.

1. Trouble arising in either direction of transmission will give an alarm at both terminals.

2. A customer connected to a channel when trouble occurs may be released.

3. Customers cannot be connected to a channel in trouble.

4. A test circuit and keys permit checking to see if the circuit has returned to normal.

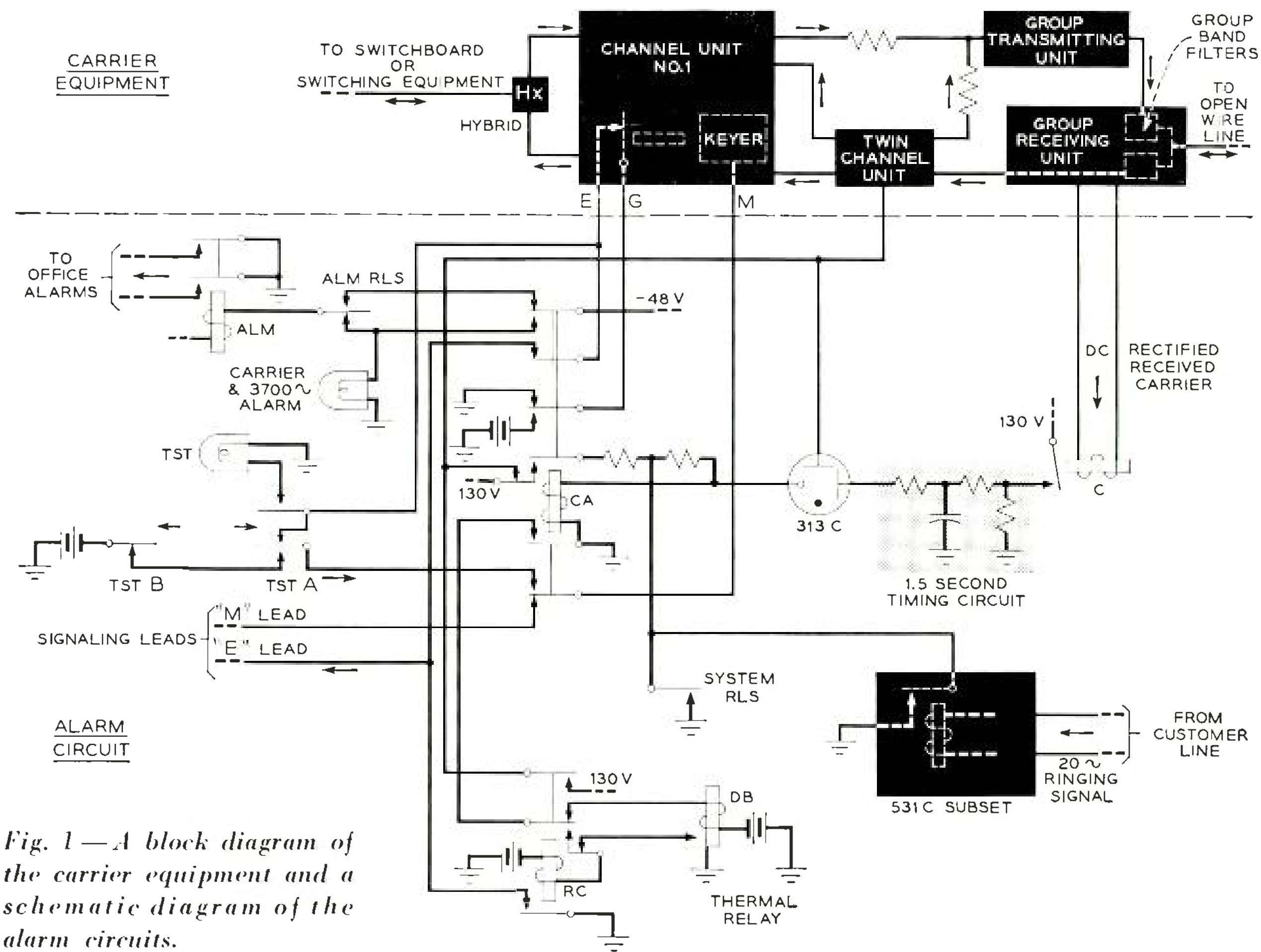


Fig. 1 — A block diagram of the carrier equipment and a schematic diagram of the alarm circuits.

Signals on a good pair may then be transmitted on the pair in trouble almost as well as on the good pair, resulting in a race between the switching equipments connected to the two channels.

A similar problem existed in cable carrier systems, and was solved in type-N carrier* by providing an alarm circuit. Whenever the carrier is reduced below the minimum level for a short interval, relays disable the signaling circuits and give the usual office alarms. A similar arrangement is used in type-O carrier, but several new features have been added without appreciably increasing the cost of the equipment:

* Record, *July*, 1954, *page* 272.

5. Once the trouble has cleared, alarm circuits at both terminals may be restored to normal from either terminal.

A simplified diagram of the type-O alarm circuit is shown in Figure 1. The circuit applies to channel one only; for the other three channels, the loop transmission test feature is omitted since it is used to check whether the line has returned to normal. Only one such circuit is needed for each four-channel system, since only one pair of wires is used.

In Figure 1, the upper portion shows a block diagram of the talking circuits of channel one. The customer is connected through a hybrid circuit to the transmitting and receiving equipment, which in turn connect to the open-wire line. The lower portion of the illustration is a schematic diagram of the alarm circuit. Signaling pulses from the local switching equipment appear on the M lead (lower left), pass through contacts on relay CA, and on to a keyer in the channel equipment. Signaling pulses received from the distant terminal appear at the output of the channel unit on the E lead, pass through contacts on relay CA, and on to the local switching equipment. The alarm circuit is held in "status quo" as long as relay CA remains unoperated.

