Bell Laboratories
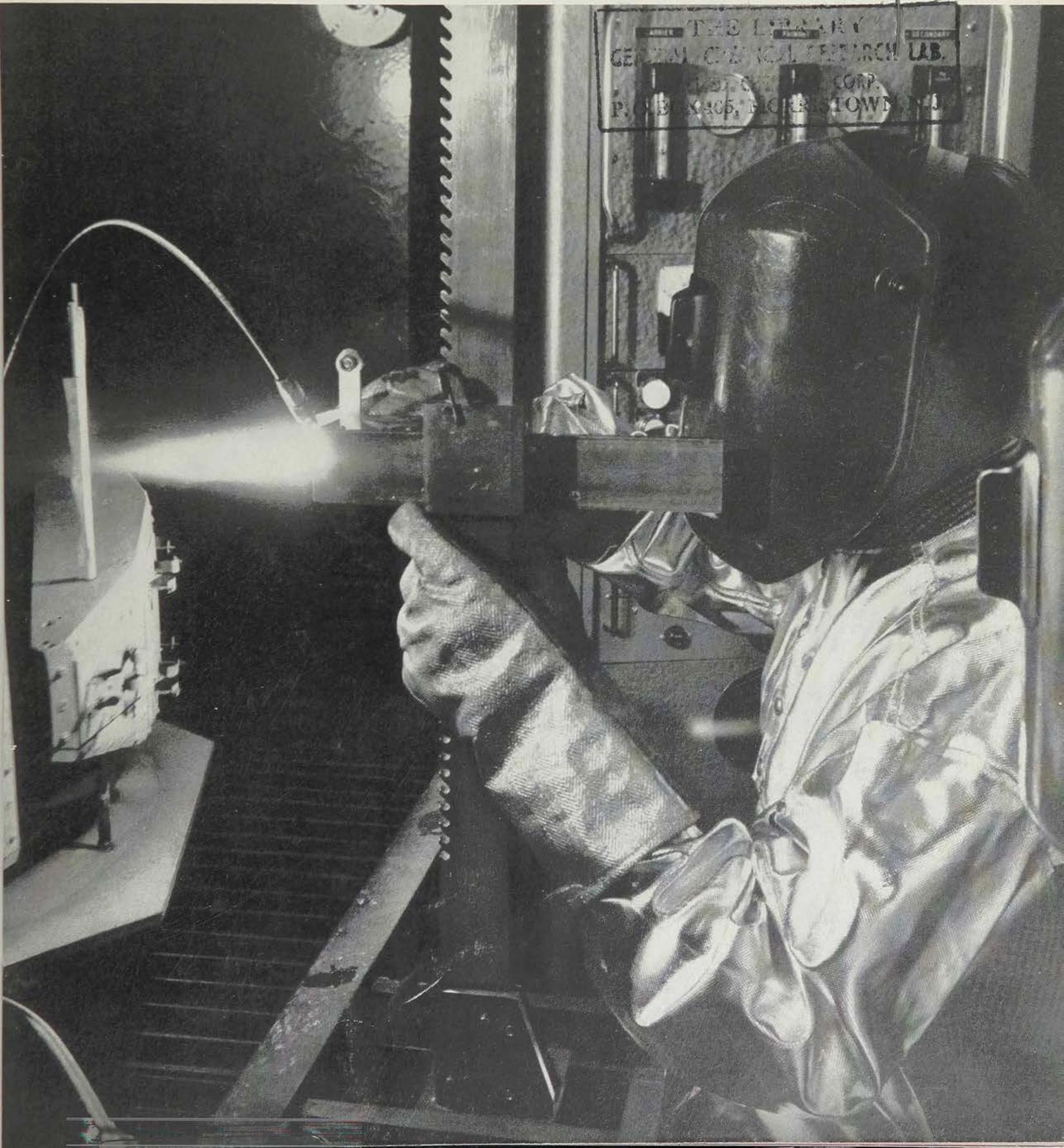
RECORD

January 1962

The Coil-Spring Connector

Accelerated Aging of Semiconductors

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Cover   *Segments of an active satellite's shell are sprayed with a purified, partially molten aluminum oxide, to give them a coating both strong and highly emmisive. The plasma jet operates at temperatures up to 30,000 degrees F (see page 23).*
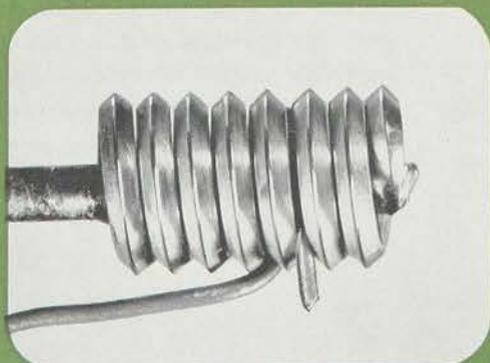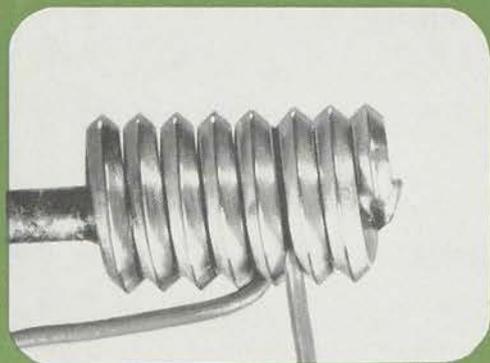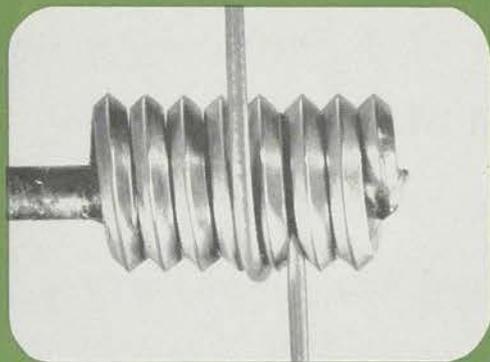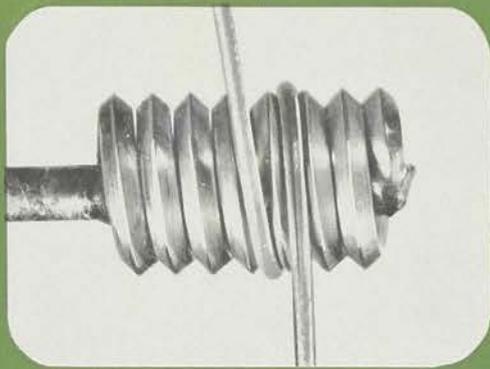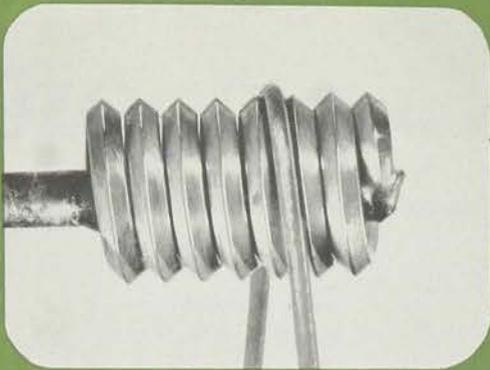
THE COI

The widespread use of cable with plastic insulated conductors in large portions of the outside plant has freed telephone engineers from a number of annoying limitations in construction practices. Most of these limitations had risen from the need to hermetically seal the cable sheath of pulp or paper insulated cable. With polyethylene insulated conductor (PIC) cable, the sheath does not have to be hermetically sealed, and many new developments have occurred in the area of ready access closures and terminals.

However, with benefits often come limitations, and one such in PIC cable was the relative difficulty of removing the insulation for conventional termination or splicing operations. A new connector—the coil-spring connector—has now been developed which overcomes this limitation, and makes more attractive the application of simpler ready-access methods in the telephone plant.

As the name implies, the new connector is in the shape of a simple coil spring. The wire from which the spring is wound, however, is square instead of the usual round cross-section. When a craftsman makes a connection using the new connector, he simply loops the wire in the groove formed by adjacent coils of the spring, and pulls one end firmly. The conductor snaps in between the turns of the coil, the corners of the square wire penetrate the insulation, and contact is

◀ *Sequence of photos shows, top to bottom, wire being looped around coil-spring connector and pulled into place within the coil. Orientation of the wire determines pressure at contact points.*

K. C. Maclean and B. C. Ellis

A new ready-access connector, shaped like a simple coil spring, has been developed to replace the familiar screw-type binding post. It promises to save both time and money in installing plastic insulated conductors.

PRING CONNECTOR

made. The spring makes contact at four points, as shown in the drawing on page 5. The angled configuration of the helix turns provides several advantages. First, the coils can be manufactured with adjacent turns tilted at a selected angle, to provide the desired pressure at the contact points. Second, the groove between coils automatically guides the conductor into place, and the coils themselves provide separation for the individual conductors. Each conductor is mechanically independent of any connected earlier or later. The mounting post keeps the conductors properly positioned within the connector.

Since the initial use of this connector will be as a replacement for screw-type binding posts in indoor terminations, it is worthwhile looking briefly at the procedures used in making connections with that device. The standard technique there is to skin the plastic insulated conductor, loop it around the binding post, and clamp it between washers with a nut. Several conductors can be added in the same way. The binding post has served well in the telephone plant; it provides a high initial contact pressure which remains high in continuous service, and it is gas-tight when properly done.

There are several points where it can be found wanting, however. A binding post connection can be electrically noisy when the nut is only partially tight. Making connections with binding posts is a fairly slow process. Also, when changes are required, wires must be removed in the same sequence as they were installed—disconnecting all of the wires above the one to which access is desired. The coil-spring connector solves all these problems, and also offers other advantages.

The development of the new connector began at the Baltimore Laboratories location, in the apparatus group, about two years ago. The original aim of the program was to provide a connector which would form a stable, rapid, electrical connection with all thermoplastic-insulated wire used in building terminals. This included both polyvinyl chloride and polyethylene insulated conductors, in all gauges from 19 to 26. The job had to be done with a minimum of available data, although information gathered during the development of wire-wrapped terminals was of considerable help. The coil spring connector has been compared to the threaded binding post during every step of the development evaluation program, as was the wire-wrapped terminal.

The most attractive feature inherent in the coil spring structure, in its use as a connecting device, is the large elastic reserve in the extended coils of the spring, which compensates for the cold flow of the copper conductor with time. The coil spring connector has more than twenty times the elastic reserve of standard screw-type binding post in a given clamped connection.
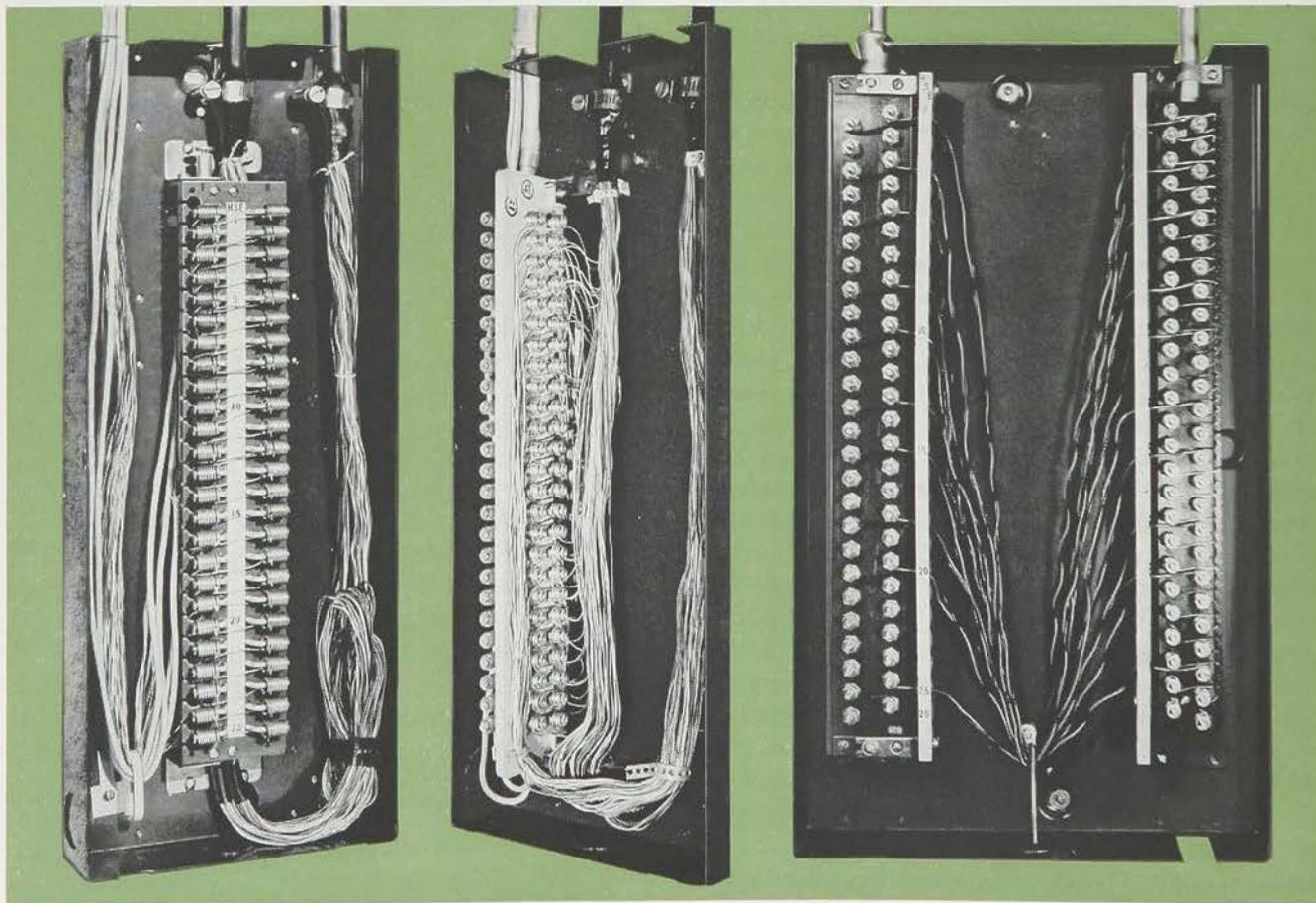
The first coil design was based on a phosphor bronze wire, 53 mils square. The connectors made from this wire were wound to give a coil 0.218 inch in mean diameter. The wire was tilted at an angle of 24 degrees to the long axis of the coil. At this stage of the development, it was

assumed that the kinetic energy used in separating the adjacent turns to insert the wire would be available as potential energy to be exerted on the contacts. Also, it was assumed initially that the connector spring could be designed by following ordinary spring formulas.

Tests conducted on the first models showed quickly that these assumptions were not entirely valid. When inserted between turns of the connector, wires of different gauges (which also have different thicknesses of insulation) did not yield the expected relationship between the spring energy and the indentation of the copper wire. In addition, permanent spring deformation occurred at a much lower separation of the coils than was anticipated. Since the stress was greater when a wire separated adjacent turns than when adjacent turns were separated an equal distance by an axial load on the spring, the initial design assumption was re-examined. Analysis showed that under an axial load the deflection was uniform over the entire 360 degrees of each turn, while a wire inserted between turns caused all the deflection to occur in about 180 degrees.

Based on these considerations, the design was changed to a larger wire (60 mils square) with sharp corners, tilted at an angle of 37 degrees to the long axis of the connector.

During development, the stability and fidelity of the new connector for satisfactorily long life had to be investigated. Its job is exacting, and its failure rate should be competitive with soldered connections, where less than one failure in 15,000 connections is the present quality level. Extensive testing to establish the electrical characteristics of the connector required automatic testing equipment with self-recording features. The system developed used a Kelvin resistance bridge in conjunction with an electronic null, or zero, detector. The dial readings were automatically converted to numbers, and recorded directly on punched cards. The equipment detects a resistance change of 0.000002 ohm, and measurements are reproducible to the same degree.

The coil-spring connectors were mounted in test fixtures for environmental tests. Initial tests were conducted on samples exposed in humidity chambers and outdoors, and on control samples kept indoors. Other samples were exposed to thermal shock, with temperature cycles from −40 degrees to 140 degrees F three times a day.

These tests did not give the requisite amount of data quickly enough, and a more rugged environment was designed to shorten the test procedure.

The 70A connecting block closed (left), swung open (center), and older binding-post connecting blocks.

