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Bell Laboratories RECORD

ECHO I PASSES HOLMDEL

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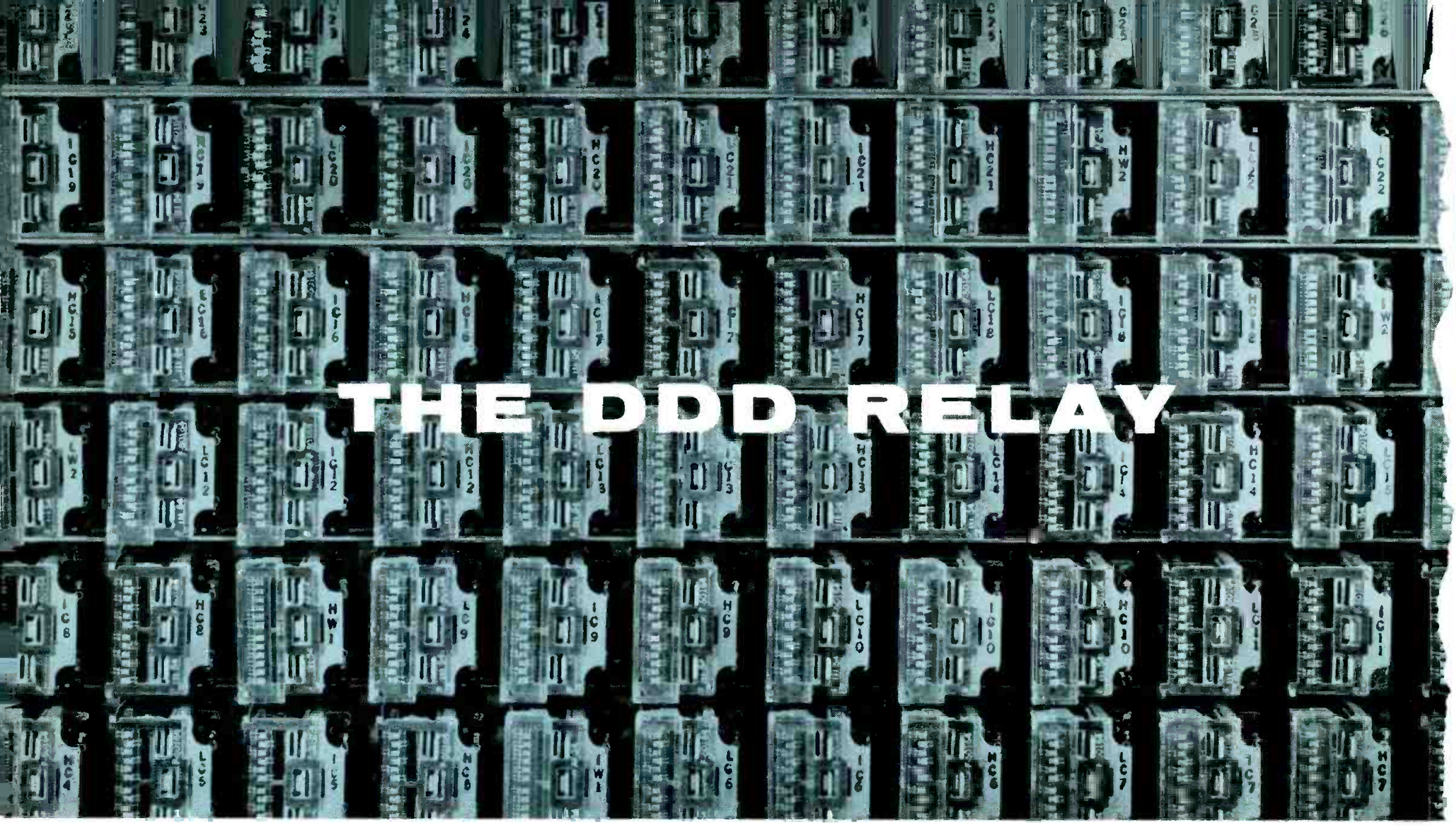
Cover

At Bell Laboratories radio-research center at Holmdel, N. J., the transmitting antenna—the "voice" of the Echo I—tracks 100-foot balloon across the night sky. Path of the satellite is visible as long white streak, upper left. (See page 334.)



THE DDD RELAY

A. C. Keller

The "DDD" relay—"Deluding" to the designer, "Difficult" to the developer, and "Delightful" to the systems engineer—has the time-tested attributes of versatility, reliability and economy. As a result, relays have become the mainstay of practical communications systems and are one of the most extensively used devices in the telephone plant.

Pinball machines, racetrack totalizers, numerically controlled milling machines, and the Bell System all have something in common. The link between these strange companions is a device in which all have a vital interest and relatively large investments—the "DDD" relay.

The American Standards Association has this to say about a relay—"A relay is an electrically controlled device that opens and closes electrical contacts to effect the operation of other devices in the same or another electrical circuit." A definition of the "DDD" relay, however, cannot be found in technical reference books, nor for that matter, in any library. It does not refer to a three-dimensional device, nor is it meant to imply Direct Distance Dialing. What we have done in this story is take the liberty of describing a relay with three unique adjectives—Deluding, Difficult, and Delightful! Later, these weird adjectives will be explained and justified. The explanation should especially interest those who have worked with relays for many years and know their many useful applications.

Relays go back to about 1878 when telegraphic devices were modified for use in very simple switching circuits. In the intervening years, engineers in many organizations have been improving relays and bringing out new forms. In the Bell System, particularly at Bell Laboratories, there has always been a substantial development program to improve electromechanical relays. In the communications industry, relays have always been basic to switching equipment, and in recent years other industries have increasingly used them in many forms. These latter applications are often called "automatic control."

How important relays are to the Bell System can be judged readily by the fact that something over 30 million of them are manufactured each year for Bell System equipment. This is more than the combined output of all other relay manufacturers in the United States. As one result of this volume, Bell Laboratories periodically has developed, and the Western Electric Company has put into large-scale production, new general-purpose relays. This has meant large investments in development and in manufacturing facilities. But experience has shown that these are more than justified—economically in improved relay performance, and sometimes in the always sought lower cost of apparatus as well.

For example, about 1917 the Operating Companies began using the "E-type," or flat-type, relay for manual switchboards and other switching circuits. About 1936, they installed another type, the "U-type," because an improved relay was needed in the then new common-control systems, notably the No. 1 crossbar system. U-type relays provide more contacts and much longer life in terms of the number of operations than do the E-type. Their mechanical life is approximately 100-million operations.

About 1952 the Bell System turned to the "wire-spring" relay as a new general-purpose relay for all types of switching circuits. The need here was for an even greater life—approximately one billion operations. Also needed was faster operation and better sensitivity, particularly in high-speed, common-control systems such as the No. 5 crossbar system.

An entirely different kind of relay—one with its contacts enclosed in glass—was developed quite a few years ago and first put into use for coaxial-cable switching at Stevens Point, Wisconsin. Later, came the glass-enclosed contact relays, some with liquid-mercury contacts and others of the so-called "dry-reed" type. These were used in Bell System applications to military work. Many of these glass-enclosed devices saw action during World War II where other types of relays were not adequate. After the war, several forms of glass-enclosed contact relays were introduced in the Bell System, particularly for No. 5 crossbar and other major switching equipment.

The wire-spring relay and the relays using glass-enclosed contacts are related through similar and interesting origins. About 1935, Dr. Oliver E. Buckley, who later became President of Bell Laboratories, wanted to stimulate fundamental development and invention that would eventually lead to a new and improved general-purpose relay. To do this, he spoke to H. C. Harrison and W. B. Ellwood about the problem. Both of these men, creative and inventive members of the Laboratories, were soon on their way to carry out the broad and general instructions Dr. Buckley gave them. However, they did not go in the same direction even though their instructions were presumably the same.

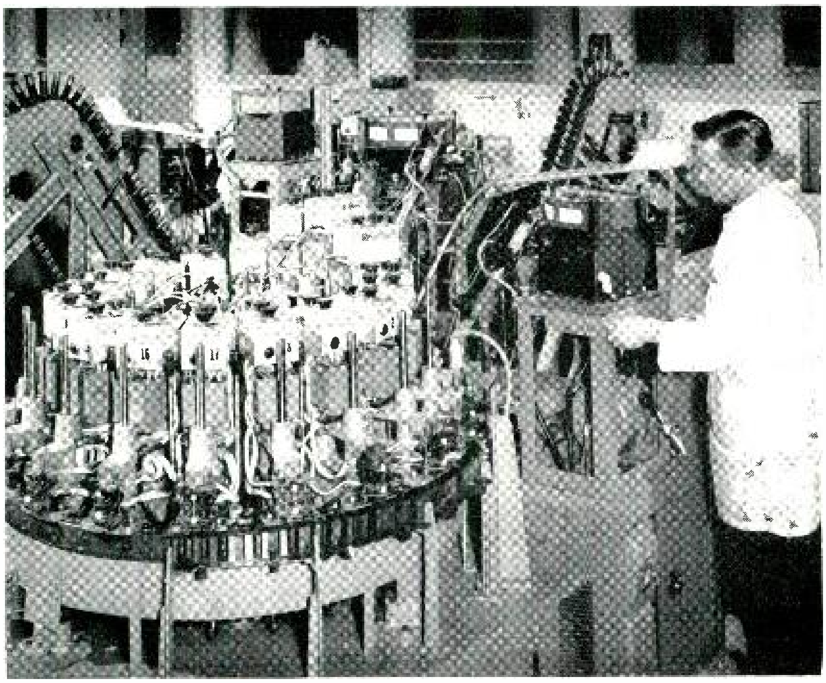
Different Design Approaches

Henry Harrison visualized, as the best solution, a "code-card" operated relay using wire springs to carry the contacts. The design permitted a high degree of mechanization in manufacture and assembly, which in turn realized the desired low costs. This work eventually led to the family of wire-spring relays now in large-scale production. Wire-spring relays are presently one of the standard general-purpose relays in the Bell System for all its telephone switching systems. Almost eight million of them are made annually, and this figure may double in the years ahead.

In contrast to Harrison's approach, Walter Ellwood saw the ultimate in reliability in a glass-enclosed contact containing the cleanest and best atmosphere, completely free of outside influences such as dust and dirt. He also visualized low manufacturing costs and product uniformity through a high degree of mechanization. His work also led to a family of relays, in this case with glass-enclosed contacts. These are also now being produced and used in large quantities. For example, the Western Electric Company is making annually more than three million of one glass-enclosed type, and this figure may also double in the near future.

It is interesting to look back and note that the very close cooperation of Laboratories and Western Electric engineers during the development and design period of both the wire-spring relay and the glass-enclosed contacts resulted not only in new relay designs but also in new manufacturing methods. These methods have been judged to be among the most advanced examples of mechanization in modern industry.

Now let's get back to our strange adjectives. First, "deluding" is apt because a relay can be thought of as misleading—it is not one device, but many. Equipped with a single contact, it sometimes can be operated as a sensitive relay in the milliwatt, and even microwatt, range of power. At other times, it takes the form of a



Machine for automatic production of dry-reed switches in Western Electric Co. plant at Allentown, Pa. Western manufactured over 2½ million dry-reed switches in 1959.

heavy-duty device with dozens of contacts. In some forms, the relay may operate with microsecond pulses. In others, it may be required to release slowly—a matter of one second or longer.

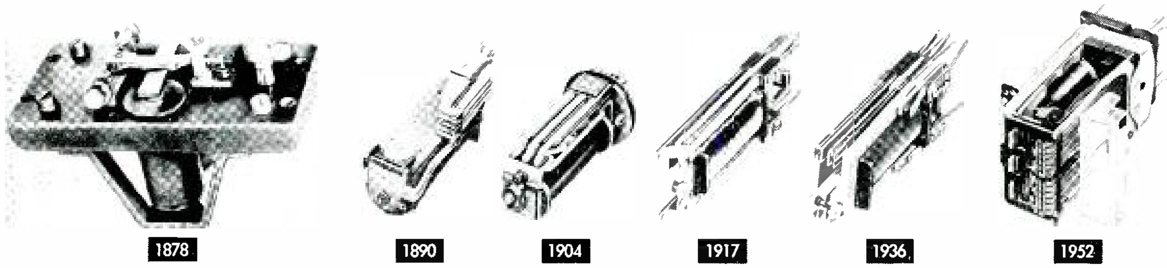
Relay Applications

Sometimes a relay must be very small, like those in military missiles. Yet it must withstand the severe environmental conditions of shock and vibration together with a wide range of temperatures. In a guided missile, a relay may not be required to operate very often, but it must operate with certainty and with its advertised properties the first time it is required to do so. By contrast, telephone central office applications may require a relay to operate a billion times. Some relays must make and break rather large currents and this may cause arcing at the contacts with consequent electrical erosion. On the other hand, some relays may never break or make current, but this raises other physical problems.

Another deluding feature has to do with the seeming simplicity of a relay. It is correct to call it a simple device which is either operated or nonoperated, and so has merely two positions, or states. But in groups, relays can do things that are far from simple. They can, for example, play games, such as Tic-Tac-Toe, and never lose! The "on" and "off" states are often referred to as corresponding to "yes" or "no." And it is not difficult to see that logic operations are possible by a collection of relays wired together in a circuit, each element answering yes or no.

All of this may still seem simple, but let us examine it more closely. We have already noted that some relays operate very fast, and some operate slowly. In addition, some have contacts which make, some which break and some have both. Some have one contact and some have dozens of contacts. Furthermore, by properly wiring a number of these "simple" relays together, engineers can make them do some interesting things that have been likened to parts of thinking machines or even to certain functions of the human mind itself. There are, for example, simple basic circuits that perform such logic functions as "and," "or," and "not." In larger groups, simple relays wired together perform functions such as counting, registration, and programming. These are switching functions, and when they are put together as systems, they become computers, control systems, business machines, racetrack totalizers, pinball machines, and most important to the Bell System, they become telephone switching systems. For all of these reasons, the adjective "deluding" has been chosen.