When conditions are normal in the carrier equipment and on the open wire line, a portion of the received carrier is rectified in the group receiving unit and holds relay C operated. If the carrier falls below a predetermined value, or is absent, relay C releases. The alarm, however, does not operate immediately so that momentary absence of the carrier will not bring in the alarm.

A time delay of 1.5 seconds is provided by the resistance-capacitance network associated with contacts on relay C. When the relay releases, 130 volts is applied to the network. After the delay period, the voltage at the 313C gas-tube becomes high enough to cause conduction, the gas-tube fires, and relay CA is operated. A locking circuit holds this relay operated, since the alarm should be maintained until an attendant at a terminal checks the system and releases the alarm. The slow regulating characteristic of repeaters and group receiving equipment permits noise and cross-talk to gradually increase, and this might reach a value sufficient to reoperate relay C.

If the carrier is absent long enough for the gas-tube to fire and operate relay CA, several things happen. The alarm relay operates, lighting a lamp

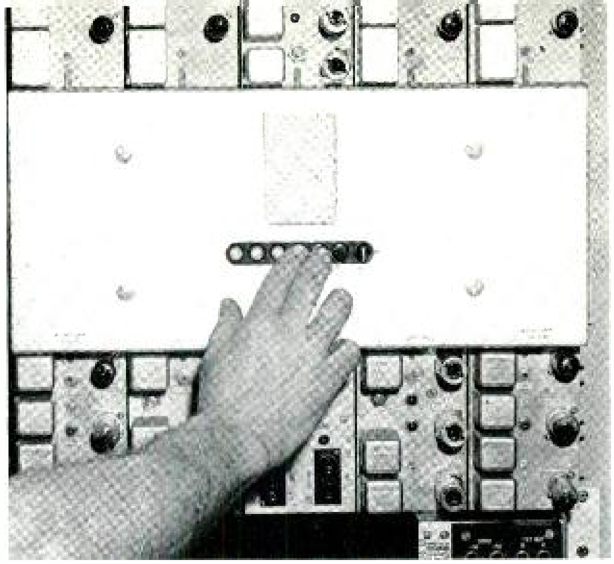


Fig. 3 — Two fingers are sufficient to operate the test keys and test the loop.

and ringing a bell. The M and E signaling leads are opened to prevent false signals from being transmitted to the local switching equipment. Ground normally supplied to the G lead is replaced by battery, and the M and E leads of the channel unit are connected together through the TST A key, to permit making loop tests of the system. Plate battery is removed from the gas-tube in the alarm circuit to extinguish it, and from the oscillator in the twin-channel unit to give an alarm at the distant terminal and complete the loop test circuit. Thermal relay DB is connected to ground and begins to heat.

Approximately ten seconds later, this thermal relay operates and in turn operates relay RC. The thermal relay is released and relay RC is locked operated until the system is returned to normal. Ground is supplied to the E lead connecting to the local switching equipment so that the channel will appear "busy" and prevent its being connected

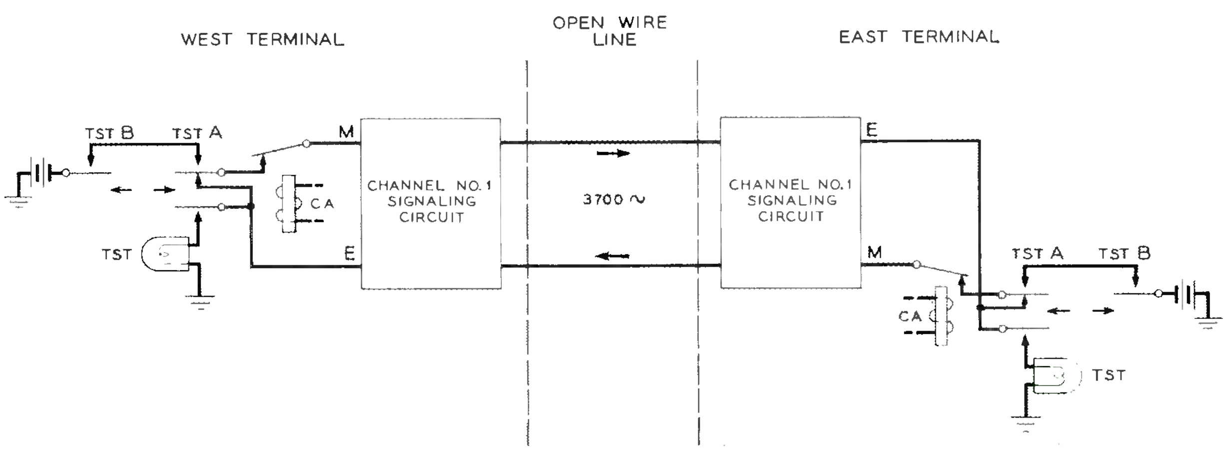


Fig. 2 — Loop testing is made possible by connecting the E and M signaling leads at each terminal.