The technique finally adopted used a special bag made from "CR Tape," a two-ply rubber material. This bag was loaded with the test fixtures, sealed, charged with 35 per cent hydrogen sulfide gas, placed in the thermal shock chamber, and subjected to three daily temperature cycles from −40 degrees to 140 degrees F. This accelerated test provided a direct comparison of the gas-tightness of the new connector with the standard binding post connector. The severity of this procedure was demonstrated by the fact that after fourteen to sixteen days of exposure, 24 and 26 gauge bare copper wire completely disintegrated at the point where it was skinned for termination to the test bridge, while the coil spring connections were still electrically and mechanically sound.

This accelerated test program was used to determine the effectiveness of a number of design aspects, for example, the corrosion and contact stability of various tin coatings. From several approaches, the best over-all finish characteristics resulted from electroplated tin over a copper flash before the wire is coiled. After coiling, the connector is heated briefly to the melting point of the tin. This treatment forms a smooth shiny surface, similar to a tinplate.

Very early in the development program, it was apparent that the use of present screw-type binding posts for multipling wires at building terminals creates wire concentrations which make identification of individual conductors very difficult. It was, therefore, quite important to develop a new mounting arrangement for the coil-spring connector which would give the craftsman not only the best view of his working area, but also an orientation with which it would be easiest for him to identify wires and work conveniently.

First Practical Application

The first application of the new connector is the 25-pair connecting block, designated 70A, shown on page 4 with its binding post predecessor. Each coil-spring connector on the front of this panel permits multipling of six conductors, while two conductors can be multipled on the back. Common mounting posts link the front and rear connections. Hinged mounting brackets provide rapid accessibility to the rear of the panel.

Arranging the connectors in this way completely separates house and station connections, and eliminates the main problem associated with heavy wire concentrations, since each side can be serviced independently of the other. The craftsman also has a good view of the connector when he terminates conductors on either the front or back springs.
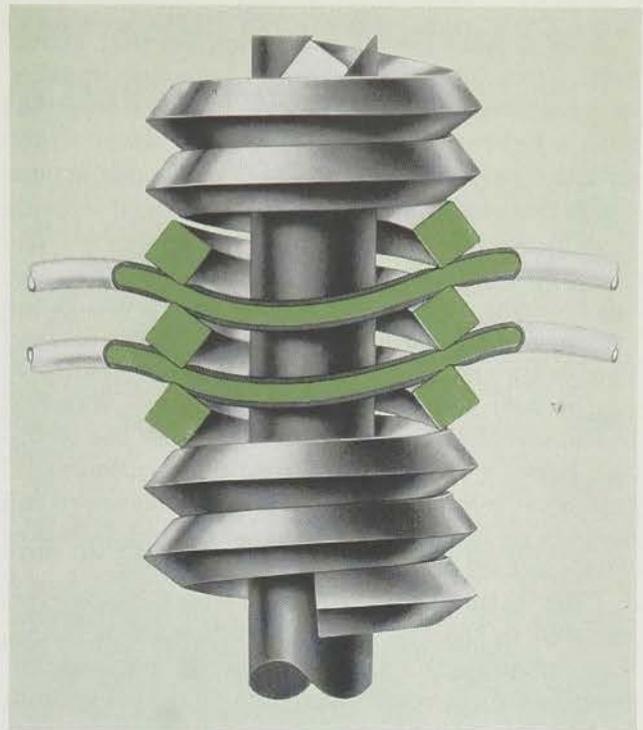
Cross-section of the coil-spring connector showing the square wire and the four electrical contact points which are made on each conductor wire.

The wiring method used for making terminations to the 70A Connecting Block is shown on page 6. The craftsman selects a connection point and holds the wire about three inches on either side of this point with his fingers. After forming a loop and moving it behind the connector, he seats the loop in the proper groove. Since the connector is wound with a right hand pitch, the wire on the right is held by the right hand. The wire in the left hand can then be moved up, completely encircling the coil and snubbing the wire. A steady pull with the right hand forces the adjacent coils apart so that the conductor is pulled inside the coil and against the mounting post. Crushing forces on the insulation mount progressively higher as the conductor slides between the coils. As it comes to rest inside the coil spring, these forces have ruptured the insulation and established contact between the conductor and the spring wire.

Disconnecting wires is as simple as connecting them: First, the end of the conductor is pushed upward about 90 degrees to relieve some of the connector's holding action on the conductor. Then the conductor is removed by pulling on the portion at the bottom of the spring. The wire insertion forces range from 2 pounds for the smallest to about 8 pounds for the largest wire, when the loop insertion method is used. The wire removal forces are about the same, and seldom exceed

half the breaking strength of the wire.

In a typical installation, such as that shown below, two 70A Connecting Blocks are installed as a building distribution terminal in a wall box, with a 100-pair even-count PIC cable placed at the rear through the center. The 25-pair cable groups are permanently identified by color-coded B Cable Ties placed above the cable group separator. The connecting blocks maintain the conventional tip-left and ring-right orientation when viewed in the closed position. Both sides of the panel are marked to give tip and ring identification. The conductors of the rear cable go on to feed other terminal boxes, and thus are continuous through the terminal. Because the wires are continuous, the craftsman must select the point of connection to the coil springs on the rear of the panel so that he leaves wire slack on both sides of the connector.

Fifty pairs of this 100-pair house cable are terminated to the rear springs of these two blocks. The remaining 50 pairs are readily available for possible future rearrangements of the cable count in this box. All the wires are "dressed" so they will be contained behind this pair of blocks. The unused cable groups are tied down on the back of the box to prevent damage to the conductors. The terminated groups are tied in individual bundles with B Cable Ties where they leave the blocks. The slack is stored at the bottom of the box and tied into a neat bundle in such a manner that no tension is placed in any of the conductors.

The 70A Connecting Block provides an impor-
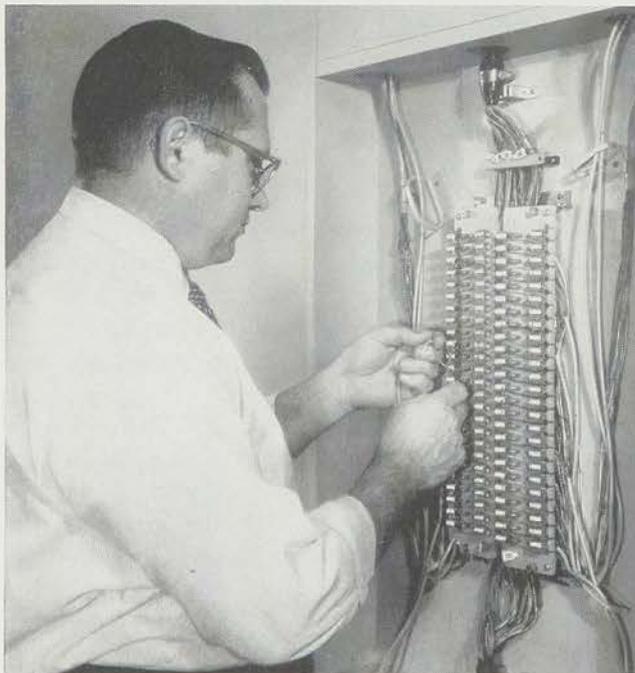
J. Kreutzberg checks contact resistance of coil connectors which were aged in hydrogen sulfide.

tant feature which permits convenient means of extending the cable plant in the future to new terminal locations. The spring connectors located on the rear of the panel can accommodate two conductors for joining two cables. The ends of the first house cable are terminated in the spring groove nearest the panel. The second house cable can be joined to the first cable by terminating the conductors in the second groove of the coil spring. Also, a new house cable can be bridged to an existing looped-through cable in this same way. Thus the splice presently required to join the ends of two cables becomes a simple termination with the coil-spring connector.

The new coil-spring connector in this connecting block provides the following advantages:

■ A simple and rapid method for making connections to plastic insulated conductors, which does not require the removal of insulation.

■ As many as eight connections at any position on the block, six on front spring and two on back.

■ Individual connection or disconnection in any groove without interference with other wires or service interruptions.

■ Elimination of the need for a splice between terminal and cable, because the cable conductors themselves are terminated or looped directly to the connectors.

■ Improved integrity of connection, since initial contact pressure remains high in continuous service.

■ All station wiring done on the front of the block while the house pairs are on the rear.

■ Natural and complete separation between the two kinds of plant for neat and orderly wiring arrangements.

■ No special tools required.

As might be expected with a device as revolu-

R. G. Baumgartner wiring pair of 70A connecting blocks installed in building distribution terminal.

tionary as this, the answers to the various development problems came only after a concerted joint effort by many members of the Laboratories and the Baltimore Works of Western Electric.

As with all new designs, certain practical compromises had to be made. In the coil-spring connector, one compromise lay in the connectors ability to terminate conductors with very thick, tough polyvinyl chloride insulation, such as B Cross Connect Wire and GS Station Wire. On these conductors, the insulation must be "rough skinned" (crushed, so the insulation is easily penetrated) before terminating them on the coil-spring connector. New insulation for these wires is now being developed, so they can be used with the new connector without any type of skinning.

Field trials of the coil-spring connector in the 70A connecting block have been completed in Baltimore, New York City, Los Angeles, and Boston. All the areas received the design with enthusiasm. Initial production began in July, 1961. The scheduled production rate for 1962 is 250,000 units of the 70A blocks. The annual savings to the Bell System, based on this quantity of 25-pair units, are estimated to be in the order of $2,000,000. Development work is continuing, to extend the application of the coil-spring connector to other areas of terminal design.

B. C. Ellis, Bell Laboratories, and A. Siegman, Western Electric, inspect connectors after aging.

Nike-Zeus Scores Successes In Development Tests

A number of developmental tests of the United States Army's NIKE-ZEUS anti-missile missile were successfully completed in the last two months of 1961. The tests were intended as trials of various aspects of the missile and the guidance and tracking systems. Bell Laboratories is responsible for the design and development of the ZEUS system under a Western Electric prime contract.

In one test at White Sands Missile Range, New Mexico, all three stages of the missile were fired for the first time. Other tests performed at White Sands and at Point Mugu, California, demonstrated progress in precision in-flight control of the 45,000-pound-thrust missile.

The Army also began firings of target rockets from the NIKE-ZEUS system test installation on Kwajalein Atoll. In a system test at Ascension Island, the ZEUS target track radar tracked an Atlas ICBM fired from Cape Canaveral.

The purpose of the White Sands test of all three solid-fuel rocket motors was to ignite the relatively small third-stage reaction motor used to maneuver the "business end" of the missile at very high altitudes. The first two stages of the ZEUS have been tested successfully in previous firings.

In the second test at White Sands, the missile, using Bell Laboratories command guidance system, correctly executed maneuver commands while traveling at high velocity within the atmosphere. In the shots from Pt. Mugu, all of which were "100 per cent successful," the first and second stage rocket motors fired as planned in a test to gather further data on the missile's performance at high altitudes over extended ranges.

Earlier, the Army had announced the successful firing of a two-stage unguided target rocket from the island of Roi-Namur, north of Kwajalein. This test was in preparation for beginning target tracking tests at the island locations. Next year the Army will use the Kwajalein site to test the NIKE-ZEUS system on target nose cones that will be sent down the Pacific Missile Range by intercontinental ballistic missiles fired from Vandenberg Air Force Base, California.

The Ascension Island track was one of a series of ICBM behavior studies being carried out as part of the ZEUS development program. All the NIKE-ZEUS radars were designed and developed at the Whippany location of Bell Laboratories.

*One might say that the optimist predicts
future success and the reliability
engineer predicts future failure. However,
only by being able to predetermine the facts
of failure can we achieve future success.*

B. T. Howard and G. A. Dodson

Accelerated Aging of Semiconductors

A favorite subject for authors of science-fiction stories is the time machine which speeds up time so that one can take a look at the future. However, this kind of machine is not yet available. Thus, when an engineer wishes to determine whether certain semiconductor devices will function reliably 40 years from now, he must look for help elsewhere. One of the ways to determine future reliability is by using accelerated aging techniques. However, before we deal with these in more detail let's consider for a moment the general aspects of the problem of reliability.

When a semiconductor engineer considers the reliability of his devices, he is most interested in the distribution of device failures that occur in a certain time under certain operating conditions. This failure distribution pattern can be quite complicated. The pattern is often considered to consist of three parts, as shown on the diagram on the opposite page.

The first part, the early failure region, usually indicates the failure of semiconductor devices which were not manufactured properly. Such failures, for example, might be caused by a malfunction of some piece of equipment or by faulty handling in the assembly line. Since there are many assembly-line workers and machines involved in the manufacture of semiconductor devices, a failure in this region may have many possible causes. Consequently, it is often difficult to detect the source of failure. The solution to the problem of such failures has two aspects: (1) improvement in the quality control of the product, and (2) the use of pre-aging techniques to determine which units are weak and to screen them out before they leave the factory.

Let us consider next the third, or wearout, region of the pattern. Here, devices which have been properly manufactured are failing because of some mechanism inherent in their design. Because most wearout failures are caused by a small number of mechanisms, they are somewhat easier to study.

The region intermediate between these two has

been called the low failure-rate region and is also considered as a region of constant-failure rate. In most cases, this represents the useful life of the product. The region is probably made up of failures from a number of different causes which might perhaps be equally well assigned to the other two regions. However since these, in some sense, are failures below the "noise level," it is generally easier to consider them in a separate region.

Methods of Determining Failure

There are three ways of gathering information about the failure pattern itself. These are (1) field trials, (2) life tests, and (3) accelerated-aging tests. Each method yields significant information and each has its limitations.

In field trials the actual reliability of the device under operating conditions is determined directly by testing a model of the system in which the device is used. In general however, it is not feasible to obtain information about failure which occurs over a long period of time. In particular, field trials give little information about wearout mechanisms. Further, because such tests are made in the field, they cannot be made until the system is built. This means that they can give no early warning of failure, and are primarily useful as a verification of success.

In the case of life tests, aging racks in a laboratory are used to simulate the operating conditions of the device. These tests can be made early in development but the information which is obtained is only as good as the accuracy and completeness of the simulation. Also, life tests, just like field trials, require large numbers of devices to be tested for long times before information can be obtained about the long-time end of the failure pattern.

In accelerated aging tests, we depart even further from the operating conditions of the device and deliberately raise the stresses which are believed to be important so that the device fails in a short time. Naturally, for this to be successful we must pick all of the important stresses, and we must also know the relationship between these artificial conditions and operating conditions so that we can make meaningful predictions. However, if these things are done, it is possible to run a testing program that parallels the rest of a device development program. Another advantage is that smaller numbers may be used since we expect most, if not all, of the devices to fail in these accelerated tests. These factors allow the device engineer to design reliability into his device rather than to achieve it as an afterthought.

There are two main disadvantages of accelerated aging tests. First, the conditions are far removed from those of operation; this means that the results must be applied with care. Second, even though these tests give more information about the long-time failures and raise failure rates to easily measurable levels, the information about all the three regions of the failure pattern is obtained at once and hence must be carefully separated if the results are to be properly applied. Despite these drawbacks, accelerated-aging tests are becoming increasingly important—not to replace the first two testing methods discussed— but to complement them. All three methods of testing have a place in reliability evaluation at some stage in the development of semiconductor devices.

Now let's consider what is meant by an accelerated-aging program. What we actually wish to obtain is a reliability acceleration curve of the kind shown in (a) on page 10. Here, the distribution of failures we wish to measure is represented by plot I—the number of devices failing at any given time. This statistical distribution has a central value, say the median, which corresponds to the stress on the device. By stress we mean any condition which tends to cause a device to fail, such as temperature, power, vibration, or humidity.

In developing this acceleration curve, we hypothesize that the increased stress accelerates the failure mechanisms and causes a device to fail in a shorter time than it would in actual use. With this in mind, we expect to obtain distributions, such as shown in plot II, at higher stress. Thus, by conducting a number of short-time tests at successively higher stress levels, and determining the central value for device life in each case, we obtain the acceleration curve relating this central value to the applied stress. We use this relationship to predict the central value of the failure distribution under the operating level of this stress.
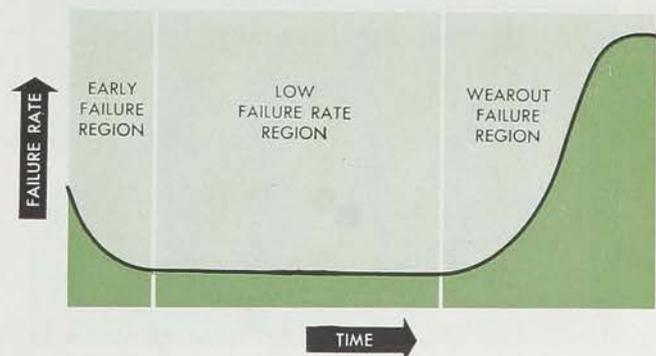
Generalized failure-rate pattern showing failures caused by improper manufacture, random failures, and later failures caused by inherent weakness.