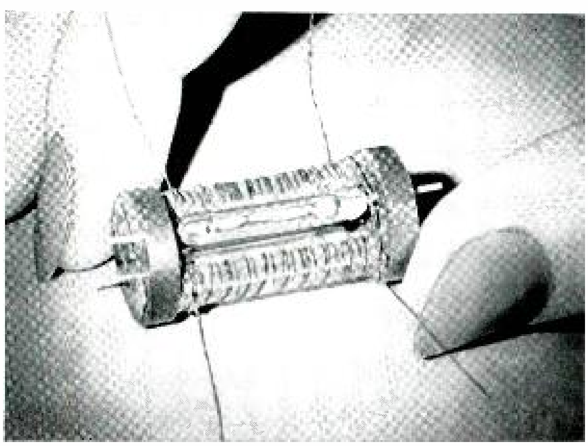
Development engineers concerned with relays are more likely to use another adjective—"difficult." A relay has certain basic and fundamental problems associated with its operation and use which have never been fully solved. This is true



Some steps along the road to modern electro-mechanical relays. At left is telegraph key modified for telephone circuits. Device labeled 1890 depicts first step-by-step telephone switching relay. Next is relay of early manual switching systems, followed by first version of flat-type device. 1936 device depicts crossbar systems relay. At right (1952) is today's widely used wire-spring relay.

even after more than 80 years of continuous study, development, and improvement. Even now there are things about the relay we do not understand as well as we would like. One thing is the action of the electrical contact. This is a problem in fundamental physics and chemistry and involves, on the one hand, the study of electrical discharges in gases, and on the other, the formation of organic polymers on metallic contact surfaces. Both of these problems are a real challenge to basic research in modern day physics and chemistry.

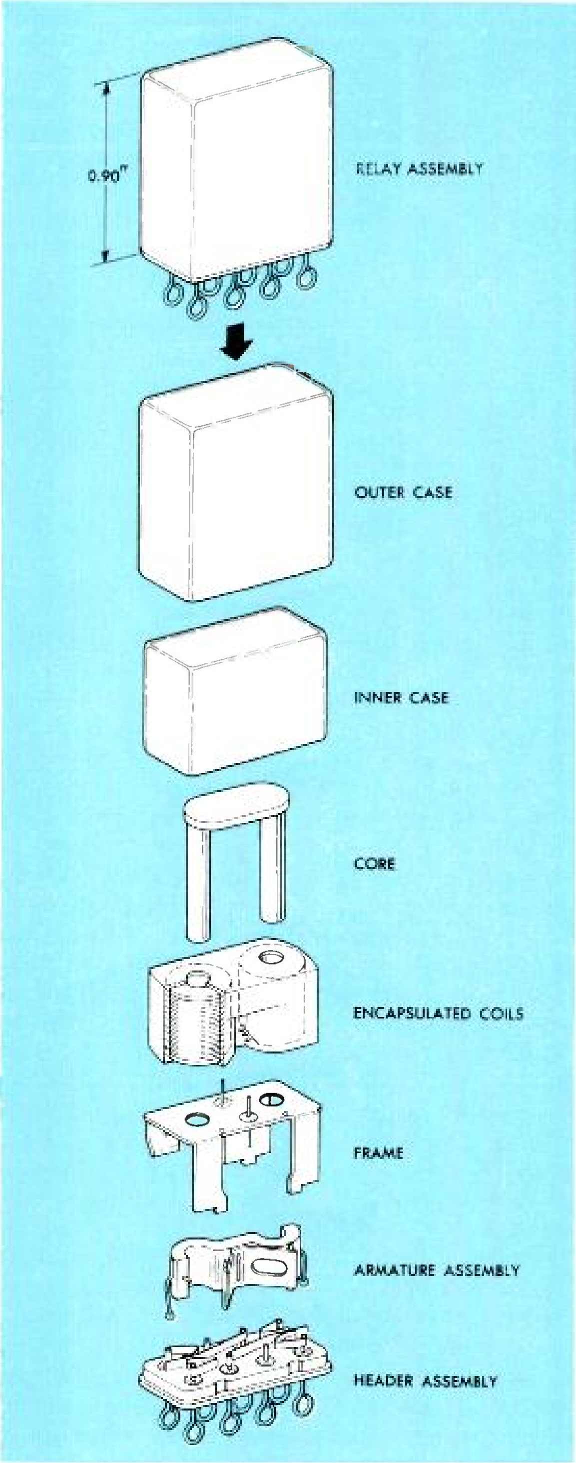
The first part of this problem—electrical discharges, or arcs—involves excessive erosion of the relay contacts. This seems to be closely associated with the basic physics of electrical arcs. For example, theoretically, the minimum arcing current for clean palladium contacts is 0.7 ampere, but in practice any current above 0.1 ampere will usually initiate an arc. In these "activated" conditions, the contacts become good emitters of electrons and therefore are more subject to arcing.

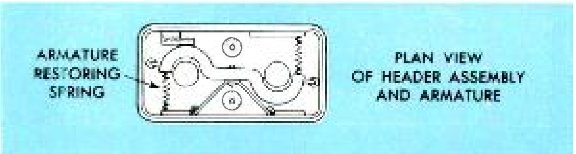


A ferreed consisting of two ferrite bars, two glass-sealed, magnetic-reed switches, and two plastic "magnetic" end pieces as major parts.

The other part of the contact problem—the formation of polymers—exists under diametrically opposite conditions. On some nonarcing contacts, such as those made of palladium or metals in the platinum family, there sometimes appears a brown amorphous organic deposit. We believe this is caused by the metals rubbing together in the presence of low concentrations of organic vapors. Formed by a wide variety of organic materials, the deposit is thought to involve "chemisorption" of the vapor on the metal together with frictional activation and polymerization of the chemisorbed layers to form the so-called "brown powder." This has been particularly troublesome in designs where relays have been enclosed in hermetically sealed containers. We've found the contact resistance increases and becomes excessive when this type of relay is put into service, and in many cases we've found the service is poor compared to that given even by unsealed relays. Only by complete elimination of organic materials in the contact chambers can these effects be avoided.

Another fundamental problem of relays involves the basic mathematical equations describing the action of the simple form of a relay. These equations take the form of two simultaneous differential equations, one for the mechanical "mesh" of the relay and the other for its electrical "mesh," each with an electro-mechanical coupling factor. These equations have never been solved, except by approximations, because the coupling factors between the electrical and mechanical meshes are nonlinear. Of course, we've proceeded anyway, mainly by approximations, with experimental verification, and sometimes by numerical solutions obtained from general-





purpose computers. At one time, the Laboratories gave serious consideration to designing a special analog computer to solve the differential equations for relays.

There are other matters to make the so-called simple relay "difficult"—for example, reliability. Presumably, if a relay in a pinball machine fails to operate when it should, the result merely will be a delighted or disgruntled player. However, for more sophisticated applications, a relay must operate or release without fail every time it is called upon. Such is the case in a guided missile where relays must operate after days or even months in storage. Some Bell System relays are expected to operate one billion times—a very large number in any frame of reference, corresponding to about one operation every second for almost 40 years. This leads to some very strict design requirements, as in the case of the wire-spring relay. Here, the need for reliability in one billion operations resulted in a number of detailed requirements. For example, one specified that whenever any two contacting parts of the relay touch each other, they should never slide more than 1/1000 of an inch. The high degree of reliability required in relays for Bell System common-control switching systems may be evident by considering a single telephone connection between two customers. Such a connection uses, for a very short time interval, about 1,000 relay operations involving a total of about 7,000 contacts.

Development of the wire-spring relays, led to new methods of measurement and new designs for several electrical, mechanical and magnetic parameters. These new methods, with associated material used in Bell Laboratories Training Courses for electromechanical apparatus, were published in a book, *Switching Relay Design*, by two members of the Laboratories, R. L. Peek and H. N. Wagar. First published in 1955, it is a unique book in its field.

The third "D" in our definition of the DDD Relay is for another rather weird adjective—"delightful." This seems suitable because relays are constantly being invented in new forms, with additional and better characteristics. Thus they become more useful, compatible, and competitive, even in the present age of solid-state devices.

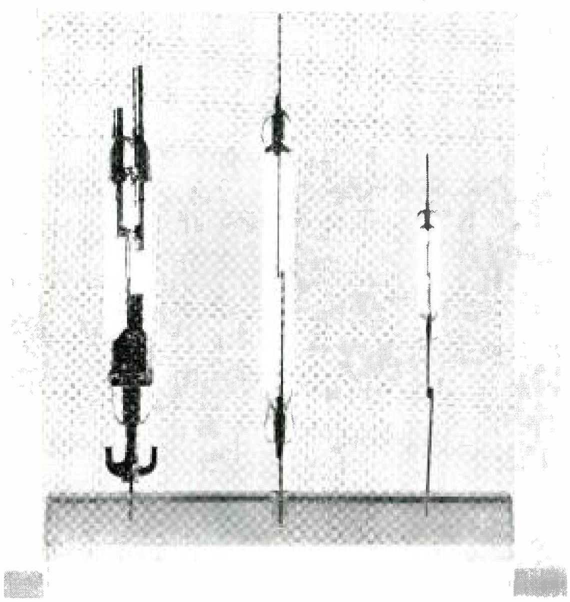
One "delightful" aspect of the relay is its use as a dc power amplifier. In this case, a low-level dc input operates the relay and substantial

◀ *The "crystal can" relay—a specially designed compact relay used in military missile systems.*

power passes through its contacts. As a result, it is possible with a single relay to get a particular kind of dc power amplification of about 80 db. By "cascading" relays in stages, larger power gains may be had without too much difficulty. People who work with dc amplification appreciate the advantage of this simple form.

Another delightful experience with relays is to watch them, old as they are, being constantly developed into new and better forms. The most recent example of this is the "ferreed," a device that uses one or more miniature, glass-enclosed contacts in combination with several pieces of ferrite material. Before describing this further, we might go back and examine an earlier statement about different types of relays having a variety of speeds of operation or release. On the fast side, the best operating time for a wire-spring relay is about three milliseconds, and the 224A glass-enclosed contact in a relay will operate in about one millisecond. In the ferreed, however, operating pulses as short as *five microseconds* can be used to operate the contacts. This is the time required to change the state of the ferrite to a magnetized condition. Later, perhaps ½ a millisecond, the dry-reed switch operates.

Another way to describe the ferreed is to say that it is basically a "magnetically latched" relay that pulses can operate or release. The magnetically latched relay is particularly important because it is a form of relay compatible with the solid-state devices with which it must work in modern switching systems. In fact, the basic properties of the ferreed—sealed metallic contacts, control times in the microsecond range, coincident selection; memory without holding power; and small size—make it ideally suited as a crosspoint in telephone switching networks of the "space-division" type. Applications lie in such directions as the Electronic Central Office.



A family of glass-enclosed contacts. At left is the 218A mercury switch. In center is a dry-reed switch known as the 224A. At right is type of reed switch considered for use in the ferreed.

Why Relays Remain Popular

It may seem strange, in a period when transistors, diodes, and other solid-state devices are taking over so many switching functions, that there are more relay manufacturers in the United States and more relays made and purchased by the Bell System than ever before. But there are several good reasons for this.

First, as in many technical areas, often several devices can be used for some particular project. The final choice is made in terms of many factors, such as speed, size, power, and life, and perhaps most important, the cost. Relays often result in equipment designs which are simple and inexpensive, and yet operate fast enough to make unimportant any increase in operating speed.

Second, relays, can be used in circuits singly and in small numbers without the associated common equipment often required to take full advantage of the sensational speeds of solid-state devices. In addition, what might be called the input and output circuits are completely isolated in relay circuits, a condition not easy to achieve with many of the new solid-state devices.

The third reason for large-scale use of relays is the rapidly expanding applications for all kinds of switching tools. This requires more of everything, including many kinds of relays and solid-state devices. Finally, relays and solid-state devices are developing a "compatibility" and, in fact, combinations of both as illustrated in the new ferreed are the best examples of this. Again, cost factors often dictate the use of each.

Whatever the future of the relay may be, there is one thing certain. Bell System earnings, for many years to come, will be based on central-office and other equipment using electromechanical relays. The Bell System now has some 500,000,000 relays in the telephone plant, used to serve some 58 million telephones. Much of this equipment, designed to last 40 years, has a long life ahead of it.

By simulation with a large-scale digital computer, engineers at Bell Laboratories can now evaluate the stored programs, or built-in intelligence, of experimental electronic switching systems long before such systems are actually built.

W. A. Budlong

Simulating Electronic Switching With a Computer

The speed and versatility of modern, general-purpose digital computers have made it possible to simulate the operation of large and complex systems that have not yet been built in their final form. At Bell Laboratories and elsewhere, computer simulation techniques are proving to be valuable aids in the development of experimental systems.

As part of a continuing program of study of such techniques at the Laboratories, switching systems development engineers have undertaken the simulation of an experimental electronic switching system (ESS), or electronic central office (ECO). This simulation project is specifically directed toward the use of digital computers as an aid in the evaluation and perfection of new stored programs for telephone switching. By computer simulation, "calls" were put through an experimental ESS some time before the proposed equipment was built.

This article will describe briefly some of the techniques involved in the simulation of an ESS on a large-scale computer. These simulation techniques were designed chiefly to test the logical performance of the stored program for the ESS, not to test the design of system hardware or traffic capabilities. Logical performance, in somewhat simpler terms, means: were the proper connections made in response to dialed information?

Simulating the procedures of the control portion of an ESS on a large-scale digital computer, though complex in detail, is relatively straightforward. An electronic switching system is very different from a large-scale digital computer in many ways. A good example of these differences is that the computer is not organized to perform tasks within the different operating-time requirements of an ESS. There is, nevertheless, a basic similarity in operation between the control elements of an ESS and a digital computer. As an introduction to the actual simulation techniques, it would be well to consider first, in some detail, these basic similarities. The diagram on page 330 will be helpful in following this discussion, since it shows in block form the basic units of both the ESS and a computer.

In the experimental ESS, (RECORD, *October, 1958*), the lines of all customers terminate in concentrator switches. These, in turn, connect the customer to either side of a switching network. Through this network, he can then be connected to any other line or to any one of a group of trunks that terminate directly on the switching network. Ringing tones to both the called and calling lines of a connection are provided through the signal switches when required.

The switching network is controlled by the network marker, while a concentrator marker controls the concentrator and signal switches. These markers "end mark" the desired connections, but to do this they require "put-up" or "take-down" indications and the specific locations in the network of the lines or trunks involved. Instructions of this kind are supplied by the central control.

Incoming lines and trunks are examined by a scanner for changes in status that convey origination, termination and dialing information. The scanner then conveys its indication back to central control for interpretation. Outgoing trunks often contain some relay circuits operated by central control through the signal distributor.

Central control (RECORD, *February*, 1960) initiates all of the actions of the system on a time-sharing basis, moving from one task to another at microsecond rates. Associated with the central control are a temporary, erasable memory and a semipermanent memory. In early versions of the ESS, including the one currently being prepared for trial in Morris, Illinois, the temporary memory is a "barrier-grid store" (RECORD, *December*, 1959) and the semipermanent memory is a "flying-spot store" (RECORD, *October*, 1959). The semipermanent memory contains two types of information: (1) "translations"—such as those associating a customer with a particular class of service or relating his directory number to an equipment number; and (2) the "stored program"—the coded orders that control the entire system.