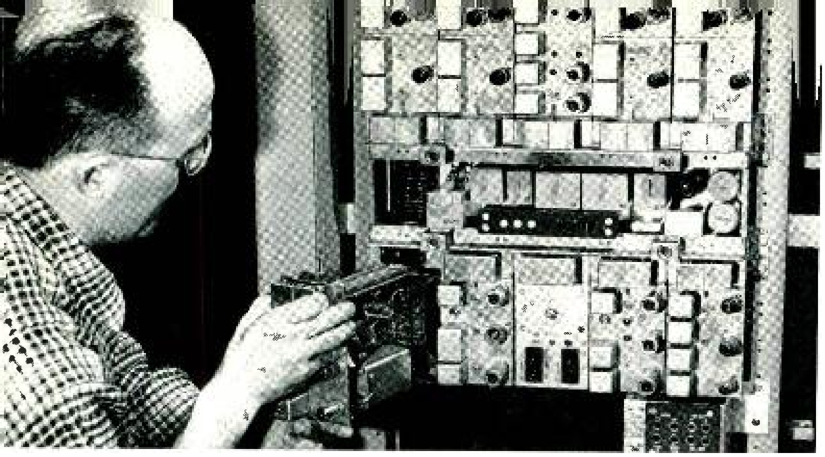


Fig. 4 — C. W. Irby removes a twin-channel unit to give better access to the alarm circuit just above.

to a customer. Plate battery is reconnected to the twin-channel oscillator to restore transmission to the distant terminal, permitting loop tests to be made. Loop testing is a simple, rapid way of determining whether the trouble has been cleared before restoring the system to normal. Restoring the system while the trouble still exists merely invites the signaling troubles that the alarm circuit is designed to prevent.

Two different restoring keys are available to the attendant at a terminal, Figure 3. One, of course, is to restore the system to normal, after it has been checked (SYSTEM RLS, Figure 1). The other is an alarm release key, (ALM RLS), to shut off the gong in the office without restoring the system. After the system has been checked and restored to service, this key must be returned to normal before any subsequent alarms can be made known. The alarm release key is connected to an alarm relay in such a manner that an alarm will sound if the key has not been returned to its normal position when the system is restored.

When an attended station is notified of a trouble condition, the attendant releases the alarm to quiet the gong and then, after the trouble has been cleared, tests the system. Figure 2 shows how this is done. Since the E and M leads are connected together at both terminals, the test may be made from either terminal. The TST A key is operated and the TST B key is then rapidly operated and released, Figure 3. If transmission has returned to normal, a signal will be sent to the distant station, returned to the originating station, and the test lamp will light each time the TST B key is operated. This "round-robin" test checks the line, repeaters, and signaling equipment at both terminals. If the test indicates that the system is again in good order, it may be restored to normal operation.

An attendant must restore the system to normal at both terminals, but may do so from his own location. At his own terminal, he merely operates the SYSTEM RLS key, grounding relay CA and permitting it to release. If, however, there is no attendant at the distant terminal, he either dials or calls a preassigned telephone number. This connects him to a customer's set at the distant terminal and the ringing signal operates a relay in the customer's set to supply ground to relay CA and restore the system at that terminal.

A customer connected to the channel in trouble will be disconnected from the channel if he operates his switchhook during the ten-second timing interval before relay DB operates. If he does not operate his switchhook during this interval, he will remain connected to the channel, but his line will be dead. On certain types of trunk circuits, removal of ground by the alarm circuit will automatically release the customer, even if he does not operate his switchhook.

THE AUTHOR

V. J. HAWKS joined the Laboratories in 1925 soon after receiving a B.S. in E.E. degree from the University of Michigan. He first worked on the long wave transatlantic radio. For many years he concentrated on privacy devices, including band splitting and speech inversion types and miniature privacy equipment. Later he engaged in development of radio control terminals and in 1937 he went to Hawaii to install a control terminal and privacy system for use on radio circuits between Honolulu and San Francisco. During World War II he worked on carrier terminals, a PCM system for Signal Corps use, and on the development of mines. Since 1948 he has been engaged in the development of terminals for types O and N carrier. Mr. Hawks is now engaged on a military project.

New Long-Distance "Helical" Waveguide

Scientists examine wood forms used in testing signal transmission around curves through the new "helical" waveguide.

A new and radically different way of transmitting television and telephone conversations over long distances has been used successfully in experiments at the Laboratories Holmdel, N. J., radio laboratory.

The new medium, a long-distance waveguide, is markedly different from modern cable or radio relay systems – and from previous waveguides. It uses hollow tubes, roughly two inches in diameter, made of tightly coiled copper wire.

It is believed that the new waveguide may someday simultaneously carry tens of thousands of cross-country telephone conversations along with hundreds of television programs. Top capacity for the most modern of coaxial cable systems is 1,860 two-way telephone conversations or 600 such telephone conversations and two TV programs simultaneously on a pair of coaxial tubes. Modern coaxial cables have eight such tubes, two of which are kept as spares for emergencies.

Waveguides made of metal tubing – roughly like an ordinary water pipe – have been widely used for some time for short distances. It would be possible to use these solid metal tubes for long distances if they were perfectly straight.

The newly developed long distance waveguide is also a hollow tube, but it is constructed of thin copper wire, very tightly coiled – like a spring under pressure – and wrapped inside a flexible outer coating which holds the coiled wire in place. This type need not be straight and can actually carry signals around curves.

Experiments indicate that both the solid tube type waveguide and the new coiled wire or "helical" type waveguide can be used together in communications systems; the first for straight runs, the second for curved regions. Recent experiments at the Holmdel laboratory indicate that this new waveguide transmission is extremely promising and might, when fully developed, join coaxial cable and radio relay as an everyday transmission medium for the Bell System.

Although this new form of transmission is still in the experimental stage, a long distance test was made at Holmdel in a copper pipe 500 feet long. Signals were bounced back and forth in the tube for a distance of 40 miles. Calculations showed that, in comparison, similar signals could have traveled only 12 miles in a coaxial cable with the same loss in strength.

The new transmission system operates in a frequency range so high that it has never before been put to practical use for communications. The "super high" frequency range established by the FCC goes up to 30,000 mc. The carrier frequency for the new waveguide is about 50,000 mc.