Another method of obtaining this acceleration curve is represented by plot III. Here, we fix the time interval of the test and obtain the distribution of device failure in stress. In this case, we fix the life of the device and determine the amount of stress necessary to make the device fail during this time. In this instance, we obtain the central value of stress, rather than time, and assign it to the specified time interval or life; then, by repeating the experiment for different time intervals, we obtain the acceleration curve. From the details of the stress distributions and the form of the acceleration curve, we can again predict the form of the failure distribution in time under operating stress levels.

This technique, called step-stress aging, is particularly suited for short times. And, because we can and do increase the stress as an experiment proceeds, it is possible to ensure that in a single experiment all devices fail with respect to all parameters and all failure criteria. Thus, we derive a maximum of information from a minimum number of devices. This makes the technique particularly suitable for use in early stages of device development where we wish to compare small batches of devices manufactured by different methods.

The way these step-stress aging experiments are carried out is shown in (b) on this page. Random samples are placed on the aging racks and left there for a specified time at some initial stress level. The devices are then removed and measured, and the number of failures is recorded. Next, the devices are again placed on the racks and measured. The next stress level is set, and the devices are removed after undergoing the stress test for the same time as before and measured again. This procedure is repeated, increasing the stress each time, until all the samples have failed. The failure vs stress distribution is then plotted and the significant parameters, (such as the central value of stress) are determined.

The type of distribution curve obtained by plotting electric power as a stress on a diode for two hours is shown by the black line in (c) on page 11. Note that half of the devices failed in two hours under a stress of 1.1 watts. The white line of the diagram shows the corresponding distribution of failure times obtained with a power stress of 1.1 watts. In this case, half the devices failed in almost exactly 120 minutes, illustrating excellent agreement between comparable information obtained by the two accelerated aging techniques.

Various types of acceleration curves for a num-

(a) Acceleration curves showing how either time or stress can be fixed to determine central values.
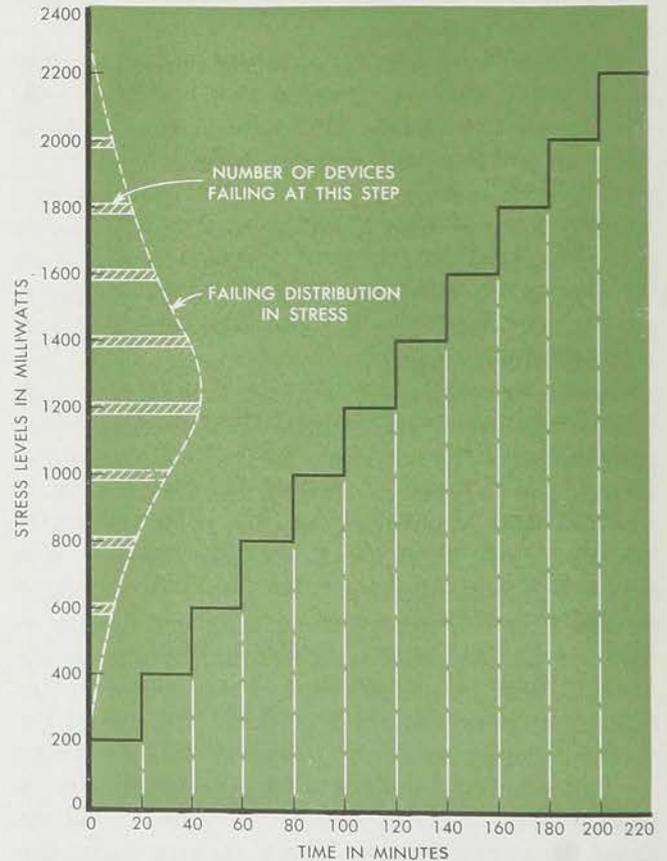
(b) Diagram shows failure distribution pattern developed by the method of step-stress aging.

ber of silicon and germanium devices, both diodes and transistors are shown in (d) on page 11. These results were obtained using ambient temperature as the stress. The devices were placed in an oven at an elevated temperature. To make it easier to extrapolate results, the scales of the plot were transformed so that the acceleration curves are linear. It was mentioned earlier that accelerated aging is useful in comparing different ways of making a given device design. The two acceleration curves for the germanium transistor are marked "old" and "new"; the only difference is in the method used to encapsulate the devices.

With this system of accelerated aging, we can determine in a matter of a few hours or a few weeks whether a device may continue to operate effectively for tens or even hundreds of years.

It was stated in the beginning of this article that the reliability of semiconductor devices is a complicated subject; that is indeed true. Therefore, to insure that a proper picture is obtained, we must do more than produce a single acceleration curve of the kind we have discussed. We must produce acceleration curves for many different kinds of stresses—all those conditions which the device will encounter in operation and all those which will accelerate any of the mechanisms which are important in causing failures. Then, all these data must be carefully studied and assembled like a jigsaw puzzle to complete the picture; and when this is done, we must check against field-trial results to make certain that our picture is correct.

Even with all these reservations in mind, accelerated aging is a powerful tool which enables the semiconductor device engineer to look at the reliability of his device from the beginning of development so that he can adjust his design to optimize initial device performance and subsequent aging in use. Lastly, this same early reliability information is available to the system engineer so that in the earliest stages of system design he can take advantage of any improvement in reliability that is indicated.

In this way, accelerated aging helps both in development and manufacture. These techniques are also useful in providing more of an understanding of the reliability of semiconductor devices. The increased reliability resulting from these techniques is invaluable to the systems engineers who use semiconductor devices in building complex electronic systems. It is one of the most effective methods of predicting the future of today's semiconductor devices.
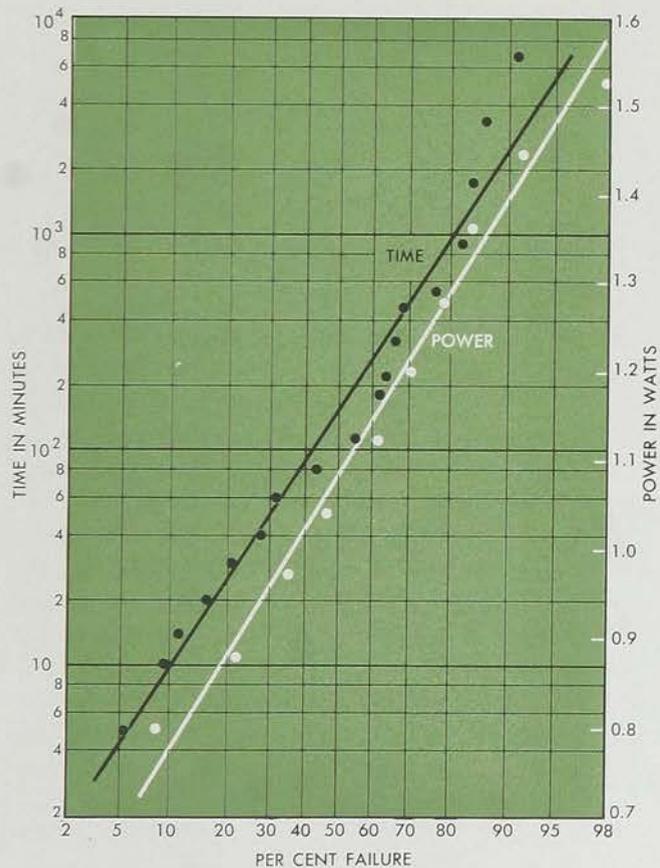
(c) The two curves show failure distributions in time for fixed temperature and fixed power levels.
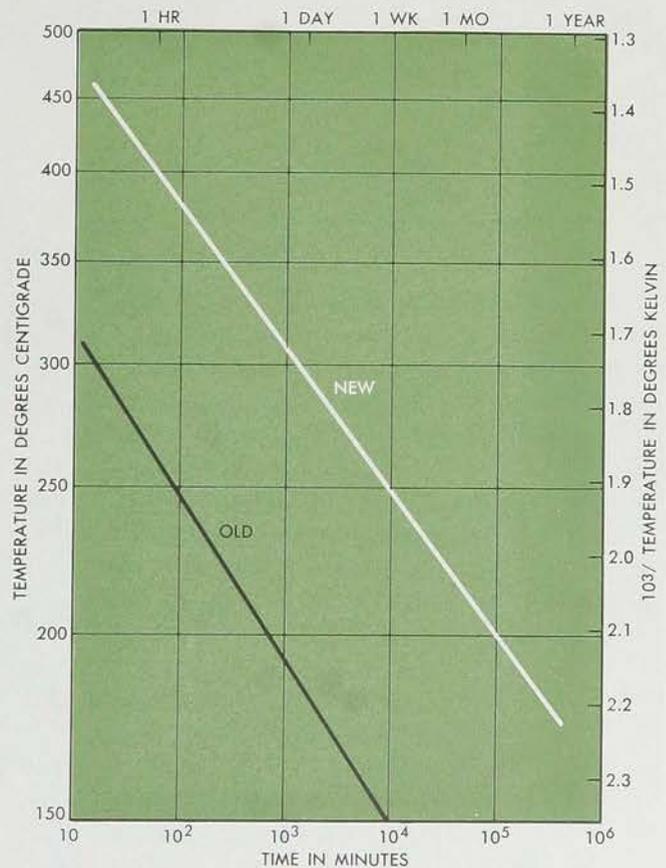
(d) Acceleration curves for fifty per cent failure of past and present production of a transistor.

A telephone central office may serve customers of different types with widely varied requirements. It must thus be able to determine the kind and extent of service which any given customer has selected.

Charles E. Brooks

# Class-of-Service Markings— What and Why

When a customer in the Bell Telephone System lifts his receiver to place a call, he is entitled to all the service for which he pays. The extent of this service varies, however, depending on the type of calling line. For instance, coin lines are obviously limited as to the area to which calls can be completed on the initial dime, and calls originating from message-rate and flat-rate lines may need to be differentiated for charging purposes. Therefore, an automatic telephone switching system must be able to determine the exact extent of service to which any particular customer is entitled. The signal which characterizes this ability is called a "class-of-service" mark. The originating equipment in a central office, in addition to furnishing dial tone to the customer, must be able to generate this class-of-service indication, and forward it to other equipment in its own and, very recently, in other central offices. A line marked for a particular class of service always

passes this mark forward even though it may not be used on some calls, such as service code calls.

The need for these identifying marks has increased greatly in the last two decades, because the customer is rapidly being given dialing access to successively larger areas through consolidation of service areas and DDD (RECORD, *August,* 1960). Also, as numerous new types of service are offered or planned by the Bell System, the need grows proportionately greater.

The No. 5 crossbar system, most modern electromechanical local switching system now in use, provides facilities for one hundred originating classes of service. This large class-of-service capacity in turn provides the tremendous flexibility needed to even consider offering the variety of new services now being studied in the Bell System. Every expansion in service capability is a challenge to the older types of dial systems, because an attempt must also be made
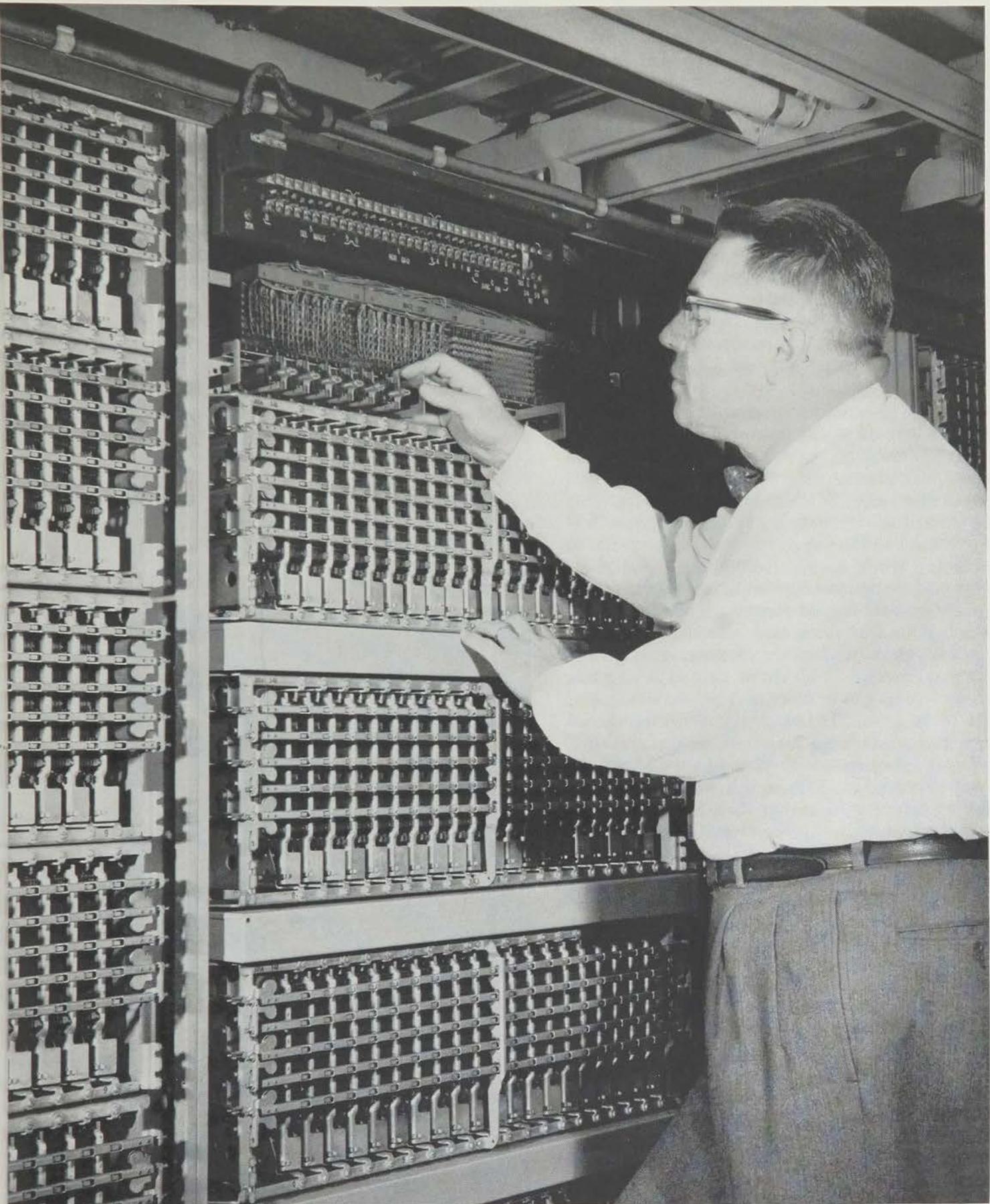
Author Brooks inspects class-of-service relays at a N. Y. Telephone Co. central office.

to modify or arrange them so that they too can furnish the new service. So let's look for a moment at the origin and development of class-of-service features. This will depict the inherent capabilities of the older systems, while giving some historical perspective.

By the time the telephone had come into general use, subscriber lines were divided into three main classes: coin, message rate and flat rate. On the manual switchboards of those days the coin lines were segregated, and appeared only at a small group of positions. The message-rate and flat-rate lines were scattered throughout the board, and colored lamp caps were used to distinguish the two different classes of service. The flat-rate lines were entitled to unlimited local service, while the message-rate and coin lines were charged on a "per call" basis for the same local service. All three classes of lines had to place long-distance calls through a toll operator.

By the time the step-by-step dial system had come into general use, the design provided for automatic recognition of classes of service. This required the segregation of lines in the switching office and the provision of separate paths to outgoing trunk groups individual to a class-of-service, or the introduction of arrangements to pass forward class-of-service signals to trunks serving lines of more than one class-of-service. Regardless of the trunking method chosen, lines were segregated in either of two ways—by line finder group (100 or 200 lines) or line finder level (10 or 20 lines). If the trunking method chosen was to pass forward a class-of-service signal, it was transmitted over the fourth wire of a four-wire switch train. That is, this method made necessary a four-wire, rather than the usual three-wire, switch train. This noticeably increased the cost of an office solely to provide a class-of-service feature.

This cost factor, combined with the fact that differentiation between lines is relatively seldom required in step-by-step areas, made this method of class-of-service distinction uneconomical in most cases. It is beneficial in community dial offices, where it is expensive to provide separate trunk groups for different types of service which require an operator, because the operator's office may be located many miles away from the step-by-step equipment.

In contradistinction to common control offices, the routing in a step-by-step office is governed strictly by the digits dialed and the class-of-service signal cannot be used to change this route. It can be used to block access to a particular trunk group, but usually its use is limited to controlling

the generation of a tone which can be transmitted to an operator, enabling her to distinguish between coin and non-coin lines where separate trunk groups are not provided for these services.