The stored program is a set of rigorously defined orders, coded in a form that the system can readily use. The orders are stored in a group of memory locations with specific "addresses." When addressed and read out by the control system, an order causes one of a limited number of specific actions at a location usually specified by part of its code.

In effect, this program stored in the semipermanent memory is an "instruction book" describing all of the required operations in a machine language. Central control might be likened to a man of limited capabilities who can read only these machine-language instructions, but can carry them out rapidly and precisely. After completing each instruction, he must go back to the book to find out what to do next.

By having a sufficiently long instruction book, even though it might be written in a language of limited vocabulary, it is possible for him to accomplish an endless variety of tasks. A man could not possibly execute instructions rapidly enough to do the many jobs needed to control an entire switching system. But modern logic cir-

The author, left, and Miss D. M. Habbart review results of simulation run. Papers are, from right to left: data sheets printed by computer, folder containing order-sequence charts, and data input cards.

cuitry, working at microsecond rates, can handle data fast enough to interpret incoming information and set up calls accordingly (RECORD, *April*, 1960).

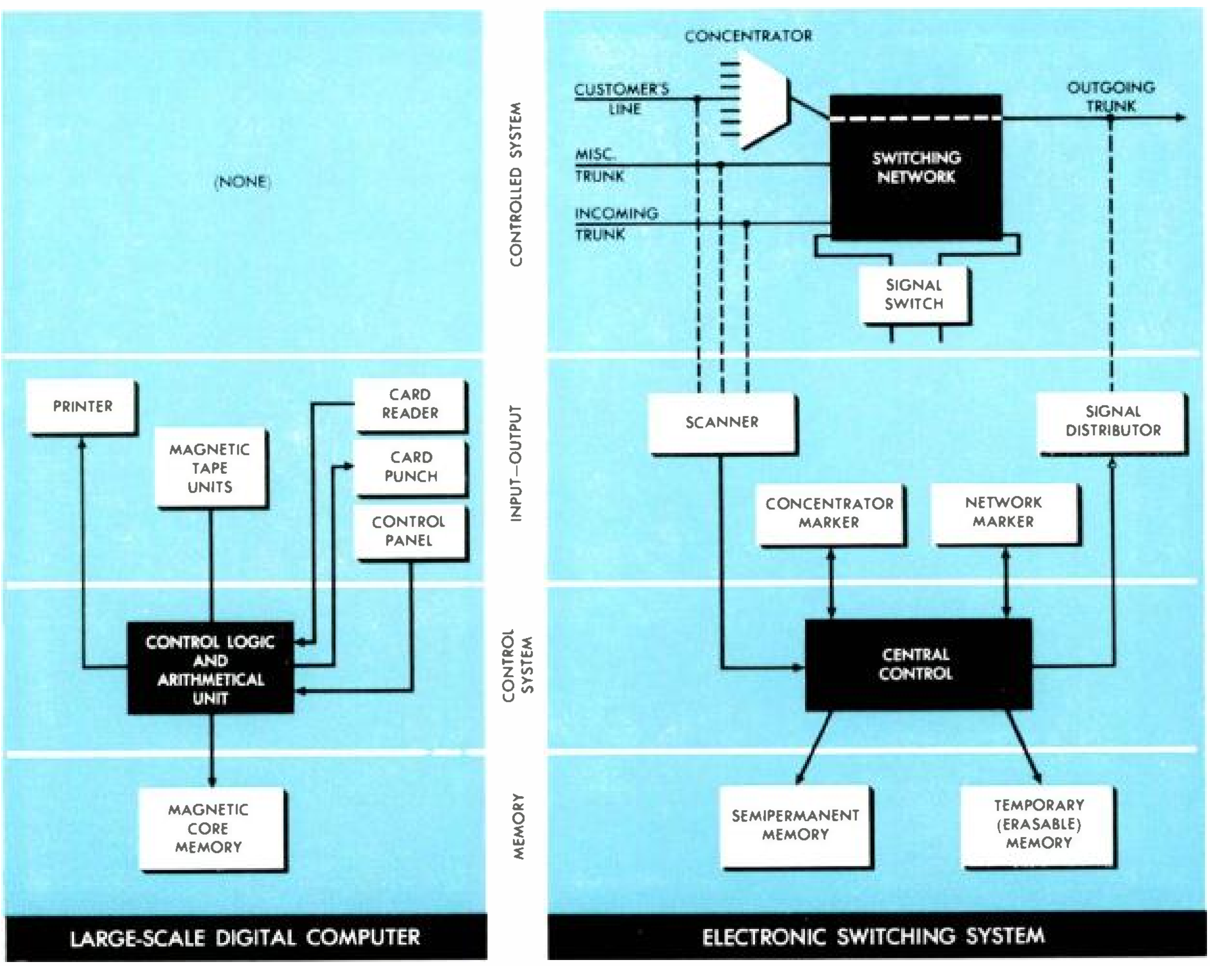
The same instruction-book principles apply in large-scale digital computers. All modern computers have a large memory, which stores instructions, and a control mechanism that executes them at very high speeds. A previously prepared set of such instructions—the computer's stored program—causes the computer to act in a way prescribed by the programmer in his instructions.

Computer Memory

In the general-purpose computer, the entire memory is usually of the erasable type and is organized into words of a standard length. The same memory stores both the program instructions and the temporary data that the program uses. The IBM 704 computer at the Whippany Laboratories and the IBM 7090 computer at the Murray Hill Laboratories have an erasable memory of 32,768 (2^{15}) words of 36 binary digits each. Words can be instructions, addresses, or data, or combinations of all three.

In its vocabulary, the computer contains many types of instructions that allow logical manipulation of data rather than routine arithmetic operations. These logical instructions are used extensively in simulation programs. Actually, there are over 100 different types of instructions in the computer's vocabulary, and each of these can be interpreted and executed by the control, arithmetic and logic units. The basic memory system of the computer is constructed of magnetic cores, and its capacity and versatility can be further expanded by the use of magnetic tapes. These augmenting tapes can be read into or out of the memory by suitable orders.

Information is put into the computer by a card reader, which reads data that has been punched



This diagram compares the important elements of an ESS with those of a digital computer. Incoming and outgoing lines and trunks appear on both sides of the switching network in the actual ESS.

on business-machine cards. Usually, this punched data is first transferred to magnetic tapes and put into the computer in this form. Peripheral equipment associated with the computer prints out the results, at high speeds, on large data sheets, shown in the photograph on page 329.

Thus, the basic similarities between the computer and the control portion of the ESS are: large memory for the storage of programs and data; a central control for executing the sequence of operations; and input and output mechanisms that can readily translate data to or from machine language. The relationship of these similarities, by units, is shown in the diagram mentioned earlier.

The fundamental simulation problem is to write a computer program that will cause certain outputs which, by interpretation, describe connections or other system actions performed in response to customer actions. These actions—releasing the switchhook, dialing, hanging-up, and the like—can all be simulated by properly sequenced inputs to the computer.

A portion of the computer's memory is assigned as a set of "images" of various information-storing sections of the ESS (*see diagram on page 332*). These image sections of the computer memory store the same type of information contained in the various ESS elements, and are arranged to react the same way. Another portion of the computer memory is devoted to a computer program which interprets and executes the stored program of the ESS in the same way that the central-control circuitry of the ESS would.

The electronic central office sets up real connections between telephone lines. By contrast, the computer makes its "connections" by marking its own memory, in the proper image. Whenever a network connection is changed, the computer prints out an interpretation of its memory in a way that shows the human simulator what connection has been established at that time.

A certain section of the computer's memory is assigned as the image of the temporary memory. Another section serves as the image of the semipermanent memory and contains, in binary form, the ESS orders normally stored there. A separate section of the image of this memory system contains translation information. Still another section of the computer memory contains bits of information that tell the present status (on-hook or off-hook) of customers' lines and the condition of various trunks in the office. This is called the scanner image because the output of the simulated scanner depends on the information stored in its image. When a customer originates, dials, answers or terminates calls, his actions can be simulated by properly "marking" the scanner image. In doing this, the programmers must consider the time relations for defining interdigital and interpulse times (RECORD, *December*, 1958).

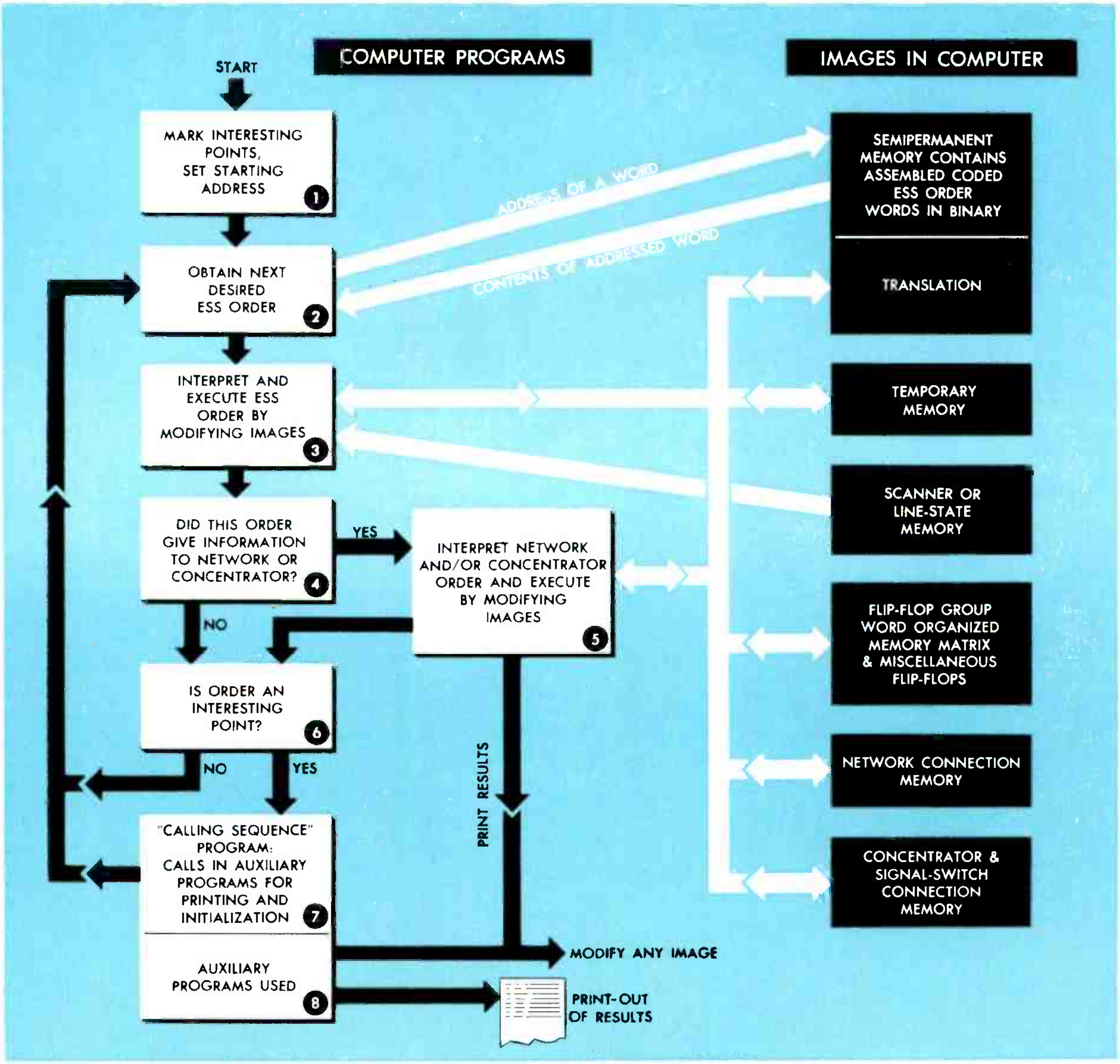
The controlled portion of the system—the switching network—is imaged by a section of the computer memory that remembers what connections are made among which lines and trunks. It is possible to trace all connections that have been made by reading out the information from this image. The sequence of a typical simulation run on the computer is shown in the full-page diagram on the next page.

In the central control of the ESS, there is a so-called "flip-flop group matrix," which is a set of flip-flop circuits that form a word-organized memory capable of storing 16 bits of information in parallel. Nearly all of the information processed by the central control passes through this matrix. Central control also uses a group of miscellaneous flip-flops. All of these flip-flops in both groups are directly imaged by a section of the computer memory.

Action on Orders

The data in all these images are static until manipulated by simulated execution of ESS orders. Hence the computer's instructions must interpret the ESS orders and cause the indicated action in the proper image. For example, the ESS order W1Y-6 means: write 1 in the temporary memory (in this case, the barrier-grid store, or BGS) at the Y address 6 and the X address given by the contents of the BGS flip-flop group. This order would appear as a coded, 20-bit word in the image of the semipermanent memory. The computer's instructions would interpret this order as: "go to the BGS image at the Y address 6 and the X address given by the contents of the BGS flip-flop group, and then write a 1 in the BGS image."

There are more than 70 different types of ESS orders of this kind, and each of these is executed by a program of instructions in the computer, just as the W1Y-6 order was. The simulated execution of any individual ESS order requires the execution of 50 to 150 computer instructions. The ESS executes one of its own orders in just a few microseconds, and the computer requires about 24 microseconds to execute one of its own instructions. Since an average of 100 computer instructions is required to complete a single ESS order, the time required by a simulation run is about 1000 times that required for the same



This block diagram shows broadly the progress of a simulation run. All of the information in the images is written into the memory section of the computer and remains there, unchanged, until modified or read out by the computer program. The program portion of the simulation run is executed by the arithmetical and control units of the computer working on the various images.

The progress of the program is in most cases shown by the black flow lines. In general, the white flow lines indicate an exchange of information between the program and the images. For example, the second program (2) sends the address of an ESS word order stored in the semi-permanent memory image to that image, and the order is returned. It then passes the ESS order along for interpretation and execution. To do these two jobs, the next program (3) must interrogate or modify the images of several units of the ESS, as shown.

The next two programs on the left (4) and (6), are primarily logic instructions that call in other orders after a "yes" reply. If the ESS order gives information to the network or the concentrator—the portions of the system which physically connect customers—the middle program (5) is called on to interpret these orders or modify the images.

Near the end of the computer program is the "calling-sequence" program (7). This is used only with certain special instructions and to call in the auxiliary programs when required. It is not a part of the main simulation program. As the flow arrow at the left suggests, the "next-order" program (2) is the key instruction in the computer program in that it keeps the entire simulation program moving along.

operations in the actual electronic central office.

The ESS uses another type of orders to control the switching network and the concentrator and signal switches. A computer routine simulates this control action and properly modifies the portion of the network image that remembers all connections in the system. Whenever a connection through the network is put up or taken down, a print-out is made. A series of such print-outs will give the entire history of a particular call. Similar print-outs are also made when the signal distributor is operated.