A major difference between transmission through the new waveguide and through previous systems is that the higher the frequency in the waveguide, the less the loss through attenuation. This is exactly the reverse of other forms of transmission.

Studies of waveguides have been in progress at the Laboratories for nearly a quarter of a century. In 1932 a fundamental experiment demonstrated that electric waves could flow through a hollow tube for several hundred feet and this was the foundation for later development work in this field. A store of mathematical knowledge was built up and many tubes in different shapes and of different materials were studied.

This early knowledge was applied by the Laboratories in the development of radar during World War II when waveguides were used to funnel radar signals from an antenna to receiving equipment. Similar waveguides and others of a more advanced design are in use in the Bell System on microwave radio relay towers. Some of these, as well as the new waveguide, are round.

Beyond the prospect of improved transmission with a long distance waveguide is the possibility of learning how to use wave-lengths on the order of one millimeter. If this should become possible, the waveguide of the future might be no thicker than a fountain pen and still carry tens of thousands of telephone messages.

Highlights from the A. T. & T. Annual Report

"More than in any other postwar year, the Bell telephone companies in 1954 had new facilities to meet promptly the personal wants and preferences of telephone users," President Cleo F. Craig of American Telephone and Telegraph Company declared in the company's 1954 annual report sent to 1,300,000 share owners last month.

Bell System earnings applicable to A. T. & T. stock were $11.92 a share on over 46 million average shares, compared with $11.71 on less than 41 million shares in 1953. Earnings on total capital of the System last year were at the rate of 6.2 per cent, compared with 6.1 per cent in 1953. During 1954, the proportion of debt in total capital was reduced from 41 to 37 per cent.

"With construction costs continuing at the high level reached in the last year or so," Mr. Craig commented, "the average investment per telephone is still rising. Where rate increases are needed the companies will continue to press for them."

The report and a sales insert which accompanies it both stress "complete" telephone service, which to residence customers for instance would include additional telephones in the home, individual rather than party-line service, and a second residence line for families which have outgrown their present service. The insert also pictures colored telephones, illuminated dials and spring cords, telephones for people with impaired hearing, the new "hands free" telephone and several other modern telephone services.

"Our progress depends on putting capital to work as efficiently as possible," Mr. Craig said.

Concerning the close cooperation between the Laboratories and Western Electric for improved and more economical service, Mr. Craig said: "We are always trying to develop new equipment that will improve service, encourage usage, make possible new services and keep down costs. Long experience has proved to us that the best way to do this is to have our own research and manufacturing organizations, working in close cooperation with the telephone companies and with the same purpose of furnishing the best service.

"The rapid postwar advance in long distance dialing, for instance, flows from this teamwork. Bell Laboratories research, Western Electric manufacture, and telephone company planning and operations have been intimately coordinated.

"The people of the Laboratories and Western Electric are full partners in our merchandising program. They are working hand in hand with the operating telephone companies to provide the services and kinds of equipment that will best meet individual wants. Customers see the results most often in new telephones of improved design and greater capabilities. In other instances the improvement may be hidden from the eye but it is there just the same.

"For example, inside the new 'volume control' telephones – especially useful to many people with impaired hearing – we now employ transistors. They amplify the sound better and eliminate the need for batteries. Inside many new telephone cables are plastic-insulated wires. These are relatively immune to moisture and thereby promise greater dependability and more economical maintenance.

"Every few miles along the routes of some of our most heavily traveled coaxial cables are new types of equipment which triple their capacity. With this equipment a pair of coaxial tubes can carry 1,800 conversations simultaneously, or 600 conversations

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TO MORE THAN 1,300,000 SHARE OWNERS

and two television programs. These are typical of the many new developments in service last year. Others are in different stages of progress at the Laboratories."

Concerning the vital defense projects on which the Laboratories and Western Electric are at work Mr Craig said: "Bell Laboratories scientists are now designing weapon systems for use on land, at sea and in the air. They have been asked to make basic studies on the handling of combat information in naval operations, and on new techniques for communications in land combat.

"On another very important defense project Western and the Laboratories are working in cooperation with the Lincoln Laboratory of Massachusetts Institute of Technology and several other organizations. The goal is to integrate the country's radars and defense weapons into a nationwide semiautomatic system. This vast undertaking will require numerous centers where radar information will be electronically computed to guide defensive weapons. To provide the interconnecting network thousands of communication channels will be needed."

The System added 1,967,000 telephones during the year, bringing the total in service to 43,322,000. The Bell companies placed new local cables containing 13 million miles of wire—the largest amount ever added in one year. All told they spent $[illegible].4 billion for new facilities.

"To carry this program forward in 1955 and provide the full service the nation needs and wants," Mr. Craig said, "large additional amounts of capital will be required."

Long distance conversations for the year increased 5 per cent, and at year end the volume had gone up to 10 per cent over the end of 1953. The average time for completing out-of-town calls dropped to 1.4 minutes, and 97 out of 100 calls were put through while the calling party stayed on the line. Operators dialed more than half the long distance calls they handled straight through to the distant telephone; the number of towns and cities connected to this long distance dial network in Bell and non-Bell companies grew from 2,450 to 3,350 during the year.

Telephone users themselves were dialing about a quarter of the shorter calls beyond their immediate local area. People in 25 places were dialing direct many of their distant calls as well. In 22 of these places they were doing so in 1954 for the first time. These developments reflect steady progress toward the goal of direct distance dialing by customers all over the nation, Mr. Craig explained.