In the panel dial system, each line group generally has a capacity of 300 or 400 lines. Any particular line group can generate only two class-of-service marks, and every line in the group will be marked with one or the other. The minimum number of lines in one class is 10 per cent of the line group, and this number may be varied in steps of 10 per cent up to 100 per cent. The class-of-service signals generated in the line groups are transmitted through the lines to the senders. Only four class-of-service marks can be handled by any single sender group. Ordinarily, a sender group serves thirty to forty line groups; thus, nine to sixteen thousand lines are restricted to four classes of service. If the office serves any coin lines, one class mark must be used for them, leaving only three of the four available for truly optional use.

One benefit which does accrue to the panel system over step-by-step is that the class-of-service signal can be used to change the route

Typical line link frames in No. 1 crossbar system.

and not merely to generate tones or to block access. Instead, it causes calls to be routed to a particular trunk group to accomplish a desired objective. These objectives vary; the end result may be routing to an operator or to different tandem offices to alter the charging method.

Crossbar System Increased Capacity

When the original No. 1 crossbar system was being developed, its designer recognized the need for more class-of-service marks than the panel system was arranged to use. Therefore, designers provided the new system with four classes per line link frame, and eight classes per sender group. Additional services were soon offered which made these provisions inadequate, but fortunately the planning was well done, and the arrangements used to generate, transmit, and register the class-of-service signals did permit ready expansion. Standard arrangements are now available for six service classes per line link frame and twenty-four customer classes per sender group.

It might be well to describe briefly the method used in the No. 1 crossbar system to generate and use class-of-service marks, because it is representative. In this system, the customer lines appear on the verticals of a crossbar switch. Each bay on the line link frame contains ten such crossbar switches mounted one above another. Although most crossbar switches have twenty verticals, the customer lines are treated in groups of ten. The ten lines vertically above one another on the ten switches in a bay are called a "vertical file" of lines. The group of one hundred lines formed by the ten files on the right or left halves of the crossbar switches in a bay, as shown on page 14, is called a "column" of lines. The classes of service on this line link frame are assigned by vertical files; that is, every line in a given file receives the same class-of-service treatment, and the various files in a column may be multipled from a class-of-service standpoint. Also, correspondingly numbered files in all columns in a frame receive the same class-of-service treatment. The number of columns on a line link frame varies depending on the arrangement of the supplementary bays, from a minimum of two to a maximum of seven. Thus, the minimum number of lines assigned to one class of service will vary from twenty to seventy.

A simplified diagram of the method of transmitting a class-of-service mark, and its use, is shown on page 16. With a class-of-service signal received at the central control marker, and ground connected to one end of the route relay winding through contacts on digit registration relays, the circuit which operates the route relay is closed by the operation of the appropriate class-of-service relay. In the example illustrated, the call was originated by a message-rate line, and will be completed on a message-rate unit charge basis. A flat-rate line seeking the same destination would receive the same treatment. A coin line would be denied completion, because its class-of-service connection would interpose the "deny route completion" (DRC) relay. If an operator had dialed a call to this destination, it would have been completed on a noncharge basis.

As originally designed, the No. 5 crossbar system had the capacity for thirty classes of service. It was later increased to sixty, and recently has been expanded to one hundred.

This continual increase in capacity brings us to the question—why are so many classes required? This can perhaps be answered best by referring to a hypothetical central office as an example, an office which serves an area including stations on both sides of a rate area boundary. An operating company in the Bell System is prepared to furnish many types of service in any central office area. Their schedule will normally include the following services:

■ Coin service, both public and semi-public;
■ Residential service, both flat-rate for individual, two-party, four-party and multi-party lines, and message-rate for individual and two-party lines; and
■ Business service, both flat-rate and message-rate, PBX and non-PBX.

In actual practice, several of these classes can be combined for class-of-service purposes because they are handled identically for routing and charging. However, at least eight individual treatments might be required in our hypothetical central office area. If, in addition, the schedule provides for restricted or extended-area dialing with each class, the number of classes required is automatically doubled, bringing it to sixteen. Finally, because it might be necessary to serve all of these classes on both sides of the boundary and because the equipment must know from which side the call is being originated, the number of classes doubles again to thirty-two. This case may seem to be exaggerated; however, there are actual cases where one unit of No. 5 crossbar equipment serves lines in three areas with different originating-rate treatments, making the class-of-service multiplier in this case three, instead of two.

In addition to these ordinary classes of service, the Bell System is presently offering, or planning to offer, several new services for more

specialized needs. One of these services is called WATS, for Wide Area Telephone Service. Under the WATS plan, a customer pays a flat monthly fee for unlimited interstate long distance service within one of six progressively larger areas in the continental U. S. There are no separate charges made for individual calls, although the rates for the service vary depending on the area covered. There is also an option under which the customer may buy WATS on a "measured-time" schedule, in which the basic rate covers fifteen hours of long-distance service per month. WATS requires six class-of-service signals per originating rate area initially if all zones are served, and it may require five additional classes if the same type of service is offered for five zones within the home state. If certain rate problems are resolved in the future, WATS may also require six more classes of service to handle those customers who contract for both interstate and intrastate service on the same line. This type of service can be handled most readily in No. 5 crossbar offices. Panel and step-by-step offices are unable to handle it, because of service class limitations. A No. 1 crossbar office can handle a limited amount of this service, depending on the number of class-of-service signals available for this use.

Another proposed service is called WADS, for Wide Area Data Service. This service is the data counterpart of WATS voice communication. It will provide communication on a flat-rate or measured-time basis between machines in various zones. The service will use a "WADS" network of switching facilities which originate and

terminate only in No. 5 crossbar offices. It will generally require six classes of service to serve all zones because the first zone always includes the home state. When the local central office serves customers in more than one rate zone, additional class marks will be required.

A third projected service is DTWX, for Dial Teletypewriter Service. Although this is also machine communication, these calls can be handled on the regular toll network and billed by the usual AMA record. They may be originated in step-by-step, No. 1 or No. 5 crossbar offices, and completed to any office. Only one class-of-service mark is required in the common control offices since charging is not done on a zone basis. No class of service mark is required in step-by-step offices because the first single pulse switches these calls to a tandem or toll office where all significant digits are registered.

The most prolific user of class-of-service marks to be proposed is the "Centrex" arrangement which has recently been applied to the No. 5 crossbar system. Under this arrangement, a No. 5 office can serve as a common switching medium for a theoretical maximum of 100 equivalent PBX's. Class-of-service marks are used to identify the various PBX groupings to the central office. Thus, calls between extensions of the same PBX group can be placed as four-digit, noncharge calls. Seven digits will be required on calls between extensions on two different groups served on the same Centrex system, and a charge may be made. To make all the distinctions required under this new concept of PBX service, the No. 5 crossbar equipment had to be modified to generate and
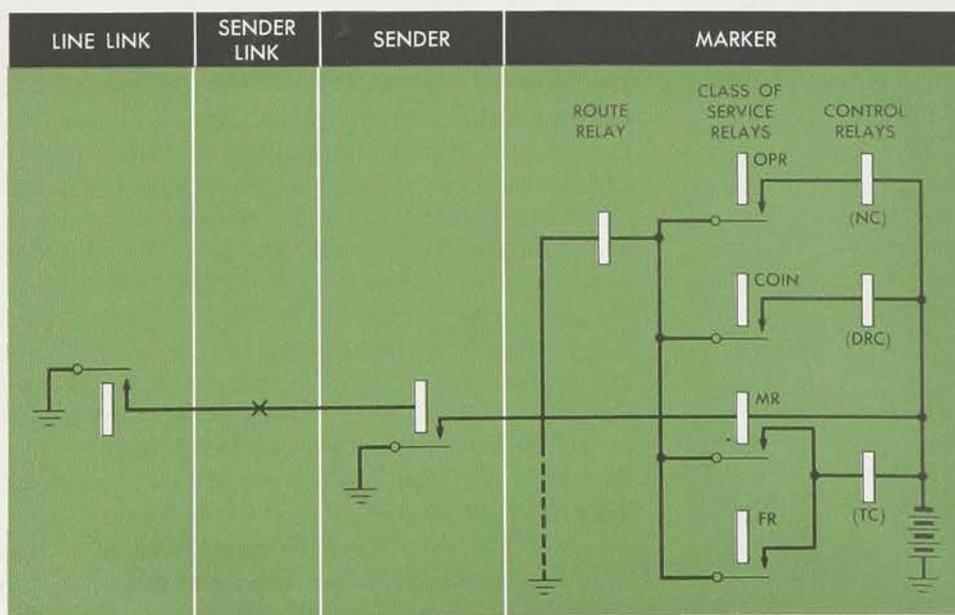
Simplified diagram which shows the method of transmission of class-of-service marks and typical uses.

recognize one hundred class-of-service marks and twenty treatments per office.

In all the applications of class-of-service marks mentioned so far, the mark has been used at the originating office only, and has not been transmitted for use in subsequent offices in the switching train. With the advent of No. 5 crossbar offices arranged for four-wire operation, this situation will be changed. Because the common control equipment in these offices will handle both two-wire and four-wire connections, a class-of-service mark will be used to indicate the type of calling line. Additional marks will be used in connection with customers served on a four-wire basis. These marks will give the customer special switching privileges, and signals derived from them, such as control or information digits, will be transmitted to succeeding offices to control the application of these privileges. Among the special services to become available will be *priority*, the ability to wait for a trunk to become idle if all routes are busy; *spill-over*, the ability to transfer from a private to the regular network when idle channels are unavailable; and *special grade*, the ability to choose specially conditioned facilities.

No. 5 Crossbar Most Versatile

It is notable in all these new service offerings that the No. 5 crossbar system figures so prominently. This is primarily the result of having designed a broad class-of-service capability into the system originally. Lack of this capability causes much head-scratching among those responsible for the older dial systems, when attempts are made to modify them to handle the latest service offerings. Many times these efforts are successful, but occasionally they are not. When this occurs, one begins to realize that obsolescence is showing.

From all trial indications, the newest addition to the automatic switching system family, the Electronic Central Office, will exhibit a flexibility and versatility that will make even the proponents of No. 5 crossbar sigh. It is evident that the way of progress for the Bell Telephone System is to provide for a continuing series of new, diversified and individualized customer services.

This underlines the importance of the ability to control calls on a class-of-service basis, which has played a major role in developing the traffic pattern of today. It also foretells that the traffic pattern of the future will be developed by the the implementation of additional services, which will almost inevitably involve the basic concept of a class-of-service mark.

Two New Science Films Produced for Colleges

Two new sound motion pictures, on the subjects of vision and magnetism, have recently been added to the Bell Laboratories College Science Film Series. Entitled "Short Term Visual Memory" and "Domains and Hysteresis in Ferromagnetic Materials," the films were prepared by Laboratories scientists who are recognized authorities in their fields, and are available on free loan through the offices of the local Bell Telephone Company.

"Short Term Visual Memory," a 16mm, sound, black-and-white film, running 18 minutes, is the story of an experiment in visual perception which was recently conducted in the Visual and Acoustics Research Laboratory. In the film, Dr. Emanuel Averbach and Abner S. Coriell, the scientists on the project, demonstrate the existence in the seeing mechanism of a temporary information storage which is used in handling visual information. The film has an unusual "audience participation" feature: the film viewers are given an opportunity to participate in the experiments by testing their own visual memory of items flashed on the screen.

"Domains and Hysteresis in Ferromagnetic Materials," a 16mm, sound, color film, running 36 minutes, discusses the theory of ferromagnetic domains and its relationship to hysteresis in magnetic materials. Actual motion pictures of moving domain walls are shown. The origin of coercive force is also discussed. This motion picture develops further some of the information that was presented in a previously released sound filmstrip entitled "The Formation of Ferromagnetic Domains."

Other films in the Bell Laboratories College Science Film Series are "Brattain on Semiconductor Physics" (16mm, black-and-white, sound, 30 min.), "Submarine Cable System Development" (16mm, color, sound, 18 min.), "Crystals —An Introduction" (16mm, color, sound, 25 min.), "Memory Devices" (16mm, color, 28 min.), and "Zone Melting" (sound filmstrip, color, 133 frame, 45 min.).

A two-record album entitled "The Science of Sound" containing demonstrations of acoustic phenomena has also been produced.

All audio-visual aids to science education in this series are designed for classroom use and contain no advertising.

The TJ diversity switch is another Bell Laboratories contribution toward better transmission in a microwave system. It automatically switches signals to a good channel from one that is noisy or inoperative because of fading or equipment failure.

C. J. Custer

The TJ Microwave Diversity Switch

All radio relay systems are subject to occasional interruptions caused by equipment failure and atmospheric fading. Equipment intended for the Bell System radio network is given rigorous quality control tests during design and manufacture, and it is meticulously maintained in the field. This program greatly reduces the probability of equipment failure by eliminating sources of trouble. Atmospheric fading is a different problem. It occurs because radio waves from a transmitter arrive at a particular receiver in a communications route over more than one path. Differences in the path lengths cause wave interference at the receiving antenna which can lead to a reduction in the strength of the received signal of 30 or 40 db, or more. The effect of these intermittent fades on the quality of the receiver output is intolerable.

Fortunately, this type of fading is highly frequency selective. Thus, by shifting transmission and reception to a different operating frequency when the one that is used fades appreciably, we can minimize the undesirable effects of the phenomenon. This article describes a unit developed at Bell Laboratories for the TJ Radio Relay System that automatically switches radio signals between two different frequencies during deep fades and also during any equipment failure.

The TJ System is used on short-haul, light traffic routes. Each TJ channel can transmit 240 telephone conversations or one television program. The system also transmits SAGE data. A method of transmission called frequency diversity safeguards these important services from interruption by fading or equipment failures. This means that signals are automatically switched from a noisy to a good radio channel. Each diversity switch monitors two TJ channels, an active and a standby channel. If transmission is impaired on the active channel the diversity unit automatically switches the signal to the standby channel. TJ repeater stations may use up to six radio receivers and six transmitters operating in each direction, each on a different frequency. Such a station has six diversity switches.

To simplify the explanation of how the diversity switch operates, let's assume a relay station with only two receivers and two transmitters. The receiving antenna picks up radio signals from a distant station and passes them to the two receivers (X and Y in the drawing on page 20). The baseband switching relay selects the output of either receiver and passes it to the two transmitters (W and Z in the drawing) which are connected in parallel. They, in turn, transmit the signal to the next station in the chain. The switching relay is controlled by the logic circuit which operates from information on the state of the system that it receives from two sources, the comparator

and the pilot monitor, as shown in the drawing.

At any time, therefore, the output of one receiver is being transmitted to the next repeater station while the other receiver is standing by. The comparator monitors the received signal strength to determine which receiver has the better signal. If the input to the active receiver fades severely, or is impaired in any other way, the comparator "instructs" the logic circuit to switch the transmitter to the standby receiver. The first receiver then becomes the standby unit.

The chart at the top of the opposite column should help to clarify the mechanics of the technique. (The curves merely divide the chart for visual convenience, they do not represent actual electrical characteristics.) Suppose that receiver X is the active one and receiver Y is standing by. The RF input to both receivers is minus 40 dbm. The coordinate for these inputs, point A, is in the chart area marked "NO SWITCH". As long as the coordinate of the inputs remain in this area, receiver X will be active.

Suppose, however, that the input to the active receiver drops to minus 60 dbm, while that of the other remains at 40. The coordinate for the new inputs, point B, is in the area under the lower curve. The relay will switch the transmitters to receiver Y. If the RF input to both receivers now fades simultaneously to minus 60 dbm, point C, nothing happens. The diversity switch operates only if there is a difference of about 15 decibels between the inputs to the receivers.

The comparator, then, does just what its name implies—it compares. Essentially, the circuit is a DC differential amplifier with a relay connected between the plates of the two amplifier tubes, as shown in the drawing below. The grid bias and, therefore, the plate current of each tube is closely related to the strength of the RF carrier signal applied to the inputs of the receivers. Because the circuit is symmetrical, the relay will not operate if the signal fades equally at both receivers. When the signals fade in different amounts, current flows through the relay winding. If the difference is about 15 decibels, the current is strong enough to operate the relay which then initiates a switch to the standby receiver.