To check the specific details of the stored program of ESS, programmers have frequently found it desirable to be able to find out what is going on in some image. In other words, they want to be able to insert a computer program that will print out some of the information contained in any image. To do this, the programmers use a system of so-called "interesting points." At any of these interesting points, a computer program can be inserted that instructs the computer to print out some portion of its image. Any order in the ESS program can be temporarily marked as an interesting point and linked to a print program.

Another type of operation that is frequently necessary is "initialization," or the setting up of a certain pattern of bits in some image. For example, it is often desirable to make a register (a device for temporarily recording numbers) within the temporary memory appear as it would at a certain point in a call. If the proper address in the semipermanent memory is initialized, it is possible to start executing the stored program of the ESS at any point in the program. Initializing the scanner image simulates customers' actions as noted above. Initializations are also linked to orders marked as interesting points.

When initialization, interesting points and the other procedures discussed above are combined into a unified system, simulation becomes a very flexible tool for assuring the correctness of the stored program to be used in the experimental ESS. As with any tool, however, there are many ways of using it, and it is difficult to pick any particular process in such a complex system as typical. The actual simulation methods used depend greatly on what stage has been reached in the development of the ESS program. If just a small portion of the required stored program has been developed, only a "block check" can be done on that portion. As more and more portions of the program are developed, it is possible to make an actual check on the progress of a call.

As one example, on a simulation run in a "call-progress" check, a special input program and a few interesting points would be used to simulate customers' actions, and the progress of the call would be followed by examining the print-out of a simulated connection. If the proper connections are made, it can be reasonably assumed that the traversed portion of the stored program is correct. To examine the action in more detail a trace program is often used. This program causes the computer to print out whenever a transfer is made within the program. The program can then be more fully analyzed until the trouble is found. Additional interesting points may be installed if necessary. Thus, there is a continuous focusing of attention and expansion of the detail that is printed out until a trouble is found.

How Simulation Helps Development

The main purpose of simulation is to insure as nearly perfect programs as possible for an ESS. In the early phase of getting such a system operating, the actual electronic machinery, or hardware, may not be available to test programs. If an untested program were put into a completely built but untried system, it would be difficult to distinguish between program errors and hardware troubles. Simulation, by minimizing program errors, can help to separate the two.

Initialization, optional print-outs, tracing programs and optional interesting points are especially powerful tools for analyzing program errors. In correcting such errors, it is much easier merely to modify the erasable memory of a computer than to modify the photographic storage plates of the present semipermanent memory. The simulation of proposed stored programs for the ESS is therefore extremely valuable as a step toward achieving a working system.

In a stored-program system, preparing perfect programs is just as vital and difficult as designing perfect hardware. And in the design of such a system, perfecting the program, or "paperware," takes considerable time and effort. Having the "system" (as simulated on a computer) available for evaluating the stored program before the actual hardware is assembled and "debugged" allows the two development efforts to proceed simultaneously.

The art of electronic switching and the use of computers in the development of systems for implementing it are still in their infancy, and there is much room for further developments in both fields. However, simulation will play a part of increasing importance in the future development of electronic switching.

Project Echo Transmits Telephone Messages Via Satellite

Radiotelephone signals were successfully transmitted for the first time via a satellite last month between the Holmdel, New Jersey, location of the Laboratories and the Jet Propulsion Laboratory at Goldstone, California. A project headed by the National Aeronautics and Space Administration, "Echo I" is the first big step toward commercial transmission of overseas telephone calls and television by way of satellites.

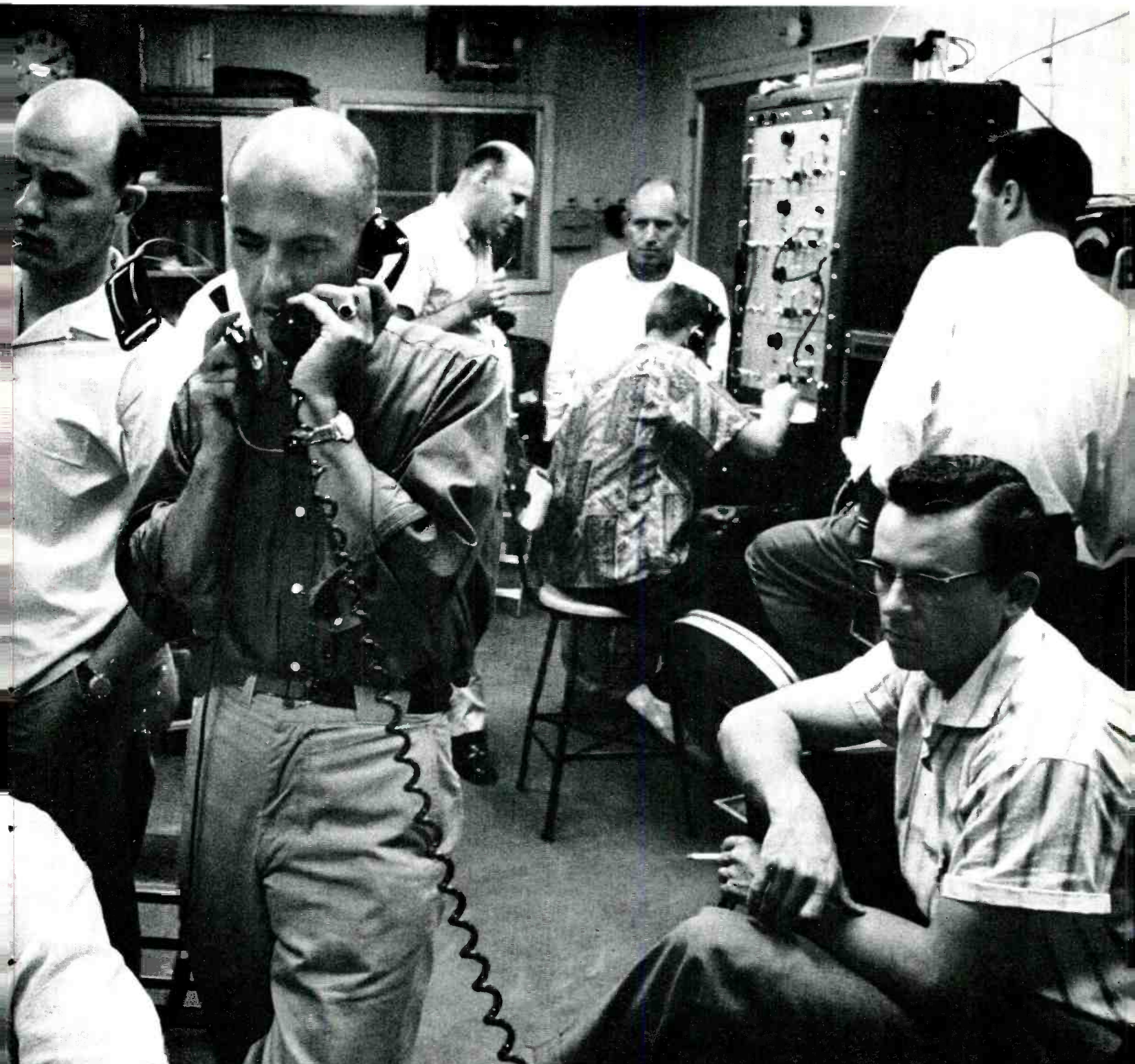
News of Space Research

Launched at Cape Canaveral, Florida, the 100-foot, aluminized-balloon satellite was directed into its selected circular orbit by the Laboratories Command Guidance System. In this guidance system, Bell Laboratories is teamed with Remington Rand-Univac, who developed and produced the computer. This is the same Command Guidance System that placed the NASA Tiros I weather satellite into its precise circular orbit earlier this year. (RECORD, *May*, 1960)

Of paramount importance to the successful experiment is a highly sensitive radio receiver developed at Bell Laboratories, and located at Holmdel. In the new receiver, three elements combine to produce the high sensitivity. One is a movable, horn-shaped antenna, 50 feet long. The second is a special demodulation circuit, extremely valuable for this use. The third is a highly sensitive ruby "maser" amplifier, cooled by liquid helium to —456 degrees Fahrenheit.

Bell Laboratories developed the horn-shaped antenna several years ago for overland radio relay. It results in less pickup of radio noise from the ground than do conventional antenna forms. Through a 20-by-20 foot opening, the horn receives weak signals from space and directs them into its small end. Attached to the small end of the horn is a "cab" in which the maser amplifier is located *(see photograph on page 337).*

Control room at Bell Laboratories "space station" at Holmdel, during actual experiment. W. C. Jakes, Echo project engineer, talks on telephone.



At the heart of the maser (RECORD, *May*, 1960) is a six-inch, rod-shaped industrial ruby. The liquid helium used as a refrigerant is drawn off as it evaporates, thus cooling it even further. The special frequency-modulation feedback circuit applied to the receiver circuitry improves the signal-to-noise ratio one hundred fold, permitting a high quality output from a weak signal.

The Holmdel station also includes control buildings, a 10-kilowatt transmitter with 60-foot dish antenna, and optical- and radar-tracking equipment. Other equipment converts predicted satellite positions received by teletype from Washington, D. C., into a form usable in aiming the antennas.

The Echo Satellite

Programmed to orbit at nearly 16,000 miles-per-hour at a one-thousand mile altitude, the Echo I satellite makes a trip around the earth once every two hours. In last month's launch, a Thor Delta vehicle sent the satellite into orbit. About ninety seconds after launch, the Laboratories guidance took control of the first stage of the rocket and directed its flight for about one minute. After separation of the first and second stages and firing of the second-stage engine, the guidance system again commanded the vehicle's flight and maintained control for about 100 seconds.

After a coasting period of approximately twenty minutes, the third stage was at the exact altitude and at the correct velocity necessary for it to be placed in the desired orbit. An automatic timer in the third stage caused the engine to fire, and the payload—the aluminized balloon—went into orbit.

During the first half-minute of the coasting phase, the Bell Laboratories guidance control station at Cape Canaveral measured the position and velocity of the vehicle and transmitted this information to NASA's Goddard Space Flight Center, near Washington, D. C. The initial prediction of the exact orbit of the satellite was made from these data.

In the Command Guidance System, small, lightweight guidance equipment is aboard the second stage. The ground guidance station controls the missile by sending orders to steer the vehicle precisely on its preselected path. Signals to control the exact moment of cut-off of the second-stage engine are also a function of the guidance system.

During the first hours of its 16,000 miles-per-hour orbital jaunt around the earth, the Echo I satellite established a number of new "firsts" in communications technology. The 100-foot diameter sphere reflected data back and forth from the Laboratories at Holmdel, the Jet Propulsion Laboratory, and the Naval Research Laboratory at Stump Neck, Maryland.

After a one-way taped message by President Eisenhower, the first communication bounced off the aluminum-coated sphere, many other microwave signals relaying voice, music and data were transmitted and received. Although the antennas lost track of the huge balloon momentarily during this first test, reception was exceptionally clear and the President's taped message was received several times during the 15 minutes the sphere was in line-of-sight of both stations.

Other early successful communications included a two-way simultaneous transmission between Holmdel and the Jet Propulsion Laboratory, accomplished when President Eisenhower's message was sent from the Laboratories to JPL. At the same time, JPL transmitted a taped message by Senator Lyndon Johnson to Holmdel. This was followed by a two-way live conversation, completed between W. C. Jakes at Holmdel and Phil Tardoni, of JPL, at Goldstone. Later, the Naval Research Laboratory at Stump Neck transmitted to Holmdel with high quality.

One particularly important experiment occurred as a "double bounce." The Naval Research Laboratory transmitted live voice via the satellite to Holmdel, where it was received and retransmitted to the satellite. JPL then received the signal bounce, proving that with a sufficient number of satellites, world communication through space is feasible.

In the first "complete" telephone conversation, Walter Victor, of JPL, picked up a telephone in Pasadena, California where the Jet Propulsion Laboratory "patched" the call to the satellite circuit, from where it was bounced to Holmdel. Laboratories engineers then patched the call back to Holmdel where Mr. Jakes talked with Mr. Victor.

Experiments are being continued in bouncing signals off the Echo I satellite. They will be evaluated to determine the feasibility of ultimately transmitting phone calls and perhaps even live television across oceans by satellite relay (*see page 354*).

Echo I is a "passive" satellite. But the Laboratories is already at work investigating another possibility—"active" satellites, which would carry electronic equipment to receive radio signals and send them back to earth. Laboratories engineers are now developing the rugged, long-life electronic devices that would be necessary for a commercially feasible "active" satellite.

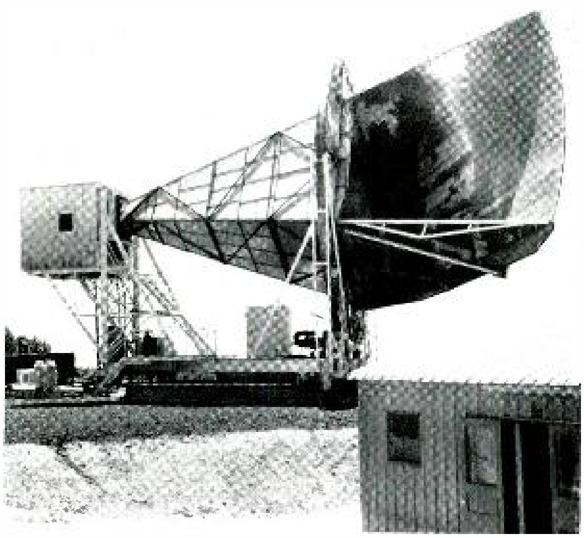
All proposals for communications satellites are based on the principle that they would permit long-distance transmission of high-frequency radio signals. These signals, normally blocked by the earth's curvature, could travel in straight lines up to a satellite and then be reflected or retransmitted back down again.

Telephone calls are already transmitted across oceans by low-frequency radio and by deep-sea cables. But here the number of radio channels is limited, and transmission is subject to natural interference. Cables also are limited in the number of channels by technical considerations, chiefly the necessity of building cables with extremely long service life.

Cables are being improved and almost certainly will continue to be used and expanded indefinitely for overseas communications, whatever the success of communications satellites. Communication by satellite, however, offers a complementary communications system having greater potential capacity. Television signals today occupy the equivalent of 500 to 900 voice channels. Communications satellites providing this capacity look ultimately possible, but are still far in the future.

Because passive satellites have an inherently greater bandwidth than active ones, reflectors could be used to bounce any type or frequency of radio signal. Active satellites would have to be designed for specific frequency bands, and obviously could not be modified once in orbit. On the other hand, passive satellites would reflect only a faint signal, so that more powerful transmitters and sensitive receivers would be needed on the ground than might be necessary with active satellites.