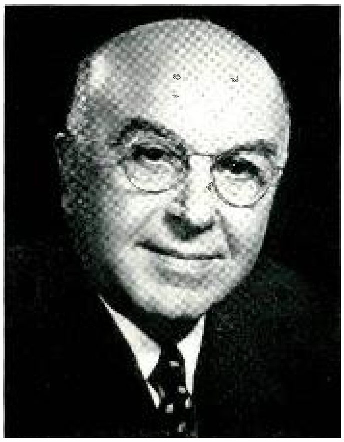
Among the photographs in the 1954 Annual Report was this picture of a "mock-up" Bell Solar Battery as it would be used to furnish power to a rural telephone line. Shown in the picture are F. W. Bingert, left, of the New Jersey Bell Telephone Company and A. C. Kane of Bell Telephone Laboratories.

Overseas telephone messages reached a new high of 1,064,000, and work went ahead on undersea voice cables to Great Britain and Alaska which are expected to be in operation before the end of 1956.

The Bell System television network was extended to almost 100 additional stations since the beginning of the year, so that it now reaches 357 stations in 233 communities. The System has equipped its network routes to carry color programs to 232 stations in 129 cities.

"In 1955 we look forward to rendering ever better, more complete and more valuable service to community and nation," Mr. Craig concluded.

A. T. & T. Announces Organization Changes



B. T. MILLER

S. B. COUSINS

A. F. JACOBSON

The A. T. & T. Company recently appointed Bartlett T. Miller Vice President in charge of Merchandising, a newly-created post in the company's organization. At the same time, Sanford B. Cousins was elected Vice President in charge of Public Relations, the office Mr. Miller has held since 1950. A. F. Jacobson was elected to replace Mr. Cousins as President of the Northwestern Bell Telephone Company by its Board of Directors.

Establishment of a separate Merchandising Department at A. T. & T. comes at a time when the Bell System's nine-year expansion program is catching up with the backlog of demands for service. In announcing the formation of the new department, Cleo F. Craig, President of A. T. & T., said, "We have an ever-improving service to sell. Our Merchandising Department's job will be to advise and assist the Bell Companies in marketing all Bell System services so that customers' desires and needs are anticipated and fully satisfied."

The new department's duties, he said, will include determining market potentials for existing and new services, coordinating the merchandising plans of the Operating Companies with other programs of engineering, construction, production and sales, and the conduct of market research and studies of marketing methods and techniques.

Mr. Miller, the new merchandising head, has been with A. T. & T. since 1946, since 1948 as a Vice President. Most of his career was spent in New England, where he rose through the ranks to become Vice President and General Manager of New England Telephone and Telegraph Company before coming to A. T. & T.

Mr. Cousins comes to A. T. & T. from Omaha, where he has been President of the Northwestern Bell Telephone Company since 1952. He began his telephone career with the New York Telephone Company in 1920, and during the past 35 years has held many important posts in the Bell System, including Vice President and General Manager of the New England Telephone Company and Vice President and General Manager of the Laboratories from 1950 to 1952.

Mr. Jacobson, new President of the Northwestern Bell Telephone Company, was formerly Assistant Vice President of A. T. & T. in the O. & E. Department. He started his long career with Northwestern Bell in 1922, rising through the ranks to become Vice President before joining A. T. & T. in 1952.

Western Electric Ships First Submarine Cable Repeater

The first submarine cable repeater, prototype of the 104 repeaters which will be built into the new transatlantic cable, was shipped on schedule from Western's Hillside, N. J., shops late in January. Packed in a specially constructed and cushioned container, it was sent to the Simplex Wire and Cable Company in Newington, New Hampshire for armoring.

Simplex will wrap all repeaters with jute and high-tensile steel wires and give them an asphalt coating in preparation for their undersea service. They will then be shipped to England for splicing into the cable.

The initial repeater will be one of four units to be used in trial laying operations in the Mediterranean to "prove in" cable-laying machinery and procedures on the cable ship *Monarch,* and to eliminate any delays when the actual job is undertaken.

The transatlantic portion alone will exceed 2,000 nautical miles in length.

Each deep-sea repeater employs three vacuum tubes and is housed in a copper tube about seven feet long and one and a half inches in diameter. This is supported by steel rings to form the structure that is built into the cable and which will appear as a tapering bulge. Thus repeaters can pass through the cable ship's gear so that laying will be orderly and uninterrupted.

Dr. Kelly Appointed to Head USAF Scientific Advisory Board

Dr. Mervin J. Kelly, president of the Laboratories, at the request of General Nathan F. Twining, USAF Chief of Staff, accepted on January 1 the chairmanship of the USAF Scientific Advisory Board.

Dr. Kelly, vice chairman of the Board since July 1 1950, succeeds Dr. Theodore Von Karman. Dr. Von Karman, who has been chairman since 1944, resigned his post with the Board in order to devote his full time to NATO's Advisory Group on Aeronautical Research and Development, of which he is chairman. Dr. Von Karman has, however, agreed to accept the honorary position of chairman emeritus of the Board, a post tendered him by the Air Force in recognition of his valuable contributions to the Board and to military aviation.

James H. Doolittle, special assistant to the Chief of Staff, USAF, and vice chairman of the Board with Dr. Kelly, will continue to serve in the same capacities.

Walter A. Shewhart Receives A.S.M.E. Holley Medal

Walter A. Shewhart, of the Mathematical Research Department at Murray Hill and a pioneer in the application of statistical methods to quality control, has been awarded the Holley Medal by the American Society of Mechanical Engineers.

Bestowed for "some great and unique act of genius of an engineering nature that has accomplished a great and timely public benefit," the medal was presented to Dr. Shewhart for his work in the application of statistical methods to quality control.