Thus, if the relative signal levels of the receivers differ, a switch occurs. But what happens if, despite the difference, the absolute level of the active receiver is high and a switch is needless? To prevent one in this case, diodes (CR1 and CR2 in the drawing opposite) connected between each comparator grid and the bay power supply, act as clamps in the grid. As one channel fades, the bias on one diode is altered. When the received
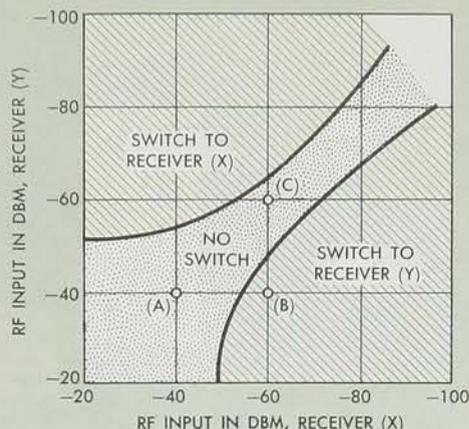
OPERATIONAL CHARACTERISTICS
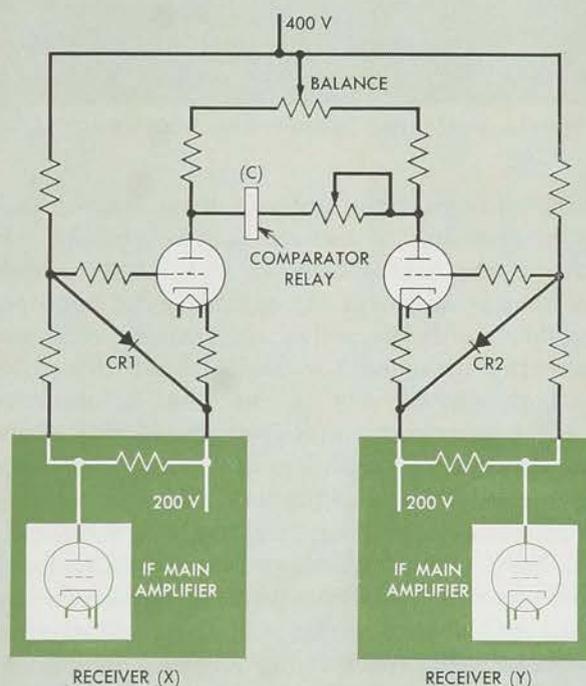
FUNCTIONAL DIAGRAM

Symmetrical configuration of the circuit prevents a switch during an equal fade on both receivers.

signal level drops to approximately −40 dbm the diode loses its clamping properties. Any more fade unbalances the comparator and current flows through the relay winding. When it reaches a level determined by a resistance network associated with the diodes, the relay operates.

If both channels fade severely, the main amplifier plate current rises and cuts off both comparator tubes. No current flows through the relay and there can be no switch between receivers. This circumvents pointless switching from a noisy active receiver to an equally noisy standby.

The second source of information to the logic circuit is the pilot monitor. This unit guards
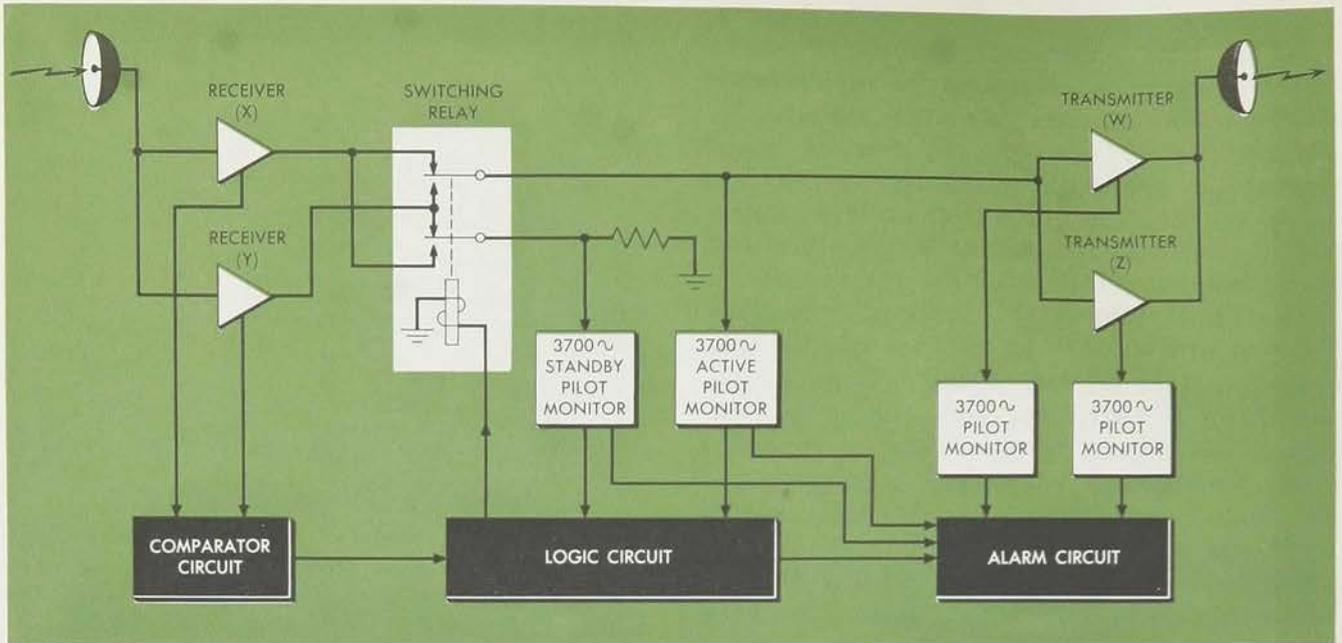
Diversity switching system has two transmitter-receiver links, each with an associated pilot monitor.

against interruptions because of equipment failure by causing a switch to the standby receiver if the active receiver fails. A 3700-cycle pilot tone is sent over the system. Pilot monitors associated with the active and standby receivers detect the presence (or absence) of this tone. The logic circuit acts on the total information from the comparator and from the output of the pilot monitors. If the pilot tone vanishes on the active receiver (an indication that the receiver has failed) or, as explained above, if a sufficiently deep fade occurs, the logic circuit initiates a switch to the standby receiver. However, this switch will take place only if the pilot monitor associated with the standby receiver detects the pilot tone. If there is no tone at the standby receiver there will be no switch. Thus, in effect, information that the standby receiver has failed overrides switching information from both the comparator and the active pilot monitor.

Another system safeguard is particularly relevant to the transmission of the SAGE data. It is imperative that the diversity system does not introduce transient changes in the signal level large enough to cause SAGE data errors. The baseband switching relay, a wire-spring type, helps prevent this. When the system switches from one receiver to the other, the relay contacts bunch together and, for an instant, the receiver outputs are paralleled. This does not cause a change in signal level because both units are carefully adjusted for equal output at normal received levels. Fades must reduce the received signal level about 40 decibels before they greatly affect the receiver

output. Thus, baseband levels are usually equal. Moreover, the comparator usually initiates a switch before such a deep fade is reached.

To guard against unnecessary switching, the diversity switch has no preferred position. If the system switches from a bad active receiver to a good standby, it will not switch back automatically when the trouble is cleared on the first, but only when transmission is impaired on the second.

The diversity switch is a very effective troubleshooting tool. A link in trouble can be quickly located by forcing a switch between two links. Accordingly, a command signal, actually a ground applied by an alarm circuit to the diversity switch, is sent to the logic circuit. The ground indicates that the active receiver has failed, and the logic circuit starts a switch to the standby. Switching between the two receivers, of course, depends on a normally operated standby link.

TJ installations for the most part are used for message service with L or ON multiplex terminals. A small number will carry television. On these circuits the 3700-cycle pilot tone used with message systems would interfere with picture transmission. Therefore, it is omitted, and so is the pilot monitor. A much simplified logic circuit, controlled entirely by the comparator relay, initiates the switching. The system is protected against selective fading, but not against equipment failure.

The reliability provided by the diversity switch is an inherent part of Bell Laboratories continuing attempt to circumvent the hazards to good transmission created by nature and by the fallibility of electronic equipment.

*Telephone service comparable to that
in urban areas is reaching sparsely
settled rural sections, through a
combination of C Rural Wire and a
new insulation-piercing terminal.*

Insulation-Piercing Terminal
For C Rural Wire

The Bell System serves many rural areas by means of long-span open wire construction. However, many additional areas which are sparsely settled cannot justify open wire construction from an economic standpoint. C Rural Wire, a self-supporting polyethylene-insulated, paired wire, was developed by the Laboratories to serve such areas economically, and to supplement existing open wire construction. It consists of two parallel 14-gauge conductors made of high-strength copper-clad steel in a common polyethylene jacket. It can be fastened to existing poles easily or can be placed on light-weight poles or trees. From the start of development, it was evident that a reliable and easily installed terminal would be needed for connecting drop wires from customer's homes to C Rural Wire before its full benefits would be realized.

When providing service to an individual subscriber prior to the development of the connecting device described in this article, it was necessary to split the wire, remove the insulation and apply bridging connectors, and to tape the entire assembly. The drop wire could be terminated directly on the bridging connectors or on a wire terminal which was connected to the bridging connectors

by bridle wire. This method was time consuming in an otherwise simple and rapid placing operation.

A new wire terminal, designated the 107A1, was developed to fill the need for a rapid and economical means of termination. It is clamped directly to the line wire after the wire has been installed and tensioned, at the chosen location, without having to cut into the line wire. All connecting operations are reduced to one simple hand press, and the tightening of two nuts with a socket wrench, designated the 216B tool. These operations cause insulation-piercing points to make firm contact with the line conductors. The customer drop wire or protector leads (when required) are then installed normally on binding posts which are integral with the line wire contact points.

A drawing showing the terminal and the detail of the insulation-piercing contact points in use is shown on page 22. The internal cavity which provides a ventilated, high-insulation resistance barrier between contacting halves of the block is also shown.

The contacts in this terminal are of special interest. They consist of phosphor-bronze hollow cylindrical details, each with two chisel-edge,

wedge-shaped points in a "U" configuration across the cylinder as shown in the drawing detail. Each "U" straddles one of the copper-clad steel conductors and is designed so that its depth will compensate for any variations in conductor spacing. Its sides deflect slightly, giving it a resultant spring action. This provides stored mechanical energy to maintain good contact. The hollow cylinder provides a "relief" area, into which the polyethylene insulation extrudes as it is displaced by metal in the contacting process.

High Current-Carrying Capacity

Of further interest is the high current-carrying capacity of these contacts. This is essential when the terminal is used to connect power cross protectors (RECORD, *April*, 1959) which are needed at regular intervals along exposed rural lines. When such a protection point coincides with a customer location, the terminal can accommodate both the customer drop wire and protector leads. The development testing program included a study of the current-carrying capabilities of the contacts. It was found that the very small areas of contact between the 14-gauge conductor and the phosphor bronze point could indeed carry currents far in excess of those ever anticipated. They could thus be relied upon to be compatible with the power line fault-fusing requirements. Specifi-

cally, in tests with 400 amperes passing through one conductor and its associated contact, the wire fused in one second, leaving the contact undamaged. Further tests indicated a current carrying capacity for the contacts larger than 600 amperes.

The characteristic behavior of the terminal with respect to temperature changes, insulation resistance, vibration, stability, and corrosion resistance were also studied. Sample terminals satisfactorily withstood exposure to rain, ice, and wind at the Chester Laboratory. Successful preliminary trial installations were made in several Southern Bell and New England Telephone areas.

During the past year, Bell System Operating Companies installed the new terminals at an average rate of a little over three per mile. The usage is of two kinds: customer connection on unexposed lines, and customer plus protector connections on joint-use lines exposed to power line potentials of 3,000 volts or greater.

Judging from the total production figures for C Rural Wire and the 107A1 Terminal, it is apparent that both the wire and the terminal are doing a major job in reaching the sparsely settled rural sections with telephone service comparable to that in more urban areas.

W. C. Schumann
OUTSIDE PLANT LABORATORY
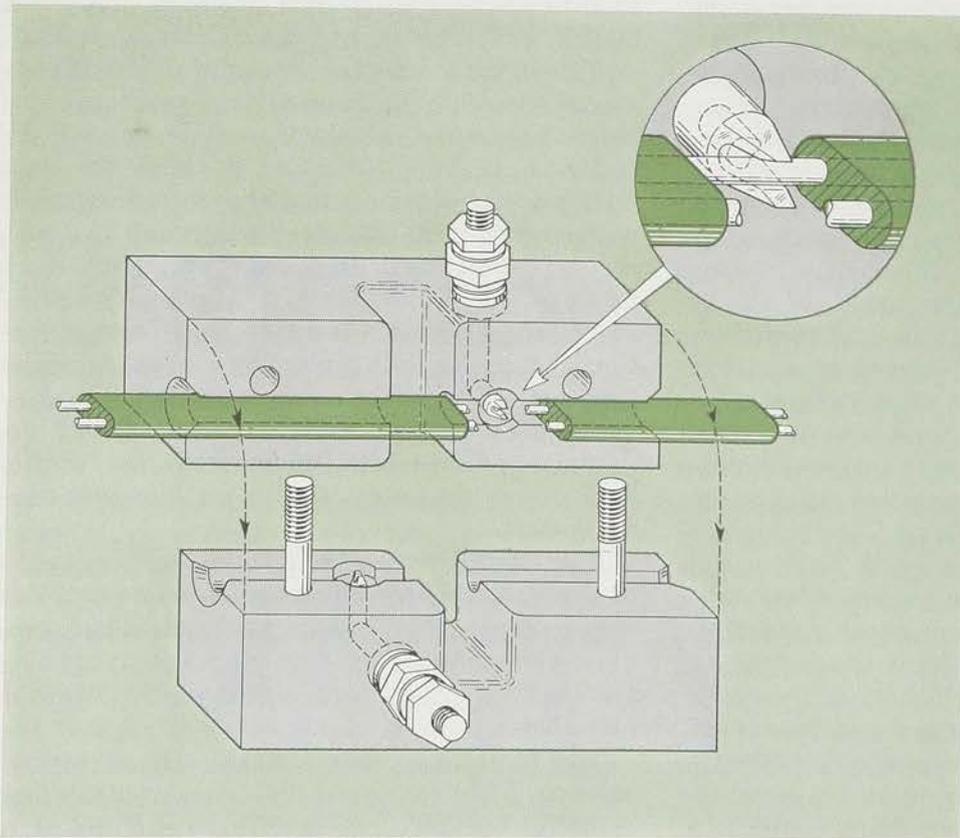
Insulation-piercing contacts make electrical contact with conductor when both halves are clamped together. After terminal is assembled, it is covered with small neoprene jacket for weather protection.
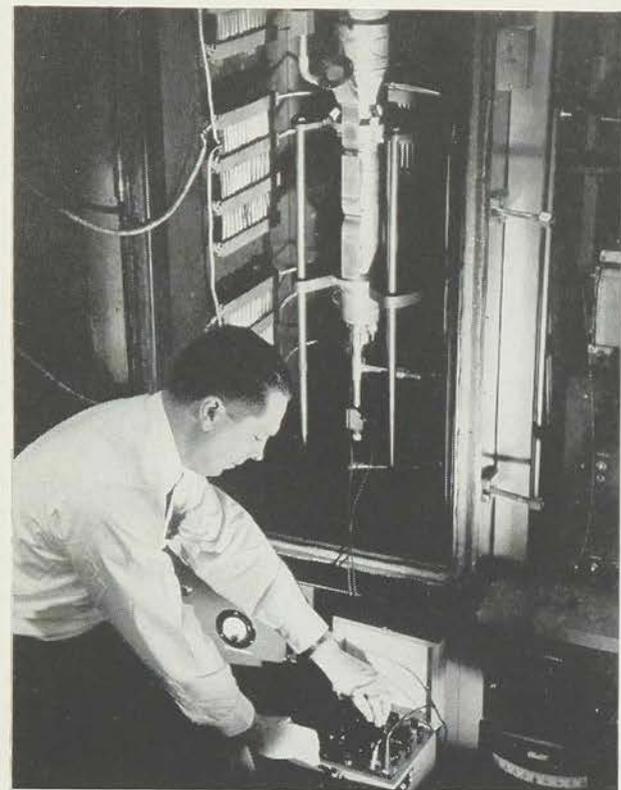
TELSTAR

Components
and
Testing

Development of an active satellite communication system spawns many problems which seem as far out of this world as the orbiting satellite on which it will depend. Combined with the many unknown operating conditions under which such a system will operate is the "crash program" aspect of the development work, to have the "bird" ready to fly at the same time the rocket booster is ready to launch it. The ground stations must also be complete and operable.

Scientists and engineers at all locations of Bell Laboratories are daily solving these problems, however, in ways which tax their ingenuity. Simulating vibration and shock conditions which exist at blastoff, as well as vacuum, radiation and temperature conditions of outer space, these men put the various components through their paces, eliminating weak links, proving stability, and working out suitable combinations of materials, circuits, and mechanical mountings.