Since passive satellites would have no electronic parts or power supplies to wear out, they therefore might last longer than active satellites. One of the purposes of Echo I is to determine how long a balloon-type satellite might be expected to retain its shape despite punctures by micrometeorites and the pressure of light energy on the surface.



The "ear" of Echo I—the most sensitive radio receiver yet built. Cab at small end of horn houses radio receiving circuitry and maser amplifier.

Altitude of Orbit Is Significant

The types of communication satellites proposed also vary according to their altitude. Low-orbiting satellites, because they are closer, would ease the problem of radio transmission. But they would be in sight from any two places simultaneously for only short periods. To maintain continuous communication needed for telephone service, a number of low-orbiting satellites would be required.

A satellite placed precisely 22,300 miles high in a west-east orbit around the equator would revolve at exactly the same rate that the earth rotates and would therefore seem to remain always at the same place in the sky. This single "24-hour" satellite could be used to link any two places in sight of it, which would mean over one-third of the globe. Arctic areas would be excluded, however, because they would not be in the line-of-sight.

Because of its distance from the earth, however, the 24-hour satellite would necessarily be an active one. It would also have to have some means for adjusting its position precisely. Also, because of its distance, telephone talkers would find it takes an extra six-tenths of a second to get the reply to a question (RECORD, *August*, 1960). But if the moon, 240,000 miles away, were used for two-way communication, over five seconds would elapse before a telephone talker heard his reply.

Planning a communications satellite system must also include all the ground equipment that would be needed for a continuous, reliable system. Such factors as size of antennas, power supplies in remote areas, interference to and from other radio systems, computers to predict orbits and local tracking facilities, all must be figured as part of the cost. Also to be considered is the cost of the satellites themselves and that of getting them into orbit.

The production of an important protective varistor for telephone sets has been dependent upon the availability of a special copper ore. Now, with silicon-diffusion techniques, Bell Laboratories engineers have developed a new varistor that outperforms its predecessor and that can be manufactured at a potentially lower cost.

W. C. Michal

A Diffused-Silicon Varistor

About 10 years ago, Bell Laboratories completed development of the 500-type telephone set. An important part of this development was a new and more efficient telephone receiver. Although the performance of the receiver for the 500 set was improved by about 5 db, acoustic disturbances caused by transient electrical effects—principally surges of low voltage—in the telephone circuit were correspondingly higher (RECORD, *August*, 1952). Without a shunt to cut off these disturbances, the telephone user would be subjected to consequent increases in noise level. A major problem in designing this new receiver was to protect the customer from such noise.

At that time an oxidized thallium-copper varistor, coded 44A, was designed to furnish this protection. This varistor, which is now in service, prevents loud bursts of noise (known as "clicks") from disturbing the customer and protects the receiver magnet from being demagnetized by these transient currents. This protection is an essential factor in making today's receivers small and light.

Some 37 million 44A varistors are in service, all with excellent life characteristics. However, the quality of the copper used to manufacture varistors has been variable for several years. Only copper that had been extracted from oxide-type ores is satisfactory for varistor use.

Where an ore bed has been exposed to the weather for centuries, the uppermost layers are converted to oxides. These oxides are usually washed away by rainfall. However, the copper used to make oxidized-copper varistors is obtained from a mine in the Chilean Andes that has scant rainfall and therefore has accumulated a large bed of oxide ore. Unfortunately, this oxide ore layer is being rapidly depleted. Metallurgists estimate that supplies of this copper will be available for only 10 to 20 years. For this reason, Bell Laboratories started a program to develop a varistor from silicon, a semiconductor material that is in plentiful supply and that possesses suitable electrical properties.

This article explains how engineers at Bell Laboratories in Allentown, Pennsylvania, evolved the design and the processing and manufacturing techniques for such a silicon varistor. This new varistor, designated 100A, surpasses the 44A unit in electrical properties, yet is smaller and potentially more economical to produce.

Varistor Requirements

Electrically, a varistor must be symmetrical to limit pulses of either polarity. In other words, the electrical characteristics of a varistor must be the same if the current is applied in either direction. At speech-level voltages (0.1 to 0.2 volt), its resistance must be high compared to the 135-ohm resistance of the receiver. At transient voltage levels (above a few tenths of a volt), its resistance must be low. In addition, a varistor must be small enough to conveniently fit into the cavity of the telephone receiver. Its long-term stability must be good, and, because large quantities are required (44A production is approximately eight million per year), the cost must be low.

Research carried out at the Laboratories several years ago proved the feasibility of a varistor consisting of two diffused-silicon wafers arranged in parallel and oppositely poled so as to present an electrically symmetrical unit. Silicon wafers are generally small, and the diffusion process lends itself to large-scale, low-cost production. For these reasons, a development program was continued along this line.

The graph on page 341 compares the nominal electrical characteristics of the new (100A) silicon varistor and the 44A varistor. The principal difference is in the lower resistance of the 100A varistor at higher surge currents. This provides greater protection against loud bursts of noise. Another difference, the higher resistance of the 100A at low voltages, implies less impairment of speech transmission, but this is negligible even with the 44A.

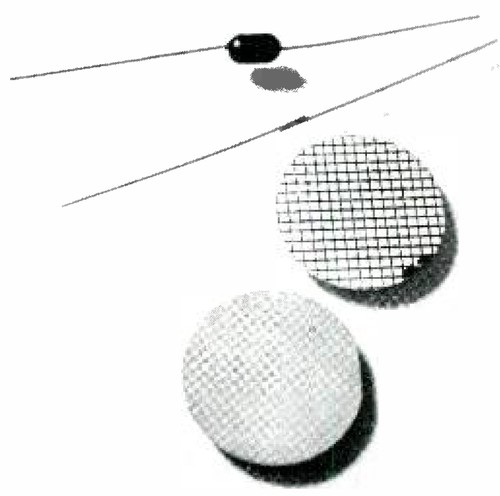
To evaluate its reliability, the new varistor was subjected to a variety of electrical, mechanical, and environmental tests. Most of these tests were much more severe than the device will encounter in use. About five million hours of testing were accumulated during 2 years of development work with some 500 models of this varistor. Throughout this period of testing, no failures were observed in any of the samples. After completion of the tests, there were only very minor changes in electrical characteristics. There is no reason to suspect any departure from these highly stable results; therefore, this varistor shows promise of remaining in service for a very long time. These tests and the investigations mentioned previously have resulted in a varistor that not only meets the physical requirements of the telephone, but which can be mass-produced at low cost.

There are three basic expenses involved in the manufacture of a varistor: (1) cost of raw material; (2) cost of processing silicon wafers; and (3) cost of assembly and encapsulation. A low-cost unit is the result of planned economy in all three of these expense categories.

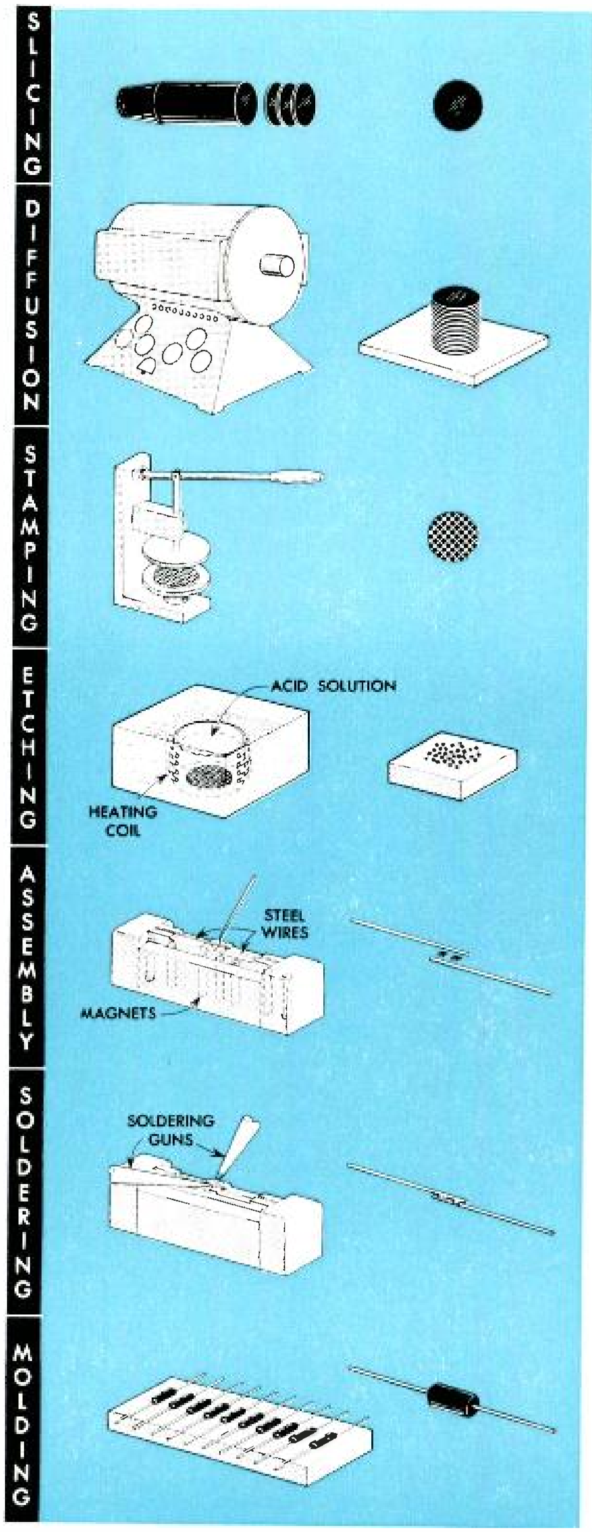
In small-scale operations without extensive tooling, the cost of raw materials is a very small part of the total expense. As production increases, however, and automatic-assembling techniques replace individual operations, the cost of a raw material such as highly purified silicon becomes a much larger part of the total cost of the unit.

The silicon is grown in single-crystal form by the Czochralski, or pulled-rod, technique (RECORD, *February*, 1955). This involves placing a seed (one silicon crystal) in a crucible of molten silicon and withdrawing the seed slowly. As the seed is pulled out, a large single-crystal "ingot" of silicon is formed. A rather wide range of resistivity can be used (0.01 to 0.1 ohm-cm), which results in a high yield of usable ingots and, therefore, a relatively low cost.

The operations involved in manufacturing the



To make the 100A varistor, from bottom to top, a slice of silicon is diffused, stamped, and gold-plated; slice is etched; resulting wafers soldered between steel leads; and the unit encapsulated.



These are the present major steps in processing and manufacturing silicon varistors. Each step can be readily modified to facilitate the manufacture of varistors on a mass-production basis.

100A varistor at the right, from top to bottom. The first step in processing the silicon junction elements is to slice the 1¼-inch diameter single-crystal ingots and grind them to a thickness of 0.010 inch. This thickness is somwhat greater than normal for devices made by diffusion techniques. It was chosen to provide more strength per slice, which reduces breakage during processing.

The simultaneous double-diffusion technique is used to process the silicon slices. Here, one face of each slide is painted with a solution of phosphorus pentoxide in methyl cellosolve; the other face is painted with a solution of boric anhydride in methyl cellosolve. Methyl cellosolve is used as a dispersing agent for the diffusants and as an adhesive to keep the diffusants in place until the slices are placed in the furnace. It dries quickly at room temperatures and evaporates completely at temperatures somewhat higher than this.

After the slices are painted, they are closely stacked on edge in an alundum container with like-painted faces together. Next, they are placed in an open-end furnace and kept at a temperature of 1300°C for 3½ hours. This technique permits large numbers of slices to be diffused at one time. As many as 96 slices have been diffused simultaneously in laboratory runs, and this number could no doubt be greatly increased for large-scale manufacture.

After diffusion, the slices are plated with two coatings of "electrodeless" nickel. The first coating is sintered into the silicon in an inert atmosphere for 2 minutes at 770°C. This provides good plating adherence. Then, as shown in the drawing, a pattern of squares, 0.060 inch on a side, is stamped on each face of the slices. This is done with two ordinary rubber stamps, imprinted with the desired pattern and oriented with respect to each other. A layer of gold is then electroplated on the slices. Since the gold does not plate over the ink lines, it is a simple matter to immerse the slices in an etching solution that reacts with and removes the ink lines and the silicon beneath them but that does not affect the gold. The slices remain in the etching solution until the etching action has reduced them to wafers.

These wafers are about 0.047 inch on a side. Thus, a slice approximately 1¼ inches in diameter yields almost 300 gold-plated, diffused-silicon wafers. The yield of wafers with satisfactory electrical characteristics has been consistently high, generally more than 90 per cent. Because of this, the electrical testing of wafers prior to assembling may be omitted, except for random-sample tests made to check the manufacturing process.

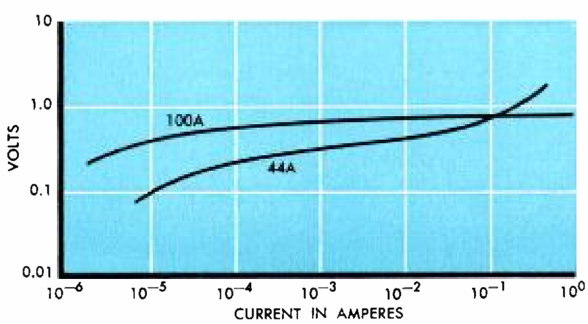
As we have seen, all of the processing is carried out on slices which, as a final step, are etched to wafers. In this way, the individual wafers are not handled at all during diffusion, plating, or etching; this keeps the processing costs at a minimum.

It is only in the last phase of manufacture — the assembling and encapsulating of the silicon wafers — that the parts of the varistor must be handled individually. For this reason, and to reduce the complexity of the mechanical equipment needed to assemble the units, the varistor is designed to have a minimum number of parts.

A subassembly and a final assembly are shown in the upper part of the photograph on page 339. The subassembly consists of: (1) two copper-clad steel wires coated with lead-tin solder; and (2) two diffused-silicon wafers. After the wafers are soldered to the lead wires, the subassembly is encapsulated in a phenolic resin. The fact that the required electrical characteristics can be maintained with this simple encapsulation is an important factor in producing a low-cost unit.

There are several interesting features about the lead wires. The coating on the entire length of the wires supplies enough solder to make satisfactory joints with the gold-plated wafers. Also, magnets inserted in the assembly fixture hold the two steel leads in position by magnetic attraction while the unit is being soldered. The assembly fixture, with the components of the varistor in place and ready for soldering, is shown in the drawing.

In cooperation with Western Electric engineers at Allentown, manufacturing equipment was designed for assembling the varistors on a limited production basis. This equipment points



Electrical characteristics of the diffused-silicon 100A varistor and the 44A varistor, now in service.

the way toward future mechanization. The operator picks up each wafer with a small vacuum pencil, and touches the wafers to a metal plate. In so doing, she completes a simple electrical circuit, and the polarity of the wafer is indicated by the operation or non-operation of a light placed directly in front of her.