A former president of the American Statistical Association, Dr. Shewhart has acted, since 1929, as chairman of the ASME-ASTM Committee for Development of Statistical Applications in Engineering and Manufacturing. This committee was instrumental in standardizing statistical methods in this country.

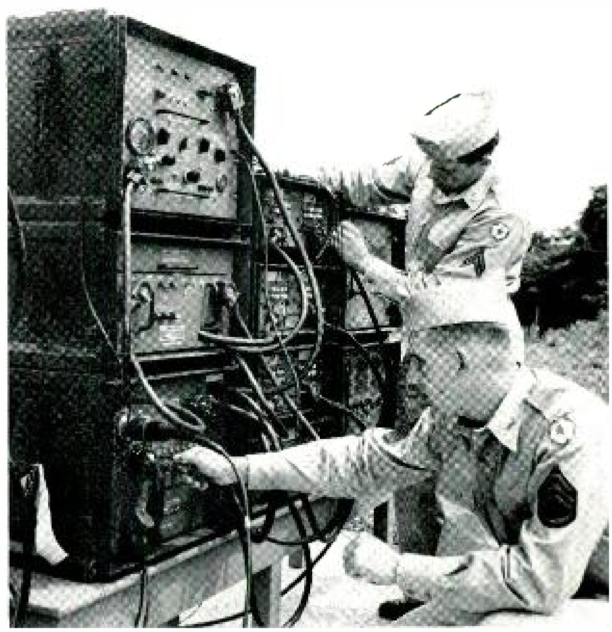
New Military Telephone System

A new portable military telephone system, which can handle three times as many conversations over a single cable as comparable Korea and World War II systems, has been developed for the U. S. Army Signal Corps by the Laboratories.

Basic equipment for the new telephone system is contained in units about the size of large suitcases, which can be handled by only one or two men. These units are designed so they can be stacked one on another. The "carrier" principle used for the new system allows twelve conversations to share the same cable by using a different frequency for each.

The system, providing for twelve simultaneous conversations, can be used for distances up to two hundred miles. Another, a four-channel system, can be used for four simultaneous conversations at distances up to a hundred miles. Several of these wire systems linked together can form a communication system of about a thousand miles. They may also be operated in conjunction with a military radio relay system developed at Bell Laboratories.

Recently developed miniaturized parts can be credited with the sharp reduction in size and weight of the new equipment. The earlier four-channel unit, for example, weighed 475 pounds and occu-



Army Signal Corps servicemen assemble the terminal units of a new portable twelve-channel telephone system designed for field service by Bell Telephone Laboratories.

pied twenty cubic feet of space. Complete with its power supply, the new four-channel terminal weighs 178 pounds and occupies only five and a half cubic feet of space. The cable used for the systems can be strung on poles, laid on the ground, or buried.

New type repeaters have also been designed, to be used at intervals in order to restore the level of the transmitted signals and extend the range of the systems.

Important new features facilitate testing and maintenance while all regular channels are in service. A portable test set provided with the twelve-channel system contains a transistor oscillator, one of the first applications of the Bell Laboratories-invented transistor in quantity-produced military equipment.

Field equipment designed by the Laboratories for the Army is tested for its ability to withstand desert heat and arctic cold. It is subjected to vibration, bounce and shock tests, exposed to 100 per cent humidity and to wind and rain.

The new military carrier systems have recently been placed in production by the Western Electric Company, manufacturing and supply unit of the Bell System.

Plans Filed for Microwave Link with Transatlantic Telephone Cable

Plans for completion of the U. S. microwave route that will connect with the proposed transatlantic telephone cable system were filed recently by the Long Lines Department of American Telephone and Telegraph Company with the Federal Communications Commission.

This segment will extend the Portland-to-Bangor, Me., microwave route to the Canadian border, where it will interconnect with similar facilities on the Canadian side. The entire route, some 600 miles long, will form an important link in the transatlantic project. The transatlantic cable itself will be laid between Nova Scotia and Scotland to provide direct circuits between New York and London, and will supplement radio telephone circuits now in use.

On the radio relay route between Portland and the Canadian border, four telephone channels are proposed. One in each direction would be for telephone service and one in each direction for protection purposes.

Telephone service via the transatlantic cable is scheduled for late 1956.

Talks by Members of the Laboratories

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

Alsberg, D. A., 6-kmc Sweep Oscillator, Conference on High Frequency Measurements, Washington, D. C.

Augustine, C. F., see Slocum, A.

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

Biggs, B. S., Correlation of Bell Laboratories Accelerated Ozone Aging Chamber with Field Experience on Rubber Samples, Military Conference on Ozone Testing, Washington, D. C.

Blecher, F. H., and Finch, T. R., Design Principles of Transistor Negative Feedback Amplifiers, I.R.E., Northern New Jersey Section, Montclair.

Brattain, W. H., Demonstrations of Some of the Uses of Germanium and Silicon as Transistors and Photocells, Physics Departments, Washington State College, Pullman, Washington and University of Oregon, Eugene, Ore.; and A.I.E.E.-I.R.E., Seattle, Wash., and Corvallis and Portland, Ore.

Buehler, E., Growing Crystals, New Jersey Mineralogical Society, Plainfield.

Christensen, H., Ultraviolet Light Induced Surface Channel and Carrier Lifetime Effects in Germanium, American Physical Society, New York City.

Felker, J. H., Performance of TRADIC Transistor Digital Computer, Joint Computer Conference, Philadelphia.

Ferrell, E. B., Control Charts Using Medians and Midranges, American Society for Quality Control, Rhode Island Section, Providence.