On the next few pages, we present a group of photos of some of the areas where problems in components and mechanical structures are being solved. They are typical of the vastly greater number of people and equipment involved in the over-all program which will put a working satellite repeater in orbit next spring.

In an anechoic chamber at the Hillside, N. J., location of Bell Laboratories, Charles Haas adjusts the beacon antenna which will be used in tracking the satellite as it orbits in outer space. Wedges of rubber-like material, impregnated with graphite, line the chamber to absorb radio waves.

The traveling-wave tube to be mounted in the satellite must undergo rigorous tests to ensure its ability to withstand the conditions of launch and orbit. One of these tests is vibration, observed here by John Milkosky, Murray Hill. The TWT is mounted in a holder, then shaken in three dimensions sequentially. The acceleration that can be applied by the shaker depends on the specimen, and is limited by its mass. Typical values are up to 20 G's at 50 to 2000 cps.

There will be several traveling-wave tubes used in the active satellite program. Here, George Helm checks temperature readings on equipment being used to "outgas" a TWT to be used in the ground apparatus at Andover, Me. Harmful residual gases are exhausted under heat and vacuum, to stabilize the unit before it is sealed off.

Arthur Chick makes electrical connections to a traveling wave tube for pre-flight life tests, which will give some indication of the tube's potential long-term performance in outer space. These tubes must be designed for the highest efficiency, because of the limited electric power available in the satellite. These tests are typical of the effort being expended on components throughout the development program on the satellite itself, and on the ground support equipment at all locations of Bell Telephone Laboratories.

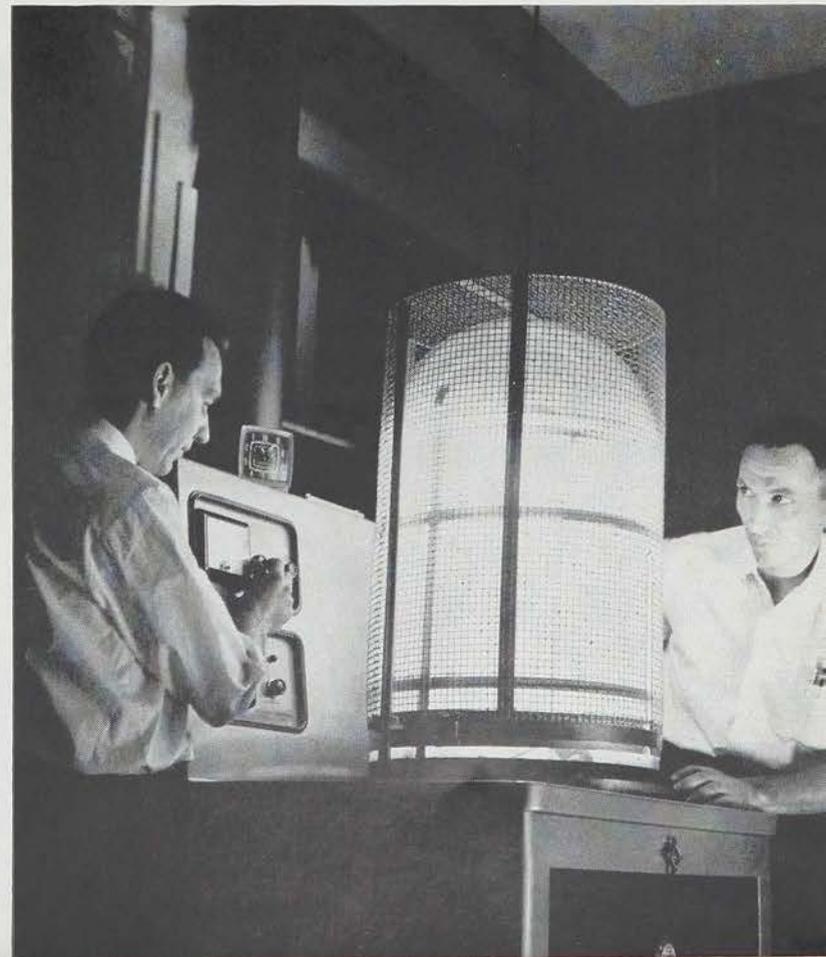After the vibration schedule is completed, the traveling-wave tube is remeasured, and its electrical performance compared with the original measurements. Here Tom Ross connects the tube to equipment which can test the electronic efficiency continuously, while the voltages to the tube are varied. In this way, an optimum operating point can be found consistent with system application.
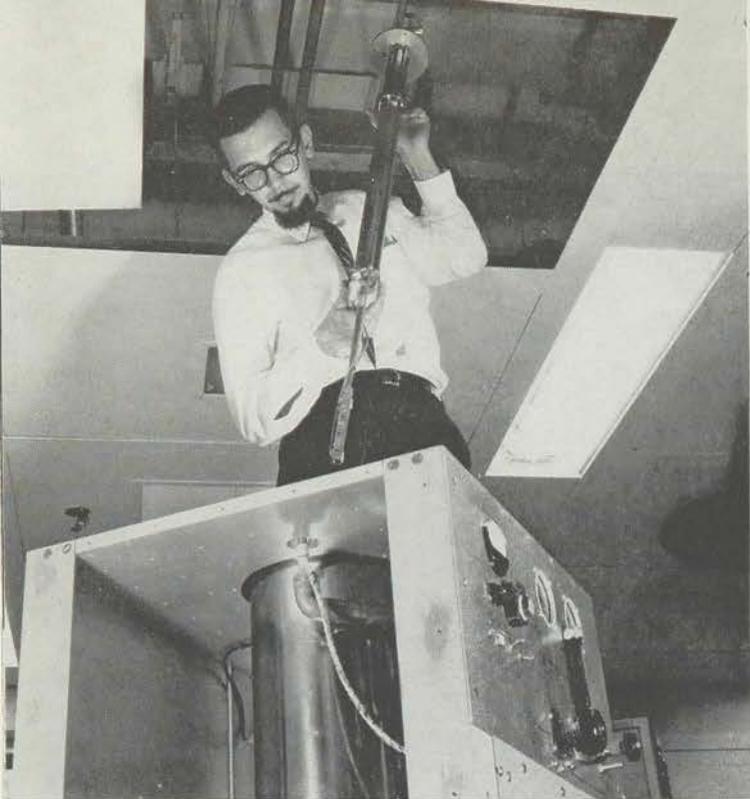

D. Tarangioli loads a solar cell into a test set to evaluate the effectiveness of anti-reflection coatings, while H. K. Gummel makes an adjustment to the set (rear). The coated cells and a standard solar cell are exposed to monochromatic light of various wave lengths, and the ratio of their response it recorded on punched cards. In addition to eight spectral measurements, seven electrical measurements are taken, all in twenty seconds. From such measurements, the output of the cells in outer space can be predicted.
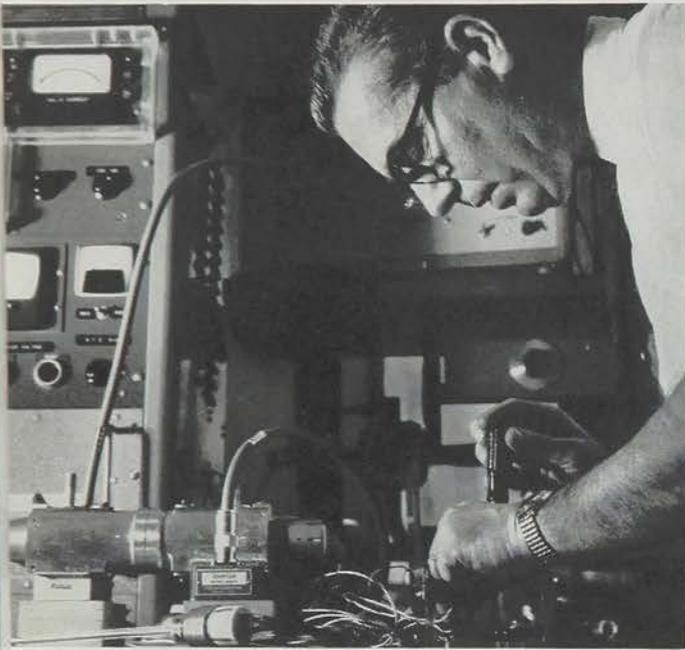
To increase the absorption of sunlight by the solar cells used to power the active satellite transmitter, the cells are given an anti-reflection coating. Here L. S. Yesis (left) and J. D. Bode first apply a glow discharge to the silicon cells, to prepare the surface for bonding the film of silicon oxide which is evaporated on later. The silicon cells are then covered with a thin sapphire plate, which has first been coated with an evaporated layer of magnesium fluoride. These coatings cut down reflections at the surface, transmitting radiation to which the cells are most responsive.

R. N. Hagenbuch, foreground, and Erwin Schmid return a group of silicon transistors and diodes to power aging racks at Allentown for life tests after periodic test and evaluation. Such aging is essential to eliminate active elements that would otherwise fail during early operation.

Jim Sibilia, Allentown, inserts the traveling-wave ruby maser assembly into its helium dewar for tests under low operating temperatures. The maser will be installed in the cab of the horn antenna now being built at Andover, Me.
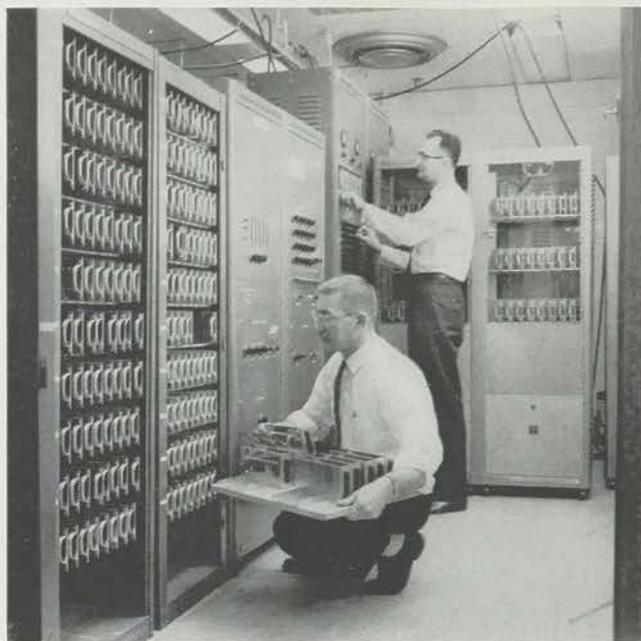
Mrs. Ella Siefert, foreground, makes adjustments on equipment for measuring the high frequency characteristics of diffused germanium transistors at the Allentown, Pa., location, while Mrs. Rose Burns operates automatic test equipment for measuring several other electrical characteristics.

In addition to the actual circuits and devices to be used in communications, the satellite will carry aloft a number of experiments designed to aid in the design of future space communication ventures. Below, Don Raver, at Murray Hill, alloys a base tab to a silicon transistor which has been specially fabricated to make it unusually sensitive to damage by radiation. The purpose of the device is to determine the amount of radiation damage such a device will receive from the various types of radiation to be encountered in space.
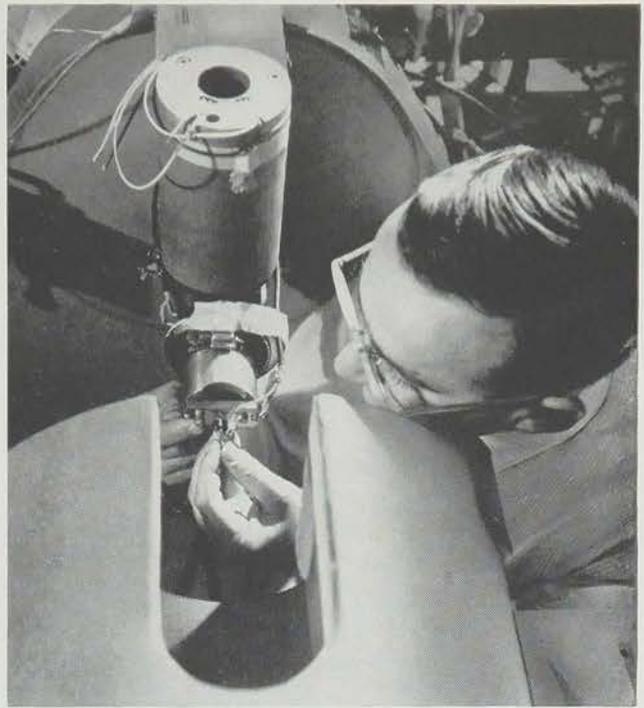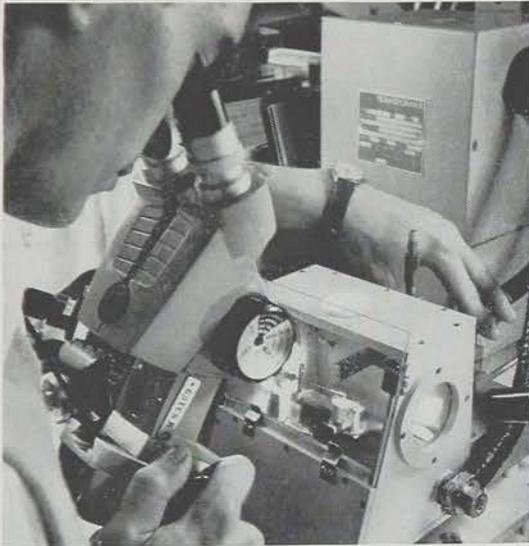
W. M. Augustyniak mounts a solid-state radiation detector, another device to probe the conditions of space, in a Van de Graaff generator at Murray Hill for testing. In the satellite, the detectors will be used to measure the high energy particles encountered in space. The detector encapsulation has a foil-covered "window" to admit the particles.

The solid-state radiation detectors shown being tested above are p-n junction diodes made from extremely pure silicon (15,000 ohm-cm.), so that they have a deeper sensitive region for detecting high energy particles. In the photo below, George Wheatley, Murray Hill, prepares to vacuum bake the encapsulated detectors prior to hermetic sealing.
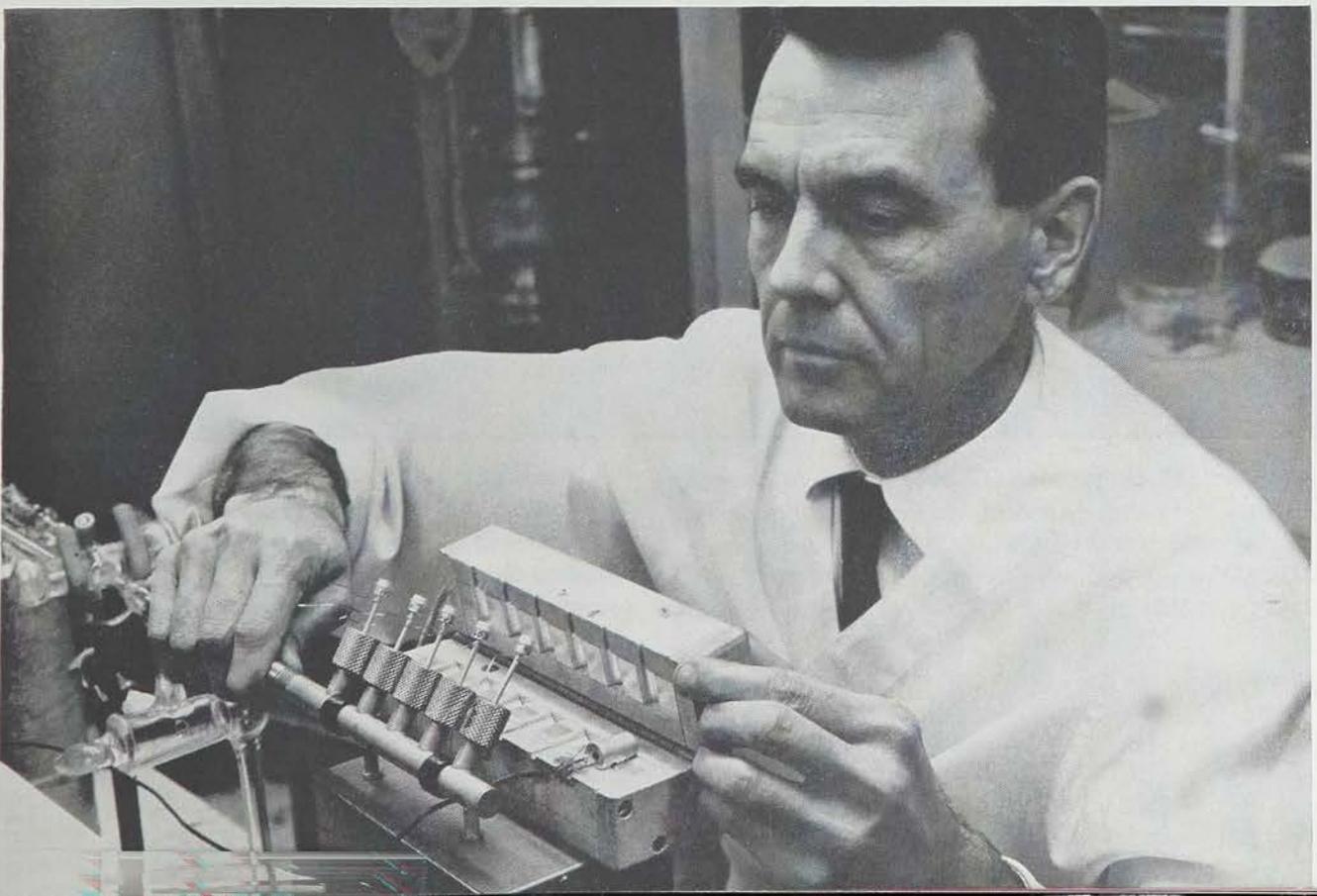
The voices of telephone customers of the ECO were carried through neon gas tubes that made up the switching network shown above, instead of through conventional electromechanical relays.