The assembly fixture is mounted on a rotating table, equipped with four assembly fixtures. During a production run, the table rotates to four different positions. In the first position, the parts are loaded into the assembly fixture. It is essential that the operator assemble the wafers with the proper polarities. Magnetic attraction between the assembly fixture and the lead wires exerts a light pressure on the wafers and prevents them from shifting. This is particularly important because the wafers are so small.

Soldering and Encapsulation

At the end of a pre-set time, the table rotates clockwise a quarter turn to the second position, bringing the loaded assembly fixture under streams of hot nitrogen flowing from two fixed soldering guns. Nitrogen, rather than air, is used for soldering to prevent oxidation of the solder. The hot nitrogen directed over the fixture quickly melts the solder. At the third position, the unit cools and the solder freezes. Then, the table rotates another quarter turn and the subassembly is automatically removed from the fixture.

At this point, since silicon is brittle and the wafers are small, the unit is quite weak. For mechanical strength, the subassemblies are then encapsulated, in groups of ten, in a phenolic resin by compression-molding. With the use of multicavity dies and a larger press, it will be possible to mold several hundred units in one press operation.

Generally, the entire manufacturing process of the new 100A varistor is simpler, more efficient, and more economical than that used to produce the 44A varistor. The end result is a unit that is smaller than the 44A varistor, and that has superior initial and long-term electrical characteristics. For these reasons, many new applications, as fractional-voltage limiters and voltage-surge protectors, have been found for the diffused-silicon varistor. This type of varistor will be used in the Speakerphone, in push-button dialing apparatus, and in pulse-code modulation equipment. Ultimate demand for the 100A varistor is expected to be much greater than for the 44A unit. Latest estimates place this demand at 20 million units per year.

For emergency-reporting systems installed in larger cities, Bell Laboratories engineers have developed a rapid, reliable and economical concentrator arrangement that extends many emergency telephone lines to a headquarters over a few trunks.

P. W. Wadsworth

EMERGENCY REPORTING

The Concentrator System

Distinctively marked telephone housings are becoming a familiar sight on street corners in municipalities throughout the country. These brightly colored housings characterize to the public the Emergency Fire and Police Telephone Reporting System developed at Bell Laboratories (RECORD, *August*, 1956). Because they help to protect life and property, emergency-reporting systems emphasize more than ever the traditional Bell System objective of prompt and dependable service to anyone who needs it.

Briefly, these systems are designed to make available to all citizens of a community a rapid and reliable method of reporting fires, accidents and other civil emergencies. Through emergency telephones located at selected sites in a city, callers are automatically connected to an operator at emergency headquarters. With the addition of a "selective-routing" arrangement, many reporting systems are also equipped to handle routine police reporting over the same telephones and lines of the emergency service.

In the direct-line reporting systems (RECORD, *July*, 1960) each line from an emergency telephone is extended to an individual appearance at the headquarters switchboard. When fire and police reporting systems are installed in larger cities, the lines from several hundred emergency stations may be located within the areas of telephone central offices some distance from emergency headquarters. Because of the very low calling-rate from each station, it is economical to have "concentrators" at these central offices. Emergency telephone lines are routed through these concentrators and the calls are extended to headquarters over a few trunk circuits. This article describes this concentrator equipment, with some emphasis on the operational and reliability features of the concentrator-type reporting system.

Each concentrator, which is basically a simplified crossbar switching system, has a capacity of 200 lines. In the majority of installations, two to four trunk circuits to the headquarters switchboard are sufficient to handle the emergency traffic. However, the system is designed to give each line access to a maximum of nine trunks if such treatment is warranted by a higher usage rate of certain lines.

Each line from an emergency telephone to the concentrator appears on a "horizontal" of a ten-by-ten crossbar switch, the basic unit of the concentrator. The ten lines associated with the ten switch horizontals comprise a "line group." If this group of ten lines is a low-usage group requiring access to only four trunks, the horizontal multiple of the switch is split in half and a line group is connected to each half. This split-multiple arrangement and the other principal circuits of the concentrator system are shown in the diagram on the next page.

Line Access

Each of the ten lines has access to five "verticals." One vertical is associated with a control circuit called the "controller," and "headquarters trunks"—the outgoing trunks—are associated with the other four verticals. If the switch is not split, one line group is associated with each switch, and the ten horizontals have access to a maximum of nine trunks to various headquarters and to the controller.

With the split-switch arrangement, the outgoing trunks may all be in the same trunk group or in different trunk groups. Leads from the line circuits of the emergency telephones are connected to the controller, which identifies the equipment location of the calling line and controls the setting up of connections. Other leads from the line circuits go to a sender, which sends the "box" number of the calling station to the selected headquarters. Here, the four digits of the box number are automatically displayed at the switchboard when the call is answered, and the box number, along with the time, is recorded by a ticketer at the switchboard.

In the emergency system, lifting the station handset from the switchhook initiates a call. However, the caller does not have to dial or send a signal. Lifting the handset short-circuits the line diode, one of two diodes in the station circuit. This diode is normally in the nonconducting direction, so the increased loop current operates the line-circuit relay. Then two leads to the controller are "marked" by the line circuit. One lead starts the controller and identifies the line group or switch on which the line appears, and the other lead identifies the level, or horizontal, to which the line is connected. After these identifications, the selected crosspoints close and extend the calling line into the controller.

The controller functions somewhat like the "marker" circuit in a common-control switching system. By momentarily reversing the battery on the loop, the controller checks for the off-hook condition and determines whether the emergency call is for fire headquarters or for police headquarters. If it is a police call, the policeman has operated the selective-routing button at the emergency telephone, and this removes a short circuit from the other diode in the line circuit—the "selective-routing diode."

This diode is connected to form a normally low-resistance path, so when the controller reverses the loop battery the diode becomes nonconducting and reduces the loop current to nearly zero. Recognizing the call as one for police headquarters, the controller finds an idle trunk to this headquarters and closes line-switch crosspoints to connect the calling line to the selected trunk. The selected trunk then takes control of the connection and the controller releases. At the headquarters location, the incoming trunk circuit receives a seizure signal and flashes lamps at its jack and key appearances on the switchboard.

When the call is answered at the headquarters switchboard, a signal requesting identification is returned over the trunk loop to the concentrator office. The outgoing trunk, on receiving this signal, connects to the identification sender and signals the line circuit to give the calling-station number to the sender. The headquarters trunk requests an idle identification receiver, which is connected to the trunk loop, and the identification-request signal is removed as an indication to the sender to outpulse the calling-station number.

A typically marked emergency telephone. These boxes can also be used for routine police reporting.

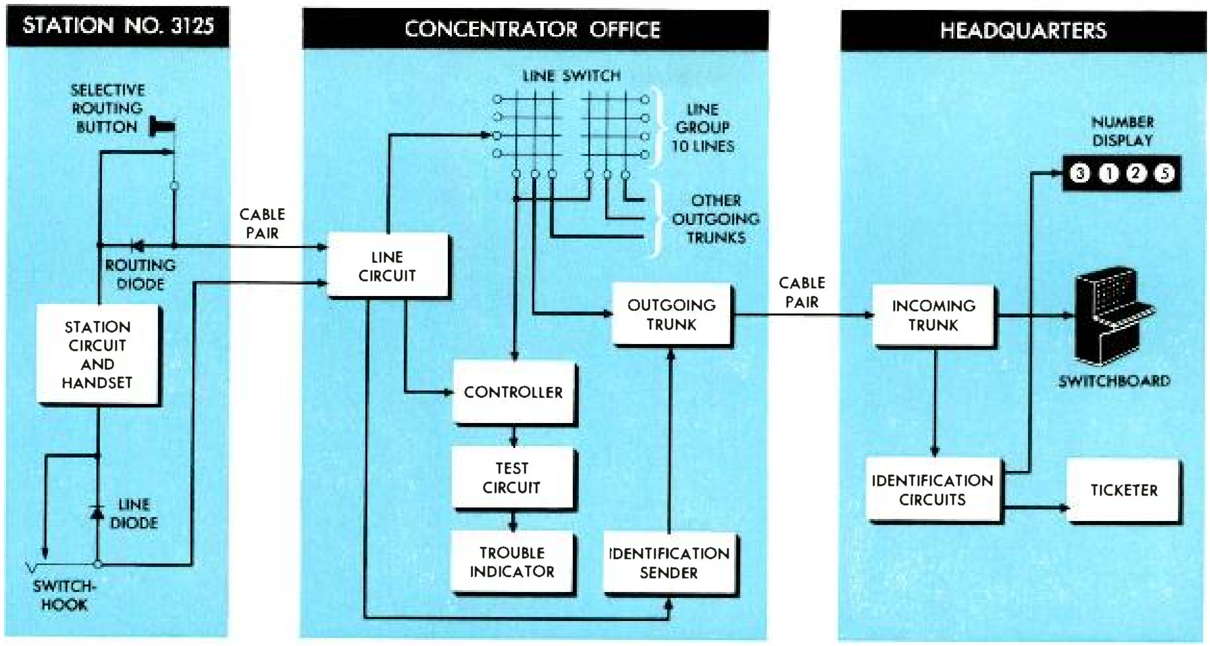


Diagram of the concentrator-type emergency reporting system. The concentrators are located in telephone central offices throughout the city. Outgoing trunks go to emergency headquarters.

This number is outpulsed to the headquarters receiver by a self-checking, two-of-five-pulse-length code, in which each digit is composed of two long and three short pulses. After pulsing, which requires somewhat over one second, the sender and receiver release from the loop, restoring it to the talking condition. Timer circuits, associated with the identification circuits at both the concentrator office and headquarters, function if identification is not completed in about two seconds. The sender and receiver are released and the trunk cut through so conversation can take place.

Station Display

The receiver stores the received digits and translates them to decimal information for display on cold-cathode, glow-discharge indicator tubes mounted at the switchboard. The display arrangement can be seen on the accompanying photograph of an emergency switchboard. The received digits are also given to the ticketer-control circuit, which controls printing the station number along with the date and time of day.

The moment the controller connects an idle outgoing trunk to the calling line (about 0.3 second after the handset is lifted), the connection is under control of the headquarters attendant. He has control even if the station hangs up before the call is answered. Thus, as soon as it is answered, the calling line is identified and the attendant can send fire apparatus or a patrol car to the box location. Similarly, if the caller is excited and unable to communicate clearly with the attendant, or leaves the phone (off hook) before talking to him, the station is identified and he can dispatch apparatus to its location.

The attendant can also hold a trunk connection and handle other calls without releasing the trunk. Each time a trunk is connected to the operator's position for talking, the number of the connected station is automatically displayed. This permits the operator to identify a calling line any time before it is released. When the operator releases a trunk connection, the trunk circuits return to normal. If the station is still off hook at this time, the line circuit is "locked-out" under control of the station switch hook. Lock-out prevents a trunk circuit from being tied up by a prolonged off-hook condition at the emergency reporting station.

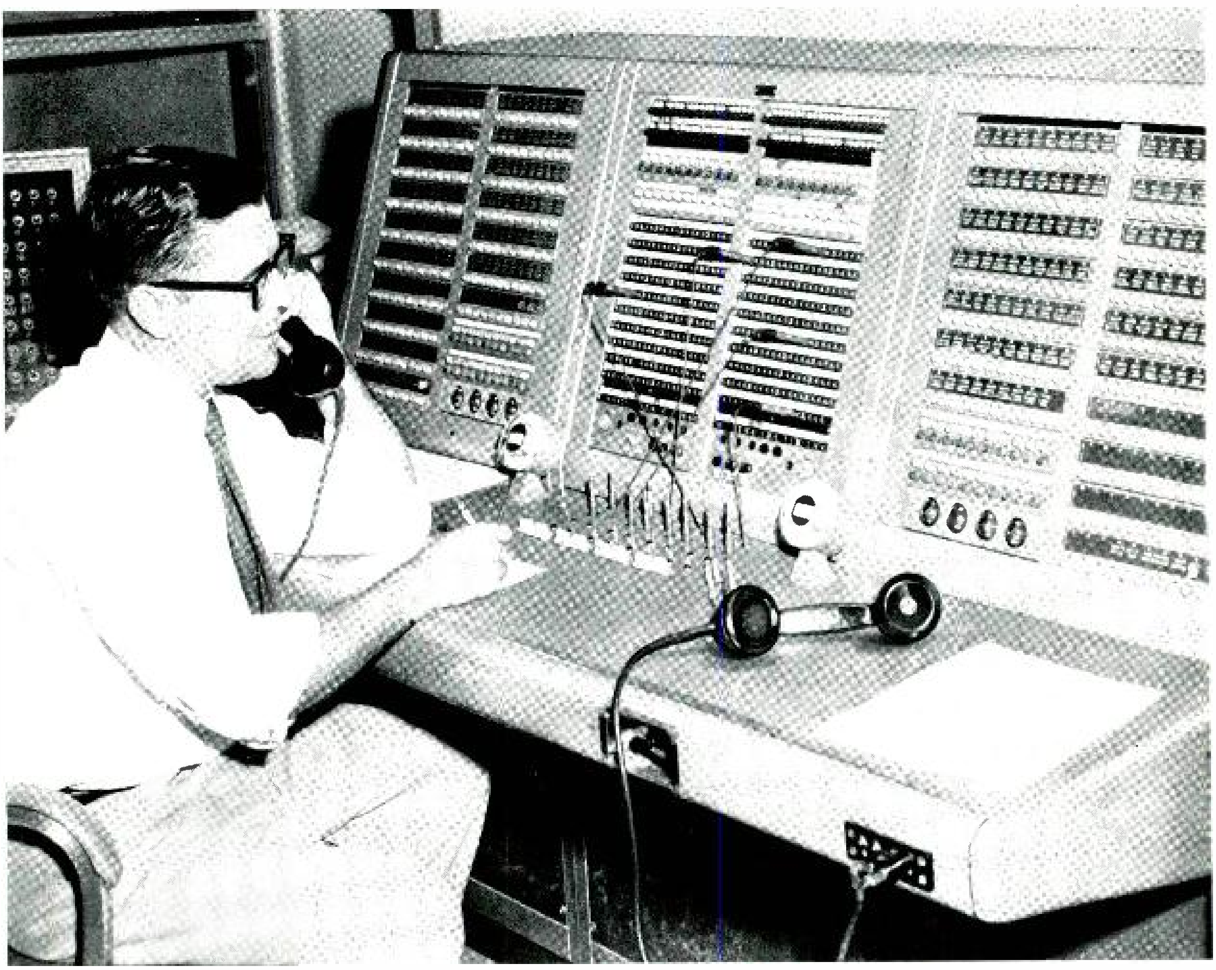
This, then, is how a call is normally handled by the concentrator system. Built into the controller and associated with it are a number of safeguards which make it almost impossible for a single trouble condition to keep a call from reaching the headquarters switchboard. For example, the controller handles only one call at a time. To prevent simultaneous seizures, the line groups are associated with a "selection-chain" circuit that at regular intervals reverses the direction from which the groups are selected. In other words, the line groups are selected first from low number to high number then from high to low. Similarly, the ten lines within a group may be selected in both directions so that a trouble on a line or line group will not block access to other lines and groups.