Finch, T. R., see Blecher, F. H.

Fletcher, R. C., Hyperfine Structure in the Spin Resonance of Donors in Silicon, Physics Department, New York University, New York City.

Gohn, G. R., Fatigue, Creep and Relaxation, Graduate Seminar, Pennsylvania State College, State College, Pa.

Hagelbarger, D. W., An Outguessing Machine, I.R.E., Princeton Section, Princeton, N. J.

Hoover, C. W., Jr., Secondary Electron Resonance Discharge Mechanism, I and II, American Physical Society, New York City.

Israel, J. O., see Mechling, E. B.

Jensen, A. G., Technical Aspects of Television, Armed Forces Institute of Pathology Symposium, Washington, D. C.

Mason, W. P., Ferroelectrics and the Dielectric Amplifier, Signal Corps Laboratories and New Jersey Ceramic Society, Symposium on Ferroelectricity, Squier Signal Laboratory, Fort Monmouth, N. J.

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

Mays, J. M., Shulman, R. G., and McCall, D. W., Nuclear Magnetic Resonance in Semiconductors: GaSb and InSb, American Physical Society, New York City.

Mays, J. M., see Shulman, R. G.

McCall, D. W., see Mays, J. M., and Shulman, R. G.

McSkimin, H. J., Ultrasonic Waves and Their Propagation, Winter Study Group, A.I.E.E., New York Section, New York City.

Mechling, E. B., Israel, J. O., Merrill, F. G., and Antonucci, P. (Rome Air Development Center), A Portable Frequency Standard for Navigation, Conference on High Frequency Measurements, Washington, D. C.

Merrill, F. G., see Mechling, E. B.

Merz, W. J., Static and Dynamic Properties of the Ferroelectric Domains in $BaTiO_3$ Single Crystals, Signal Corps Laboratories and New Jersey Ceramic Society, Symposium on Ferroelectricity, Squier Signal Laboratory, Fort Monmouth, N. J.

Mumford, W. W., and Schafersman, R. L., Data on the Temperature Dependence of X-Band Fluorescent Lamp Noise Sources, Conference on High Frequency Measurements, Washington, D. C.

Neisser, W. R., Miniaturization of Components, Madison Area Radio Group, Madison, N. J.

Orvis, W., see Rausch, J. M.

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

Pierce, J. R., Some Recent Advances in Microwave Tubes, I.R.E., Ottawa Section, and Noise in Microwave Tubes, Science Association of the National Research Council, Ottawa, Canada.

Rausch, J. M., and Orvis, W., Pressure Inside Mold During Molding of Phenolics, Society of Plastics Engineers, Atlantic City.

Read, W. T., Electrical Effects of Dislocations in Germanium, Yale Metallurgical Colloquium, New Haven, Conn. and Evans Signal Laboratory, Belmar, N. J.

Riesz, R. R., The Physics and Acoustics of Auscultation and Percussion, Cornell Medical College, New York City.

Rose, D. J., On the Magnification and Resolution of the Field Emission Electron Microscope, American Physical Society, New York City.

Schaefer, J. W., Some Characteristics of Guided Missiles, Rotary Club, Westfield, N. J.

Schafersman, R. L., see Mumford, W. W.

Schawlow, A. L., Structure of the Intermediate State in Superconductors, University of Delaware Physics Colloquium, Newark, Del.

Shannon, C. E., Communication Theory, University of Pennsylvania, Philadelphia.

Shockley, W., Transistor Physics, American Society for Metals, Lehigh Valley Chapter, Allentown, Pa.

Shulman, R. G., Mays, J. M., and McCall, D. W., Nuclear Magnetic Resonance in Semiconductors: Exchange Broadening and Line Shapes, American Physical Society, New York City.

Shulman, R. G., see Mays, J. M.

Slocum, A., and Augustine, C. F., 6-kmc Phase Measurement System for Traveling Wave Tubes, Conference on High Frequency Measurements, Washington, D. C.

Smith, K. D., Bell Solar Battery, A.I.E.E., Alabama Section, Birmingham.

Sparks, M., Transistor Chemistry, American Chemical Society, Long Island Sub-Section, Brooklyn.

Talley, H. E., Positron Annihilation, American Physical Society, Lehigh Valley Section, Muhlenberg College, Allentown, Pa.

Tendick, F. H., Jr., Transistor Building Block Networks for Digital Computers, I.R.E., New York Section Winter Symposium, New York City.

Wannier, G. H., Why Are Solids?, Illinois Institute of Technology, Sigma Xi Meeting, and A.I.E.E., Basic Science Group, Chicago.

Winslow, F. H., Baker, W. O., Pape, N. R., and Matreyek, W., Formation and Properties of Polymer Carbon, American Chemical Society, North Jersey Section, Newark.

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, R. E. D., A Magnetically Regulated Portable Battery Charger, A.I.E.E. Commun. and Electronics, **16**, pp. 607-610, Jan., 1955.

Bown, R., The Transistor as an Industrial Research Episode, Sci. Monthly, **80**, pp. 40-46, Jan., 1955.

Breidt, P., Jr., see Greiner, E. S.

Fine, M. E., Apparatus for Measuring the Elastic Moduli and Internal Friction of Solids from 1.7 to above 77°K and Some Values for α-Quartz, Rev. Sci. Instr., **25**, pp. 1188-1190, Dec., 1954.

Fine, M. E., and Kenney, N. T., Low-Temperature Acoustic Relaxation in Ni-Fe Ferrites, Phys. Rev., **96**, pp. 1487-1488, Dec. 15, 1954.