The field trial of the Morris Electronic Central Office forecast a major advance in telephone communications. The first big step will soon be taken with the installation of the Bell System's first commercial ECO.

Full-Scale Electronic Central Office Planned for New Jersey

A new era in telephone communications will soon begin with the installation of the first full-scale commercial Electronic Central Office (ECO) in Succasunna, New Jersey. The new system will serve all of the community's 4300 telephone customers.

News of the Bell System Construction of a building to house the new ECO will begin next spring. Installation and testing of the highly complex electronic equipment should be completed by mid-1965. Although similar in concept to the system on trial in Morris, Illinois, the Succasunna installation is designed for commercial production to meet the needs of Bell System customers. The exact features to be offered initially at the Succasunna office are still to be determined. However, among the unique telephone services being considered for the new ECO are:

• Two-digit-dialing for frequently-called numbers.

• Automatic routing of incoming calls to another phone when the originally-called line is busy.

• Dialing a code to forward incoming calls to another telephone when the customer is away from home.

• Dialing a third party into a telephone conversation that is in progress.

These and other features can be programmed into the ECO's memory which is capable of storing millions of bits of information to be used on instantaneous command.

Research on ECO was begun at Bell Laboratories before World War II. Investigative work on the first practical ECO was done during the same period and, by 1954, the development of components like gas diodes, electronic memories and transistors made an electronic central office appear feasible. This intensive research and development was incorporated in the Morris field trial, which begun on November 17, 1960. The Morris office, the world's first ECO, was the result

of close teamwork over the years by the Laboratories, Western Electric and operating telephone companies like Illinois Bell.

The ECO makes wide use of transistors and other solid state devices invented by Bell Laboratories scientists, which operate approximately 1000 times faster than conventional switching apparatus. It is actually a highly specialized electronic data processor. Its high speed and special equipment make possible a variety of new services which greatly increase the value and flexibility of each customer's telephone.

One novel feature of the ECO is that it continually checks itself. On its own, it can pinpoint any trouble spot, report its location and nature on a teletypewriter tied into the electronic equipment and take corrective action. It also has the uncanny ability to carry on a written conversation with central office personnel.

For example, if a central office attendant wants to know if a certain part of the equipment is working properly, he types information on the teletypewriter. Instantly, the ECO acknowledges the order by repeating it on the same machine. The attendant checks this repeated message. If it is accurate, he merely types a period. This confirms the order to the equipment which then makes the specified tests and types out the results of these tests.

Engineers from the Laboratories and Illinois Bell have acknowledged the great value of the Morris trial to the Succasunna ECO. Information gathered at Morris has resulted in modification of some components for the Succasunna installation and the complete redesign of some others. More than 100 Illinois Bell, Bell Laboratories and Western Electric employees have worked on the Morris ECO since installation began in 1959. Many of them have lived in Morris for long periods.

There are now 421 customers participating in the ECO trial. Some of them have had ECO service in their homes since June 1960, when a few customers began using ECO phones four hours a day. Additional customers were added for the formal dedication ceremony on November 17, 1960, and more were added after the dedication, to reach the present total.

On dedication day, Morris was the center of attention for the communications industry as officials from throughout the nation attended formal dedication ceremonies. Among those on hand were Eugene J. McNeely, then executive vice president and now president of the American Telephone and Telegraph Company, Dr. James B. Fisk, president of Bell Telephone Laboratories, Rosel Hyde, Federal Communications Commissioner, and William V. Kahler, Illinois Bell president. Since the formal dedication, more than 6000 persons have visited the Electronic Central Office in the Illinois Bell Telephone building in Morris.

Illinois Bell installers will begin removing ECO telephones from the homes of Morris customers on January 8 and will have the job completed by February 16, said Del Noble, local Illinois Bell manager. "Letters have been mailed to each Morris customer participating in the trial, advising them of the termination date," Mr. Noble said.

B. G. Hemmendinger, Bell Laboratories supervisor in Morris observed that the results of the trial are "gratifying," and that "customer cooperation was so enthusiastic that our engineers and scientists have gathered all results needed from the trial."

Bell Telephone Laboratories engineers E. W. Vaupel (left) and L. Eliscu as they installed a cathode ray tube in the flying spot store memory, part of the experimental ECO at Morris, Illinois.

Following is a list of speakers, titles and places of presentation for recent talks presented by members of Bell Laboratories.

Aaronson, D. A., and Kinnaman, Miss C. J., *Production of Large and Variable Size Logic Block Diagrams on a High-Speed Digital Computer*, A.I.E.E., Detroit, Mich.

Batterman, B. W., and Chipman, D. R., *Contribution of Thermal Diffuse Scattering to Integrated Bragg Reflections from Perfect Crystals*, Pittsburgh Diffrac. Conf., Pittsburgh, Pa.

Batterman, B. W., *An Unexpected Temperature Behavior in Anomalous Transmission of X-Rays*, Pittsburgh Tech. Soc., Pittsburgh, Pa.

Bennett, W. R. Jr., *Optical Masers—Their History and Future*, IRE, Fairleigh-Dickinson University, Rutherford, N. J.

Bergh, A. A. *The Spreading of Molten Indium Over Germanium*, Electrochem. Soc., Detroit, Mich.

Black, H. S., *Global Communications Via Satellites*, IRE, Greensboro, N. C.

Black, H. S., *New Developments in Communications Research*, Western Electric Company's Grad. Engg. Training Center, N. Y. C. and Winston-Salem, N. C.

Black, H. S., *Global Communications Via Artificial Earth Satellites*, Western Electric Company's Vertical Conf. of Equip. Engrs., Newark, N. J.

Black, H. S., *Global Communications Via Satellite Relays in Space*, Vacuum Metallizers Assoc., N. Y. C.

Bogert, B. P., *Correction of Seismograms for the Transfer Function of the Seismometer*, East. Sec. Seismological Soc. Am., Cincinnati, Ohio

Bogert, B. P., Menard, J. Z., and Walker, R. A., *Real Time Spectral Analysis of Seismic Body Waves and Microseisms*, Acous. Soc. Am., Cincinnati, Ohio

Brady, G. W., *Work on a Critical*

State, New York Univ., N. Y. C.

Brown, R., see Schwartz, N.

Calibick, C. J., *Electron Microscopy of Glass and Quartz Substrate Surfaces for Thin Films*, Second Intern. Cong. on Vacuum Techn., Washington, D. C.

Chaplin, N. J., *Injected Carrier Concentrations in Diffused Silicon Transistors by Observations of Interband Carrier Recombination*, IRE, Washington, D. C.

Chaudhuri, A. R., see Patel, J. R.

Chipman, D. R., see Batterman, B. W.

Cochran, W. T., *An Accurate Voice Frequency Level Calibrating Set for Field Use*, A.I.E.E., Detroit, Mich.

David, E. E. Jr., *Some Basic Processes in Human Communication*, Lehigh Univ. Bethlehem, Pa.

David, E. E. Jr., Schroeder, M. R., Logan, B. F., and Prestigiacomo, A. J., *New Applications of Voice-Excitation to Vocoders*, Acous. Soc. Am., Cincinnati, Ohio

David, E. E. Jr., see Flanagan, J. L.

Davis, C. G., *Satellite Communications*, Bethany College, West Liberty College and Wheeling College, Wheeling, W. Va.; West Virginia Univ., Morgantown, W. Va.; Marshall Univ., Huntington, W. Va.; Morris Harvey College, Charleston, W. Va.

DeMonte, R. W., *Synthesis of Two-Terminal Networks Simulating Impedance of Loaded Cable Facilities*, A.I.E.E. Salt Lake City, Utah.

Dorsi, D., see Wernick, J. H.

Dove, D. B., *Electron Microscope Observations on Deformed Copper Single Crystals*, Metallurgical Soc. A.I.M.E., Detroit, Mich.

Eckler, A. R., *A Class of Pulse*

Position Modulation Codes Resistant to Random Pulse Interference, IRE, Baltimore, Md.

Ellis, W. C., see Greiner, E. S.

Espinosa, G. P., see Geller, S.

Eucke, E. H., see Harvey, F. K.

Fabian, E. L., *Resonant Vibrations of Ceramic Rectangular Bar Transducers*, Acous. Soc. Am., Cincinnati, Ohio

Flanagan, J. L., David, E. E. Jr., and Watson, B. J., *Effects of Masking Upon Lateralization of Cophasic and Antiphasic Clicks*, Acous. Soc. Am., Cincinnati, Ohio.

Fraser, D. B., and King, J. C., *Performance of Quartz Resonators Near the Alpha-Beta Inversion Point*, Fifteenth Annual Symp. on Frequency Control, Atlantic City, N. J.

Galt, J. K., *Cyclotron Resonance in Solids at High Magnetic Fields*, Conf. on High Magnetic Fields, M.I.T., Cambridge, Mass.

Garrett, C. G. B., *Optical Masers*, Columbia University, N. Y. C.

Geils, J. W., *The Systems Engineering Concept*, Nassau Club, Princeton, N. J.

Geller, S., Williams, H. J., Sherwood, R. C., and Espinosa, G. P., *Substitutions of Divalent Transition Metal Ions in Yitrium Iron Garnet*, Conf. Magnetism and Magnetic Material, Phoenix, Ariz.

Geschwind, S., *The Axial Crystal Field in Corundum and the Susceptibility of $T^{i}2^{o}3$*, Conf. Magnetism and Magnetic Materials, Phoenix, Ariz.

Gossard, A. C., Jaccarino, V., and Remeika, J. P., *Nuclear Magnetic Resonance in the Insulating Ferromagnet $CrBr_3$*, Conf. Magnetism and Magnetic Materials, Phoenix, Ariz.

Green, A. H. Jr., *A Study of the Bivariate Distribution Function of Ocean Noise*, Acous. Soc. Am., Cincinnati, Ohio

Greiner, E. S., Gutowski, J. A., and Ellis, W. C., *Silicon Rib-*

bons and Filamentary Crystals, A.I.M.E., Detroit, Mich.

Gucker, G. B., *Long Term Frequency Stability for a Reflex Klystron Without the Use of External Cavities,* A.I.E.E., N. Y. C.

Gupta, S. S., *On A Single Sample Procedure for Selecting from Several Normal Populations a Subset Containing the Population with the Smallest Variance,* Inst. Math. Statis., Cornell University, Ithaca, N. Y.

Gutowski, J. A., see Greiner, E. S.

Harvey, F. K., and Eucke, E. H. *Compatibility Problems in Two Channel Stereophonic Recordings,* Audio Engg. Soc. Conv., N. Y. C.

Harvey, F. K., see Thomas, D. E.

Harvey, F. K., and MacLean, D. J., *An Artificial Vibrato for Entertainment Use,* Audio Engg. Soc. Conv., N.Y.C.

Harris, Miss B., *How to Sample in Market Research,* City College of New York Grad. N. Y. C.

Haugk, G., and Yokelson, B. J., *Experience with the Morris Electronic Switching System,* A.I.E.E., Detroit, Mich.

Herriott, D. R., *A Continuous Helium-Neon Gas Maser,* IRE, Princeton, N. J.

Hight, S. C., *Satellite and Space Communications,* Western Electric Company's. Vertical Conf., Newark, N. J.

Holt, H. O., *Use of Machines and Programmed Textbooks for Training in Specialized Skills,* Am. Management Assoc., Los Angeles, Calif.

Hsu, F. S. L., see Wernick, J. H.

Hutson, A. R., *Ultrasonic Amplification and Scattering Phenomena in Piezoelectric Semiconductors,* IBM, Yorktown Heights, N. H.; RCA, Princeton, N. J.

Jaccarino, V., see Gossard, A. C.

Jenkins, H. M., *Analysis of the Partial Reinforcement Effect,* Duke University, Durham, N. C.

Johanson, A. E., *Recording and Visual Analysis of "Noise" Errors,* A.I.E.E., Detroit, Mich.

Kaltenborn, P. J., and Kokinda, J. J., *A Stable 1000-Cycle Tone Generator,* A.I.E.E., Detroit, Mich.

King, J. C., see Fraser, D. B.

King, J. C., *Electrolysis of Synthetic Quartz; Effect Upon Resonator Performance,* Intern. Conv. Components and Materials used in Electronic Engg., London, England.

King, J. C., and White, D. L., *A New High Frequency Ultrasonic Transducer,* Conf. Intern. Friction, Cornell University, Ithaca, N. Y.

King, J. C., *Imperfections in Quartz, Effect Upon Acoustic Absorption,* Poly. Inst. of Brooklyn, N. Y. C.

Kinnaman, Miss C. J., see Aaronson, D. A.

Kisliuk, P., *Optical Masers,* IRE, Binghamton, N. Y.; Research Soc. Am., Beacon, N. Y.

Kokinda, J. J., see Kaltenborn, P. J.

Kompfner, R., *Masers and Optical Masers,* IRE Washington, D. C.

Kunzler, J. E., see Wernick, F. J.

Kunzler, J. E., *Superconductivity in High Magnetic Fields at High Current Densities,* Intern. Conf. High Magnetic Fields, M.I.T., Cambridge, Mass.

Kunzler, J. E., *Superconducting Materials and High Magnetic Fields,* Conf. Magnetism and Magnetic Materials, Phoenix, Ariz.

Lally, W. J., *The Changing Pattern of Telephone Outside Plant,* U. S. Army Research and Devel. Lab. and Ind., Asbury Park, N. J.

Lo, W. C., *Effect of Hydrogen Firing on Mechanical Strength of Ceramics,* Am. Ceramic, Soc., San Francisco, Calif.

Logan, B. F., see David, E. E. Jr.

Long, T. R., see Schwenker, J. E.

MacLean, D. J., see Harvey, F. K.

Maita, J. P., see Wernick, J. H.

Mardis, T. E., *The Maser,* IRE, Greensboro, N. C.

Mason, W. P., *Semiconductor Transducers-General Considerations,* Acous. Soc. Am., Cincinnati, Ohio.

Mathews, M. V., *The Generation of Music with Digital Computers,* Federated Women's Clubs, Montclair, N. J.

Mathews, M. V., see Pfafflin, S.M.

Mathews, M. V., see Pfafflin, S.M.

Matthias, B. T., *Superconductivity and Ferromagnetism,* Intern. Conf. Magnetism, Kyoto, Japan.

Meitzler, A. H., *Ultrasonic Delay Lines Viewed as Elastic Wave Guides,* Physics Club of the Lehigh Valley, Allentown, Pa.

Menard, J. Z., see Bogert, B. P.

Millman, S., *Opportunities for Physicists in Industry,* Ninth Annual Sci. and Engg. Career Conf., Brooklyn College, N. Y. C.

Moore, E. F., *Is Artificial Intelligence Just Around the Corner?* Nat. Conf. Assoc. for Computing Machinery, Los Angeles, Calif.

Morin, F. J., see Wernick, J. H.

Moriya, T., see Peter, M.

Morrison, J., *An Ultra-High Vacuum System for Low Energy Electron Diffraction Studies,* Second International Cong. Vacuum Techn., Washington, D. C.

Murray, R. W., *Some Recent Work in the Field of Carbene Chemistry,* G. E., Schenectady, N. Y.

Olmstead, P. S., *Normalizing Transformations for Reliability Data,* Conf. Reliability Assurance Techn. for Semiconductor Specifi., Washington, D. C.