If the controller fails to identify and connect to a line calling for service, it reverses the line selection and makes a second trial. Also, if the controller fails to check the line and determine the desired headquarters, it makes a second trial, this time using its duplicate set of line-check and selective-routing-check circuits. If two successive line checks show the station to be in the on-hook condition a false seizure has been caused by a current surge, or "hit", on the line from an external source such as lightning. The controller then releases the line and returns to normal.

A similar selection arrangement and check with duplicate circuits is also used on the outgoing trunks and trunk groups at the concentrator. One of the trunk groups, usually the one having the highest calling rate, is used to control the regular reversal of trunk and line selection. Each time all the trunks of this group have been seized, the idle trunks are released and the direction of selection of all trunk groups and line groups is reversed.

Independent of this regular reversal of trunk selection, the selection is also reversed if the controller encounters trouble in completing a connection to an idle trunk. On second trial of trunk selection, duplicate trunk-selection equipment is used to eliminate the possibility of a trouble in the controller equipment, and the direction of selection is reversed. Thus, all trunks get nearly equal usage, and a trouble in any trunk or its selection path will not prevent other trunks in the group from being selected.

To ensure the prompt completion of emergency calls, a call for fire headquarters will be automatically routed to police headquarters if all fire headquarters trunks are busy. Depending on the type and extent of the emergency, the call can be



The switchboard at emergency headquarters of the concentrator system installation in New Orleans.

connected through to fire headquarters over an interheadquarters tie trunk. The operator at the police switchboard can also take the information and pass it to fire headquarters.

As a visual indication of a possible trouble, the controller, when it goes to second trial, activates a lamp-display trouble indicator before releasing on the first trial attempt. Lamps on the trouble indicator are lighted and "locked-in" to indicate: the line requesting service; the direction of line selection; whether the call was for fire or police headquarters; the direction of trunk selection; and the trunk selected. Indications of the last three conditions depend on how far the call had progressed.

In addition, a number of specific trouble indications may be shown, such as "crosses" on select or hold magnets and continuity and check failure on leads. For these, "minor" alarms in the central office alert the maintenance crew. The maintenance people then record the trouble indication and release the indicator. If the call is not completed on second trial, "major" alarms in the office sound and the line is released from the controller so that other calling lines can gain access to it and have their connections completed.

Additional Trouble-Alerting Features

Along with these and several other features of the controller that ensure continuity of service, an automatic test circuit at each concentrator location serves as a watchdog over all lines and circuits associated with the concentrator. If more than 200 lines are connected through a central-office concentrator location, two concentrators are provided. Each has its own trunk groups to headquarters, but a single test circuit serves both concentrators.

The test circuit is controlled by a master timer and is normally set to test all lines and circuits periodically in a predetermined pattern at intervals of a few minutes to several hours. It may also be used to test manually any individual line, trunk or other circuit associated with the concentrator.

The common-control circuits have second trial and duplicate circuit features, while the outgoing trunk circuits and loops to headquarters are under continuous test. These checks result in an immediate alarm in case of trouble. The line circuits and station loops, on the other hand, are not under continuous test and so are checked more thoroughly and at frequent intervals. As determined by local conditions, the test circuit may be set to test all station loops as frequently as each quarter hour or at intervals of several hours. After a predetermined number of line-test cycles, the identification sender and each outgoing trunk are tested locally, and at less frequent intervals test calls are made to each headquarters location.

Progress lamps associated with the test circuit give a continuous display of the circuit or system function being tested. If trouble is encountered, the test stops. The progress lamps remain lighted, however, to show where the trouble was encountered, and the office alarms operate to alert the maintenance people. If a trouble is found on a station line, progress lamps light to identify both the line and the trouble condition.

The number of the station in trouble is also sent to a preselected headquarters and recorded. This number is preceded by a "class" digit that indicates that the recording refers to a line in trouble. The recorder recognizes this trouble-class digit and signals the switchboard attendant that a line-trouble ticket is being recorded. Thus, the headquarters attendant and the maintenance people are immediately informed when a line is found in trouble, and they can take appropriate action to cover the calling station while it is out of order.

Even with the safeguards described above, it may be necessary to remove a controller from service for a short time. To maintain service under such conditions, a manual emergency "patching" circuit can be provided in the concentrator office. At the patching location, the line from each station has a line jack and supervisory lamp, and each outgoing trunk to the headquarters has a trunk jack and lamp appearance. When a station goes off hook, the emergency line lamp lights and a common alarm sounds. This alerts the emergency attendant at the concentrator office, who patches the calling line to an idle headquarters trunk. Supervisory lamps indicate when the headquarters attendant disconnects, and the emergency attendant removes the patch.

These features—line and trunk selection, second trial with duplicate circuits, completion of calls to an alternate headquarters, the trouble indicator and the automatic test circuit—are the most important safeguards of the emergency reporting systems. They have been described in some detail to show the extent to which automatic checking and test features may be used to make a system as nearly failure-proof as possible.

An additional safety factor in such systems is the availability of the trained maintenance and repair crews of the Operating Telephone Companies. This factor is especially important in a service supplied by a municipality for the protection and convenience of the public.

Few protective devices in the Bell System are more important than the main-frame connector—a sentry that protects complex switching equipment from outside electrical surges. Using modern materials and techniques, Laboratories' engineers have designed a new enclosed connector that is compact, simple and accessible and as a result is easy to install and maintain.

P. P. Koliss

A New Enclosed Main-Frame Connector

The Bell System uses many safeguards to protect against surges of voltage or current caused by "foreign" potentials. Without these safeguards, such potentials on telephone lines might cause personal injury, interruption of service, or damage to the telephone plant. The two main sources of foreign potentials are lightning and electric power lines that may somehow come in contact with telephone conductors.

Of the various sections of the telephone plant vulnerable to damage by foreign potentials, the central-office switching area, or nerve center of the telephone system, is one of the most important. It is therefore literally surrounded with bodyguards. Actually, every wire path that is exposed to foreign potentials passes through a protective device before making contact with the wires that lead to valuable and vulnerable switching equipment. This device—the "main-frame connector"—is located at the main distributing frame, the meeting place of the outside-plant cables and the central-office switching network and controls.

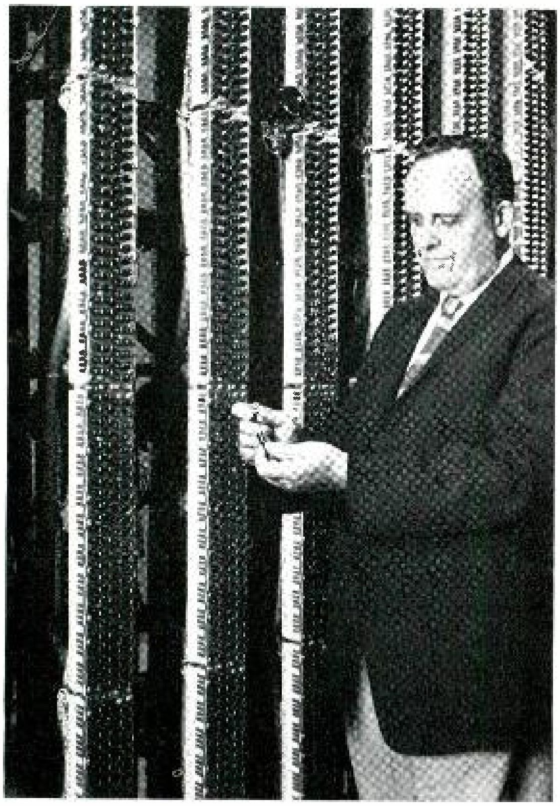
The present main-frame terminal, known as the C-type protector, is basically the same device that was introduced into the plant over 50 years ago. This protector consists of long, closely spaced cantilever springs that are clamped together to maintain a satisfactory contact with the actual protective elements.

There are two protective elements, one for excessive current and one for excessive voltage. The current-sensitive device, known as a "heat-coil," will operate on sustained currents exceeding one-half ampere. For voltage surges, C-type protectors have rectangular carbon blocks designed to shunt voltages above 500 volts (peak) to a grounded mounting plate. A sketch of the C-type protector, showing its main elements, appears on the left of the illustration on page 349.

For both voltage and current, the protective element, when it operates, establishes a path nector, it is fully equipped with the protective elements at the factory and is delivered to the exchange with the cap in the open-circuit ("disconnect") position. With the standard C-type protector, on the other hand, the installation crews must insert the heat coils and protector blocks.

By far the biggest cost-saving feature of the new connector is a lightweight "stub cable" that is connected at the factory. With this arrangement, installation crews can install and arrange for splicing to even the largest (2100-pair) feeder cable in a matter of hours. By contrast, the old design took days to install. The photograph on this page shows a splice joining 15 stub cables to a single feeder cable.

The stub cable has polyvinyl-chloride (PVC) insulated conductors prewired to the connectors, as shown in the photograph opposite. Conductors are grouped into 25-pair units and fully color-coded for easy identification. The standard color-code system used for many years in switchboard cables and for even-count polyethylene-insulated-conductor (PIC) cable is employed on the stubs (RECORD, *June*, 1959).



At the Cockeysville, Maryland, trial installation, C. R. Noble demonstrates new cap and sleeve assembly. Each vertical row of connectors in this office protects up to 300 customer lines.

In this system, individual conductors colored blue, orange, green, brown and slate are mated in orderly sequence to groups of white, red, black, yellow and violet conductors. This arrangement eliminates all the tedious electrical testing, involving two workmen, previously associated with identifying conductors for splicing the "tip" cable—the link between the connectors and the incoming cable.

With the new arrangement, the top position of the connector is wired to a blue-white pair of conductors in the stub cable; and the 25th position has a slate-violet pair. The new connector is furnished in 50- and 100-pair sizes, to fit the corresponding sizes of standard main frames. Standard main frames have 100, 150, 200, 300 and 400 pairs per vertical row of terminations, and will be built up from 100- and 50-pair units. Thus, the new design not only eliminates the need for the Operating Companies to make (tip-cable) connections to the protector terminals at the main frame, but also provides a completely indexed stub cable with the result of simplified splicing to the feeder cable.

In addition to the functions already discussed —current and voltage limiting, cut-off switching between the cable and central office, and terminations for cross-connecting—the new main-frame connector continues the practice of providing a ready-reference index board for indentifying incoming cable pairs. Holders on each side of the block accommodate standard number plates. Every fifth pair of a cable count is numbered at the connector, as shown in the photograph on page 348. Also, designation plates colored red, yellow and green are available to mark special circuit positions.

To simplify maintenance testing, three sets of special test cords have also been designed. Test plugs on the cords can be placed in the wells of the protector mounting for making connections from test equipment to the cable pairs and the central-office circuits.

Field trials of the new 300-type connector were held in Rossville, Georgia, Moberly, Missouri, and Woodstock, Illinois. A fourth experimental installation was made later at Cockeysville, Maryland. In all four of these installations, the connector more than met the requirements established for its design and was enthusiastically received by the Operating Companies.

As a result, the connector has been in production since late 1959. The 300-type connector was developed at the Baltimore location of Bell Laboratories with the close collaboration of Western Electric engineers at the Baltimore Works.

Bell System Proposes World Communications Network Via Outer Space

The Bell System recently outlined a plan for a communications network to carry telephone calls and television programs throughout the world via a string of satellites circling the globe. The picture of future worldwide communications was contained in written testimony filed with the Federal Communications Commission by J. B. Fisk, President of Bell Laboratories; J. R. Pierce, Director of Research-Communications Principles; Charles M. Mapes, Assistant Chief Engineer, American Telephone and Telegraph Company; and Brockway McMillan, the Laboratories Director of Military Research.

News from the Bell System

The testimony was filed to support the Bell System's contention that the Commission should anticipate the requirements of space communications in the portion of the spectrum above 890 megacycles. About a year ago, the F.C.C. opened up blocks of frequencies for general use, with no provision for space communications. Last May, the case was reopened by the F.C.C. to consider the space issue.

Mr. Mapes, in his testimony, said a system of about 50 satellites in random polar orbits at a height of about 3,000 miles could provide communications facilities between the United States and "all areas" of the world. He said about 26 transmitter-receiver stations, working in pairs and spotted throughout the world, would be needed to provide ground terminals. "A very important advantage of such a satellite network is the ability to communicate directly with nearly all the major countries of the world, without intermediate facilities in other countries," he said.

Mr. Mapes estimated the cost of setting up such a system at $115,000,000—divided between $65,000,000 for the ground installations and $50,000,000 for the satellites. Each pair of ground stations, relaying signals via satellites, could provide 600 telephone circuits. For about $55,000,000 more, the equipment could be adapted to provide also transoceanic television channels between each pair of stations.

"The cost, therefore, for providing the basic facilities for 600 telephone circuits and for television service between each of the 13 pairs of worldwide terminals would total approximately $170,000,000," he said. The Bell System would expect to make use of a satellite system for international communication and, in collaboration with such foreign organizations as might be involved, would expect to share the cost of launching and maintaining communication satellites.

Dr. Fisk described the need for better international communications. While radiotelephone and the growing network of submarine cables now supply telephone service to most of the world, they cannot supply all of the communications services that are available domestically. He said that the United States, with only 6 per cent of the world's population, now has 55 per cent of the telephones.