Froehlich, F. E., and Sitte, Kurt, Mean Free Path for Shower Production by High-Energy Pi Mesons, Phys. Rev., **97**, pp. 151-159, Jan. 1, 1955.

Froehlich, Fritz E., see Sitte, Kurt

Fryburg, G. C., see Trumbore, T.

Greiner, E. S., and Breidt, P., Jr., Melting Joint of Germanium and the Constitution of Some Ge-Ga Alloys, J. Metals, **7**, pp. 187-188, Jan., 1955.

Greiner, E. S., The Plastic Deformation of Germanium and Silicon by Torsion, J. Metals, **7**, pp. 203-205, Jan., 1955.

Goss, A. J., see Logan, R. A.

Hamilton, B. H., Some Applications of Semiconductor Devices in the Feedback Loop of Regulated Metallic Rectifiers, A.I.E.E. Commun. and Electronics, **16**, pp. 640-645, Jan., 1955.

Hamilton, B. H., Semiconductor Devices in Regulated Rectifiers, Elec. Eng., **74**, p. 149, Feb., 1955.

Hartley, R. V. L., A New System of Logarithmic Units, Elec. Eng., **74**, pp. 135-137, Feb., 1955.

Paper Published by Members of the Laboratories, Continued

Herring, C., Theory of the Thermoelectric Power of Semiconductors, Phys. Rev., **96**, pp. 1163-1187, Dec. 1, 1954.

Karp, A., Traveling-Wave Tube Experiments at Millimeter Wavelengths with a New, Easily Built, Space-Harmonic Circuit, Proc. I.R.E., **43**, pp. 41-46, Jan., 1955.

Kelly, M. J., Role of Industrial Research and Development in Society, Ind. Labs., **5**, pp. 6-10, Dec., 1954.

Kenney, N. T., see Fine, M. E.

Law, J. T., The Adsorption of Water Vapor on Ge and GeO_2, J. Phys. Chem., **59**, p. 76, Jan., 1955.

Logan, R. A., Goss, A. J., and Schwartz, M., Semiconductor Devices made with Single Crystal Germanium Silicon Alloys, Letter to the Editor, J. Appl. Phys., **25**, pp. 1551-1552, Dec., 1954.

Matthias, B. T., Empirical Relation Between Superconductivity and the Number of Valence Electrons per Atom, Phys. Rev., **97**, pp. 74-76, Jan 1, 1955.

Merrill, J. L., Jr., Smethurst, J. O., and Rose, A. F., Repeater Amplifies in Either Line Direction, Electronics, **28**, pp. 165-167, Jan., 1955.

Nadelhaft, Irving, see Sitte, Kurt.

Raisbeck, G., Definition of Passive Linear Networks in Terms of Time and Energy, J. Appl. Phys., **25**, pp. 1510-1515, Dec., 1954.

Scales, Miss E. M., and Chapanis, A., Effect on Performance of Tilting the Toll-Operator's Keyset, J. Appl. Phys., **38**, pp. 452-456, Dec., 1954.

Schwartz, M., see Logan, R. A.

Sitte, Kurt, Froehlich, F. E., and Nadelhaft, Irving, Electron Production in High-Energy Nuclear Interactions, Phys. Rev., **97**, pp. 166-172, Jan. 1, 1955.

Sitte, Kurt, see Froehlich, F. E.

Trumbore, F., and Fryburg, G. C., Discussion of The Electrolytic Preparation of Molybdenum from Fused Salts. III – Studies of Electrode Potentials by Senderoff, S., and Brenner, A., J. Electrochemical Soc., **101**, p. 633, Dec., 1954.

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

Bachelet, A. E., and Soffel, R. O. – *Voice Operated Switching System* – 2,696,529.

Baker, W. O., Grisdale, R. O., and Winslow, F. H. – *Methods of Producing Carbonized Substances Containing Silicon* – 2,697,029.

Baker, W. O., and Grisdale, R. O. – *Methods of Producing Dehydrogenated Hydrocarbon Bodies* – 2,697,028.

Baker, W. O., and Grisdale, R. O., – *Microphones and Microphone Granules* – 2,697,136.

Blair, R. R. – *Detector of Reverse Recovery Effect In Asymmetrically Conductive Devices* – 2,698,419.

Cornell, W. A., Hall, N. I., and Powell, H. E. – *Electronic Testing System* – 2,697,140.

Dacey, G. C., and Foy, P. W. – *Fabricating of Semiconductor Translating Devices* – 2,697,052.

Ellwood, W. B. – *Electric Switch* – 2,696,543.

Foy, P. W., see Dacey, G. C.

Fuller, C. S. – *Method of Making Semiconductor Translating Devices* – 2,697,269.

Gooderham, J. W. – *Automatic Ticketing Telephone System* – 2,697,748.

Grisdale, R. O., see Baker, W. O.

Hall, N. I., see Cornell, W. A.

Holbrook, B. D., Malthaner, W. A., and Vaughan, H. E. – *Check Circuits* – 2,696,599.

Houghton, E. W. – *Reflectionless Wave Guide Termination* – 2,697,208.

Jeanne, A. L., Keller, A. C., and White, S. D. – *Multifrequency Telephone Switching System* – 2,697,749.

Keller, A. C., see Jeanne, A. L.

Kersta, L. G. – *Elastic Conductor* – 2,697,157.

Madden, J. J. – *Tool for Making Electrical Connections* – 2,696,656.

Malthaner, W. A., see Holbrook, B. D.

Meszaros, G. W. – *Current Supply Apparatus* – 2,698,414.

Mills, J. K. – *Howler Tone Circuit Involving a Motor-Driven Interrupter* – 2,697,792.

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