Patel, J. R., and Chaudhuri, A. R., *Oxygen Precipitation Effects on the Deformation of Dislocation-Free Silicon,* A.I.M.E., Detroit. Mich.

Peter, M., and Moriya, T., *Antiferromagnetic and Paramagnetic Resonance in $CuF_2 2H_2O$,* Conf. Magnetism and Magnetic Material, Phoenix, Ariz.

Pfafflin, S. M., and Mathews, M. V., *The Effect of Biased Stimulus Information on the Detection of Auditory Signal in Noise*, Psychonomic Soc., N. Y. C.

Pfafflin, S. M., and Mathews, M. V., *An Energy Detection Model for Monaural Auditory Detection*, Acous. Soc. Am., Cincinnati, Ohio.

Pierce, J. R., *Frequency Modulation with Feedback Receiver Performance and Modulation Methods for Satellite Communication*, URSI Symp. on Communication Aspects of Space Research, Paris, France.

Pierce, J. R., *Communication Applications*, Am. Rocket Soc., N. Y. C.

Pierce, J. R., *Non-Acoustical Means of Communications*, Acous. Soc. Am., Cincinnati, Ohio.

Pollak, H. O., *On the Nature of Applied Mathematics*, Union Junior College, Cranford, N. J.; U. S. Military Academy, West Point, N. Y.

Pollak, H. O., *Content and Philosophy of the SMSG First Course in Algebra*, Assoc. Teachers Math., Norwich, Conn.

Prestigiacomo, A. J., see David, E. E. Jr.

Rappeport, M. A., *Four Phase Data System Evaluation by Digital Computer Simulation*, A.I.E.E., Detroit, Mich.

Reizman, F., *Epitaxial Germanium Layers by Cathodic Sputtering*, A.I.M.E., Los Angeles, Calif.

Remeika, J. P., see Gossard, A. C.

Rothkopf, E. Z., *Criteria for the Acceptance of Self-Instructional Programs*, Am. Coun. Education, N.Y.C.

Saltzberg, B. R., and Sokoler, R., *A Multifrequency Data Set for Parallel Transmission up to 20 Characters Per Second*, A.I.E.E., Detroit, Mich.

Schroeder, M. R., see Sessler, G. M.

Schroeder, M. R., *Novel Uses of Digital Computers in Room Acoustics*, Acous. Soc. Am., Cincinnati, Ohio.

Schroeder, M. R., see David, E. E. Jr.

Schwartz, N., and Brown, R., *A Stylus Method for Evaluating the Thickness of Thin Films and Substrate Surface Roughness*, Second International Conf. Vacuum Techn., Washington, D. C.

Schwenker, J. E., *An Engineer's First Five Years in Industry*, Oklahoma State Univ., Stillwater, Okla.

Schwenker, J. E., and Long, T. R., *Support and Extension of the Rotational Model of Thin Film Magnetization*, Conf. Magnetism and Magnetic Materials, Phoenix, Ariz.

Schwenker, J. E., *An Electrical Engineer's Role in Device Research*, IRE—A.I.E.E., University of Oklahoma, Norman, Okla.

Scott, J. W., *Design of Fixtures for Shock and Vibration*, Inst. Environmental Sciences, New York Univ., N. Y. C.

Sessler, G. M. and Schroeder, M. R., *Sound Velocity in Slightly Ionized Gases*, Acous. Soc. Am., Cincinnati, Ohio.

Sherwood, R. C., see Geller, S.

Sikorski, M. E., *Esaki Diode Pressure Transducer*, Acous, Soc. Am., Cincinnati, Ohio.

Slepian, D., *Recent Results on the One-Sided Barrier Problem for Continuous Gaussian Processes*, Univ. of Calif., Berkeley, Calif.

Smolinsky, G., *The Chemistry of the Monovalent Nitrogen Species, Azenes*, Eastern Reg. Div., U. S. Dept. Agri., Philadelphia, Pa.

Sokoler, R., see Saltzberg, B. R.

Spencer, W. J., *Frequency Control Using Solid State Devices*, Kansas State University Manhattan, Kans.

Thomas, D. E., and Harvey, F. K., *A Cordless Voice Assist. System For A Small Auditori-um*, Audio Engg. Soc., N. Y. C.

Thomas, D. G., *Excitons in a Magnetic Field*, Westinghouse Pittsburgh, Pa.

Townsend, R. L., *Some Error Characteristics of a Data Communication System*, A.I.E.E., Detroit, Mich.

Treuting, R. G., *Effect of Heat Treatment on Nb-Zr Alloys*, Intern. Conf. High Magnetic Fields, M.I.T., Cambridge, Mass.

Tung, S. K., *The Influence of Process Parameters on the Growth of Epitaxial Silicon*, A.I.M.E., Los Angeles, Calif.

Van De Mark, W. J., *Communicating Ideas: The Modern Engineer's Function "Clearity and Simplicity,"* IRE, East Lansing, Mich.

Walker, R. A., see Bogert, B. P.

Walker, L. R., *Ferrimagnetic Resonance in Terbium Doped Yttrium Iron Garnet*, Conf. Magnetism and Magnetic Materials, Phoenix, Ariz.

Watson, B. J., see Flanagan, J. L.

Wernick, J. H., *Purification of Metals by Zone Melting and Very High Temperature Melting Techniques*, ASM Sem. Ultra-High Purity Metals, Detroit, Mich.

Wernick, J. H., Morin, F. J., Hsu, F. S. L., Dorsi, D., Kunzler, J. E., and Maita, J. P., *Evidence for a Critical Magnetic Field in Excess of 500 Kilogauss in the Superconducting V-Ga System*, International Conf. High Magnetic Fields, M.I.T., Cambridge, Mass.

Wertheim, G. K., *Radiation Effects in Semiconductors*, High-Power Accelerator Applications Symp., N. Y. C.

White, D. L., see King, J. C.

Whitney, W., *The New Line Concentrator 1A*, A.I.E.E., Detroit, Mich.

Wier, J. M., *Simple Data Transmission Terminals*, A.I.E.E., Detroit, Mich.

Williams, H. J., see Geller, S.

Yokelson, B. J., see Haugh, G.

PATENTS

Following is a list of the inventors, titles and patent numbers of patents recently issued to members of the Laboratories.

Ashkin, A.—*Low Noise Amplifier*—3,009,078.

Becker, J. A.—*Radiant-Energy Translation System*—3,011,058.

Beeler, T. L.—*Synchronized Multivibrator with Selectable Clamping Means for Rendering It Inoperative*—3,008,088.

Budenbom, H. T.—*Hybrid Ring Arrangement*—3,010,081.

Budenbom, H. T.—*Hybird Ring Network*—3,010,082.

Burcz, J. J.—*Dispenser for Pressure Sensitive Tape*—3,007,619.

Collins, R. W.—*Power Supply System*—3,009,089.

Courtney-Pratt, J. S., Mason W. P.—*Bearings of Reduced Friction and Fatigue*—3,088,773.

Darlington S.—*Guidance Control System*—3,008,668.

Darwin, G. P.—*Signal Synchronizing System Utilizing Adjustable Delay Apparatus*—3,008,-087.

Davey, J. R., Ostendorf, B. Jr., Pace, F. P.—*Route Translator for Telegraph Switching*—3,-009,014.

Davis, C. G. — *Semiconductive Scanning Device*—3,010,029.

Dunlap, K. S.—*Electrical Memory Circuit*—3,011,155.

Ebbe, G. L., Sperry, R. V.—*Equalizer*—3,010,087.

Ellwood, W. B.—*Rhodium Plating*—3,007,855.

Feder, H. S.—*Transistor Bilateral Switching Circuit* — 3,011,-074.

Gardner, M. B.—*Torpedo Control System*—3,010,417.

Gaunt, W. B.—*Constant Current Pulse Generator*—3,010,027.

Goodall, W. M.—*Electrical Stroboscope*—3,009,105.

Graham, R. E.—*Noise Suppressing Video Circuit*—3,009,016.

Gretter, R. W. — *Cable Engine Load Distribution Means*—3,-010,631.

Haring, H. E.—*Electrodes and Cell Containing Them*—3,007,-993.

Henning, H. A., Jacobitti, E., Lewis, B. F.—*Magnetic Drum Translator for Automatic Toll Switching Center*—3,011,029.

Jacobitti, E.—see Henning, H. A.

Ketchledge, R. W.—*Signal Comparison System*—3,011,151.

Ketchledge, R. W.—*Signal Comparison System*—3,011,051.

Ketchledge, R. W.—*Combination Radar and Thermal-Energy Detection System*—3,010,102.

Ketchledge, R. W.—*Signal Comparison System*—3,010,654.

Ketchledge, R. W.—*Signal Comparison System*—3,010,655.

Lazo, N.—*Test Circuit for Telephone Ringers*—3,009,992.

Lee, B. W.—*Monostable Circuits*—3,009,069.

Lewis, B. F.—see Henning, H. A.

MacPherson, D. H.—*Information Storage Arrangement*—3,011,-156.

Marcatili, E. A. — *Pseudohybrid Microwave Devices*—3,008,099.

Mason, W. P.—*Pulse Operated Reed Switch and Storage Device*—3,008,020.

Mason, W. P.—see Courtney-Pratt, J. S.

Mims, W. B.—*Tunable Two Mode Cavity Resonator*—3,009,123.

Moore, H. R. — see Ketchledge, R. W.

Mueller, G. E.—*Radio Control System*—3,010,416.

Ostendorf, B.—see Davey, J. R.

Pace, F. P.—see Davey, J. R.

Pfann, W. G.—*Strain Transducers*—3,009,126.

Pollard, C. E.—*Electrically Controlled Switching Device*—3,-008,021.

Reynolds, F. W. — *Solid State Light Sensitive Storage Device*—3,011,089.

Rogers, J. L.—*Magnetic Memory Circuit*—3,011,158.

Ronci, V. L.—*Electron Discharge Device*—3,011,084.

Sauter, J. F.—*Check Circuit for a Registration System*—3,011,-148.

Schwenzfeger, E. E.—*Spiral Error Checking System* — 3,008,-003.

Seidel, H.—*Microwave Isolator*—3,010,084.

Seidel, H.—*Isolators in Lumped Constant Systems*—3,010,085.

Seidel, H.—*Microwave Isolator*—3,010,086.

Sperry, R. V.—see Ebbe, G. L.

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B. C. Ellis, co-author of the article on Coil-Spring Connector, was born in Baltimore, Md. Prior to graduation from The Johns Hopkins University in 1948, he spent two years in the Naval Aviation Training Program. He began his Bell System career with the Baltimore Works of Western Electric, where he worked on the problems associated with the manufacture of paper and plastic insulated cables. In 1957 he transferred to Bell Laboratories at Baltimore in the Outside Plant Department, and has been involved in the design and development of apparatus for outside plant. Mr. Ellis is a member of Tau Beta Pi.

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C. J. Custer, the author of "The TJ Microwave Diversity Switch" was born in Pottstown, Pennsylvania, and now lives in Andover, Massachusetts. He received the S.B. degree from M.I.T. in 1929 and joined Bell Laboratories the same year. His initial assignment was on aircraft radio receiving equipment. In 1938, he transferred to the Transmission Systems Department where he was concerned with measuring equipment for television transmission and the L1 carrier. During World War II he worked on proximity fuses and radar and after that was assigned to work on pilot regulators for the L3 coaxial sys-

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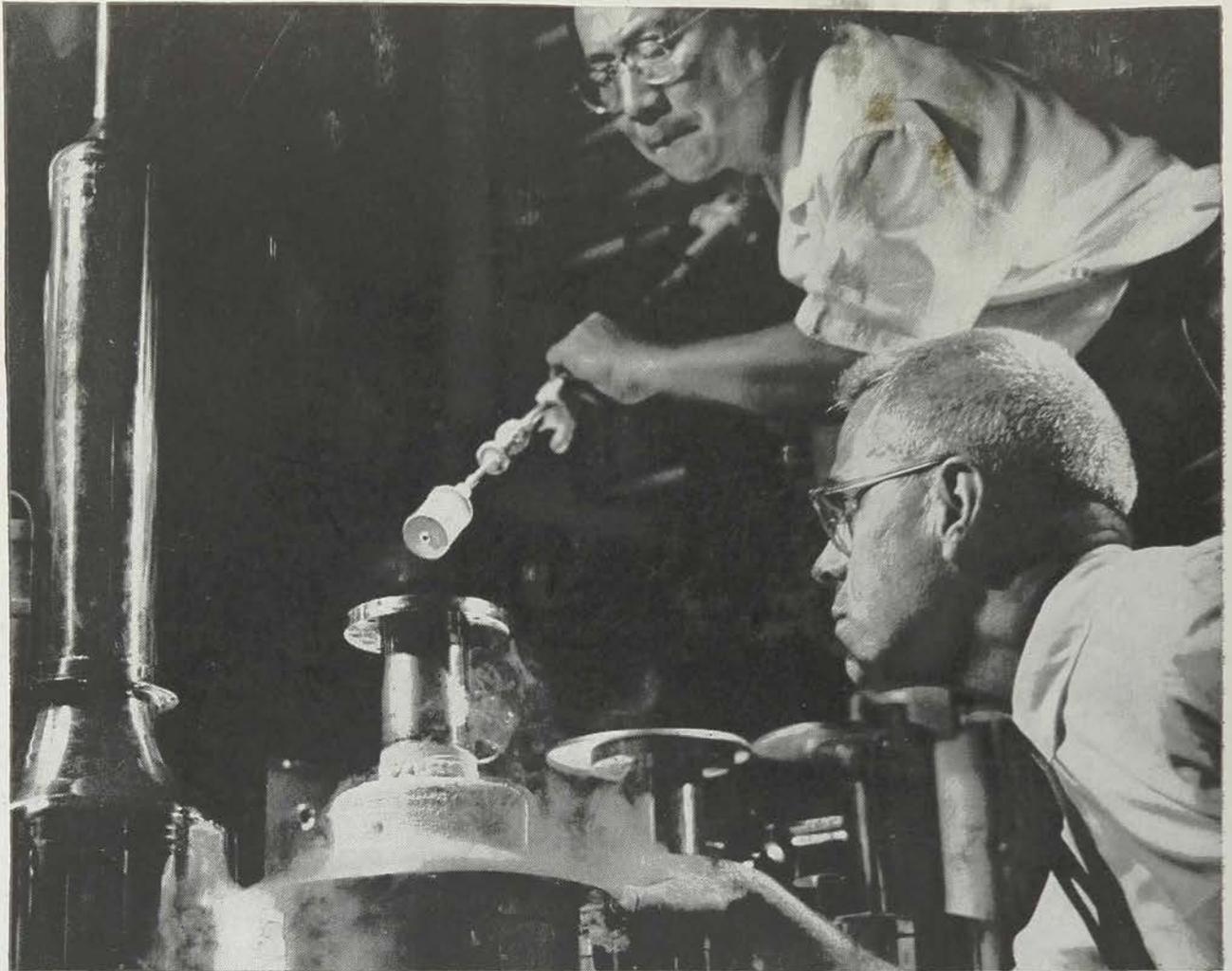
The Making of a Magnet. Bell scientists test new superconducting electromagnet, the small cylindrical object being removed from helium bath at minus 450° F. An early experimental design produced a field strength over 65,000 gauss.

OUT OF SOLID STATE SCIENCE COMES A POWERFUL NEW MAGNET

Bell Telephone Laboratories' creation of a powerful superconducting electromagnet once again illustrates the role of materials research in the advancement of communications.

It has long been known that certain materials called superconductors have a zero electrical resistance at temperatures near absolute zero. A solenoid of superconductive wire carrying a large current should be capable of producing an extremely powerful magnetic field without the bulky power equipment that is needed for conventional electromagnets.

A formidable obstacle blocked the way, however. The strong magnetic field tended to destroy the wire's superconductivity.

Bell Laboratories scientists studying superconductors—as part of their endless search for new materials for communications—were led to the discovery of a number of alloys and compounds having exceptional superconductive properties. One of these materials, a compound of niobium and tin, was found to possess a startling ability to retain its superconductivity in intense magnetic fields of over 100,000 gauss. Bell scientists went on to show how the brittle, intractable material could be made into a wire and wound to form a powerful electromagnet.

By finding a low-cost way to create enormously powerful magnetic fields, Bell scientists have brought closer new applications of magnetism in communications. Intense magnetic fields provide an invaluable tool in research, and offer an attractive means for containing hot plasma in thermonuclear experiments.

The new magnet is another example of how Bell Laboratories research not only works to improve Bell System communications but also benefits science on a broad front.

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