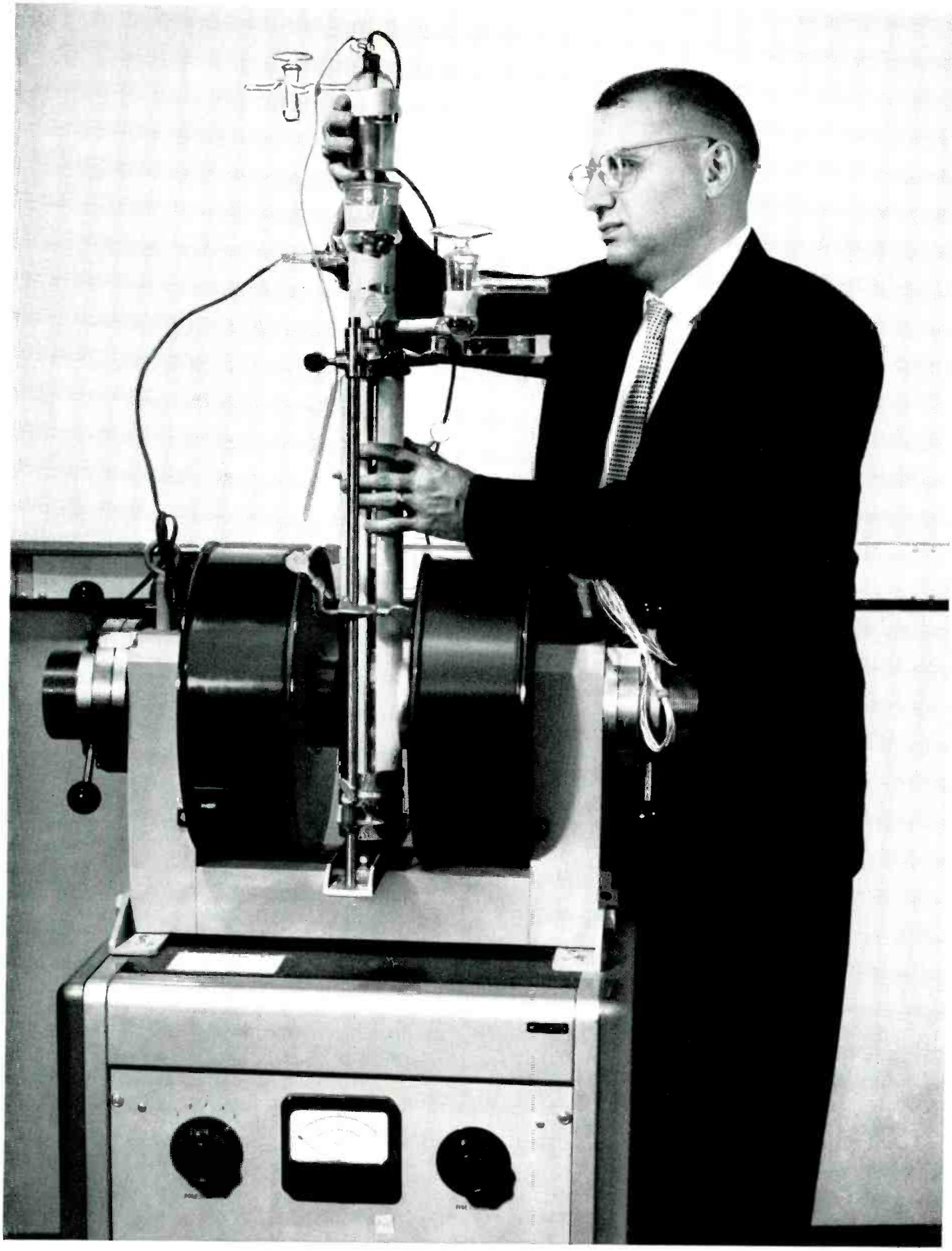
"We will necessarily expect a tremendous increase in telephones abroad as the 94 per cent of the world's people outside the United States become more industrialized. In addition to talking with many of these people by telephone, we will need to communicate with them by transmitting and receiving data and other business communications, and by means of television."

Dr. Fisk said it would be impractical for satellite systems to share frequencies with cross-country microwave systems. He said that satellite-system ground receivers can function only if they are well beyond the horizon from any ground microwave transmitters operating on the same frequency.

"Our future in world communication and our future in the exploration and in the exploitation of space depend on the wide use of the very limited range of frequencies in the electromagnetic spectrum which is suitable for satellite communication and for other space purposes.

"We firmly believe that it is clearly in the public interest at this time for the Commission to conserve the use of the frequency spectrum and to maintain its earlier sound policy of restricting the licensing of private microwave systems."

Dr. Fisk said the most favorable frequencies for space communications range between 1,000 and 10,000 megacycles, although those up to 16,000 megacycles might be used. But he said that "natural laws" prevent the use of frequencies above 20,000 megacycles for reliable satellite communications. Frequencies above 890 megacycles, he said, also are needed for many military and governmental uses such as Nike radars and for Project Mercury.



J. H. Wernick places silver antimony telluride specimen into dewar for Hall-effect measurement. Equipment measures deflection of carriers, due to magnetic field, which produces an electric field.

A thermoelectric principle discovered a century ago suddenly faces new applications as a result of research at Bell Laboratories. Involving the behavior of current in two dissimilar metals joined together, this principle now shows promise of extensive use with semiconductor materials.

New Efficient Thermoelectric Material

News of Chemical Research

Studies are underway at the Laboratories on one of the most efficient thermoelectric materials yet developed. The result of research by R. Wolfe, of the Solid State Device Development Department, and J. H. Wernick and S. E. Haszko of the Metallurgical Research Department, this material was discussed at the International Conference on Semiconductors held last month at Prague, Czechoslovakia. The compound is composed of the elements silver, antimony, and tellurium, and is chemically designated silver antimony telluride.

Today's thermoelectric devices are based on a principle discovered over a century ago. This discovery showed that when two dissimilar metals were joined together in a circuit, a current could be produced by heating one junction, while keeping the opposite one at a relatively lower temperature. The effect is also reversible—if a current passes through the pair, one junction becomes hotter and the other cooler, depending on the direction of current flow. The effects in metals are quite small, but researchers have found more effective materials among the semiconductors.

Extensive development work is now being carried out on practical devices such as heat-to-power converters and localized coolers, especially for miniature electronic devices. Although inadequate for many proposed applications, the materials most widely used in present-day thermoelectric devices are lead telluride and bismuth telluride. The search for improved materials at Bell Laboratories has centered on ternary intermetallic semiconductor compounds, many of which have a cubic crystal structure similar to sodium chloride. The desired crystal formulation is somewhat disordered and contains heavy atoms such as tellurium. Laboratories scientists have produced and studied many compounds, and alloys of compounds, some with as many as seven elements. The best of these invented to date has been silver antimony telluride, a material which, at present, is being widely studied.

This material possesses a very low thermal conductivity, necessary to maintain the temperature differential between two ends of a device. Its thermoelectric "figure of merit," is reported to be about 1.75×10^{-3} per degree Centigrade, over a range of 200 to 500 degrees C. This is the best that has been observed for p-type thermoelements in this range.

In the studies reported at Prague, Mr. Wolfe described silver antimony telluride as having a disordered cubic structure, exhibiting a thermal conductivity as low as 0.0064 watts per cm degrees C at room temperature, only one-hundredth that of germanium. While the material is always thermoelectrically p-type, its "Hall effect" is p-type in some specimens, and n-type in others, even when taken from a single ingot.

This anomalous behavior is ascribed to the presence of a small amount of a "second phase" consisting of silver telluride, which is swept to one end of the ingot by zone refining. This n-type compound appears to dominate some of the electrical properties at concentrations as low as 10 to 20 per cent, while the p-type silver antimony telluride dominates the thermoelectric properties. Further study of these anomalies are in progress and are expected to advance considerably the knowledge of semiconductors in general.

Among the objectives of these investigations is the realization of the best properties of this potentially useful material. In particular, the metallurgical problems of producing single-phase materials, and controlling carrier concentration are of primary importance.

news in brief

J. P. Molnar Elected Vice President of the Laboratories

J. P. Molnar, formerly a vice president of the Laboratories and president of the Sandia Corporation and a vice president of the Western Electric Company, has been elected a vice president of the Laboratories and returned

J. P. Molnar

to the Company on September 1. He will assume the responsibilities of E. I. Green, executive vice president, upon the latter's retirement on December 1. Mr. Green will retire under the Company's age rule after a career of nearly 40 years of Bell System service.

Mr. Molnar was previously associated with the Laboratories from 1945 until October 1958, when he assumed his present posts with the Sandia Corporation and Western Electric.

His early work at the Laboratories was in physical electronics research and the development of microwave tubes. Early in 1955 he was appointed Director of Electron Tube Development. Later that same year he was appointed Director of Military Systems Development and undertook responsibilities for work on guided missiles. In February, 1957 he was named Director of Military Development, and in August of that year became vice president in charge of one of the military areas.

A native of Detroit, Mich., Mr. Molnar received the A.B. degree from Oberlin College in 1937 and the Ph.D. from Massachusetts Institute of Technology in 1940. Before joining the Laboratories he worked with the National Defense Research Committee and the Gulf Research and Development Co.

Telephone Conversation Goes by Way of Moon

A public demonstration was held last month at the Holmdel Laboratory of a complete coast-to-coast telephone conversation via the moon. The signals were beamed from Holmdel to the moon, and reflected to the Jet Propulsion Laboratory at Goldstone, California. The signals required about three seconds to reach Goldstone. The replies from JPL also were "bounced" off the moon to be received by the Holmdel Station. During the test, W. C. Jakes of the Radio Research Department talked with W. K. Victor at JPL.

This transmission was part of the program in the aligning and testing of radio equipment being used in satellite communication experiments (see page 344). These experiments are being conducted in cooperation with the National Aeronautics and Space Administration. Their successful completion will be a major step toward eventual establishment of a satellite communications network to carry telephone calls and television programs through the world. A plan for such a network was filed recently by the Bell System with the Federal Communications Commission (see page 351).

The experimental space communication station at Holmdel consists of a 10-kilowatt transmitter, a 60-foot diameter transmitting antenna, a horn-shaped receiving antenna and associated tracking equipment. The horn-reflector antenna is an adaptation of smaller antennas which have been used for some time in the Bell System's microwave radio relay systems. Together with special receiver circuitry and a ruby maser amplifier, the space communications equipment comprises the most sensitive microwave voice receiving radio system ever assembled.

Successful Public Demonstration of Anti-Feedback Circuit

Bell Laboratories recently conducted the first successful public trial of an acoustic anti-feedback circuit (RECORD, *September*, 1959). The trial was held during the annual stockholders meeting of the Standard Oil Co. of New Jersey in the field house of the Lawrenceville School, Lawrenceville, N. J. The building has a floor area of 40,625 square feet and volume of 1,218,750 cubic feet.

The anti-feedback circuit was used with a commercial audio system built specifically for this meeting. No technical difficulties were encountered in combining the two. The system operated at an amplification level of three to four decibels above the "sing" level, or six to seven decibles above the operating point. Thanks to the anti-feedback system, this was done without any sign of instability. In fact, there was enough stability margin left to cope with occasional further increases in gain as during switching between various microphones, or when "small" voices had to be boosted.

Spontaneous and complimentary comments were heard from a number of stockholders, company officials, and the audio technicians on the improvement over a standard public address system.

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Quate, C. F., see Cook, J. S.

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Spencer, A. T., see Baker R. G.

Spencer, E. G., see Fletcher, R. C.

Stout, J. W., see Shulman, R. G.

Suhl, H., see Matthias, B. T.

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PATENTS

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

Aamodt, T.—*Vapor Seal Leadin*—2,945,914.

Barber, C. C.—*Electrical Contact Member*—2,944,240.

Breed, R. N.—*Tape-to-Card Converter Circuit*—2,946,984.

Brown, W. J.—*Automatic Telephone Answering and Message-Recording System*—2,946,852.

Crowe, W. J.—*Nonreciprocal Wave Transmission*—2,946,966.

Doba, S. Jr.—*Television Transmission Evaluator*—2,945,178.

Drexler, J.—*Internal Cavity Reflex Klystron Tuned by a Tightly Coupled External Cavity*—2,944,183.

Geyling, F. T.—*High Pressure Insulating Seal for Electrical Cable System*—2,945,082.

Groth, W. B., see Breed, R. N.

Hunt, L. E.—*Waveguide Phase Inverter*—2,946,972.

Hussey, L. W.—*Electrical Circuit for Communication Networks*—2,946,855.

Irwin, G. C., see Breed, R. N.

Karp, A.—*Traveling-Wave Tube Structure*—2,945,979.

Karp, A.—*Magnetron-Type Traveling-Wave Tube*—2,945,981.

Ketchledge, R. W.—*Communication Switching System Employing Gas Tubes*—2,944,114.

Kille, L. A., see Breed, R. N.

Knox, K.—*Magnetic Materials*—2,945,744.

Kretzmer, E. R.—*Television System Having Reduced Transmission Bandwidth*—2,946,851.

Mattson, R. H.—*Transistor Circuit Temperature Compensating Device*—2,945,190.

Mayo, J. S.—*Direct Coupled Transistor Logic Circuits*—2,946,897.

Miller, R. A., see Brown, W. J.

Miller, S. E.—*Nonreciprocal Attenuator*—2,946,025.

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Reenstra, W. A.—*AC Coding Systems, For Multiple Load Selection*—2,946,043.

Riggs, G., see Breed, R. N.

Rigrod, W. W.—*Beam Focusing System*—2,944,182.

Ritchie, W. J., see Reenstra, W. A.

Schelleng, J. C., see Hunt, L. E.

Taris, C. M., see Brown, W. J.

Tidd, E. D—*High Pressure Hermetically Sealed Terminal*—2,944,102.

Westberg, R. W.—*Method of Fabricating Semiconductive Devices*—2,944,321.

Wirth, H. J. Jr.—*Polarized Connector For Printed Circuit Cards*—2,946,033.

TALKS

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

AMERICAN PHYSICAL SOCIETY MEETING, Montreal, Canada

Bederson, B., see Eisinger, J.

Donovan, P. F., Miller, G. L., and Foreman, B. M., Jr., *Application of Thick-Depletion-Layer Silicon p-n Junctions to Proportional Detection of Gamma Radiation and Penetrating Nuclear Particles.*

Eisinger, J., Salop, A., Pollack, E., and Bederson, B., *Polarizabilities of the Alkalis.*

Foreman, B. M., Jr., see Donovan, P. F.

Helfand, E., and Stillinger, F. H., *The Radial Distribution Function of a Hard Sphere System.*

Miller, G. L., see Donovan, P. F.

Moore, G. E., *The Dissociation, by Slow Electrons, of CO Adsorbed to Molybdenum.*

Pollack, E., see Eisinger, J.

Salop, A., see Eisinger, J.

Stillinger, F. H., see Helfand, E.

EIGHTEENTH ANNUAL CONFERENCE ON ELECTRON TUBE RESEARCH, UNIVERSITY OF WASHINGTON, Seattle, Wash.

Adler, R., see Ashkin, A.

Ashkin, A., Gordon, E. I., and Adler, R., *Excitation and Amplification of Cyclotron Waves and Internal Beam Motions in the Presence of Space-Charge.*

Ashkin, A., see Gordon, E. I.

Cook, J. S., and Louisell, W. H., *Parametric Amplifiers Using Superconductors.*

Cook, J. S., see Yariv, A.

Dayem, A. H., *Effect of Upper Sidebands in Traveling-Wave Parametric Amplifiers.*

Dayem, A. H., see Lambert, C. A.

Forrester, P. A., and Mims, W. B., *See-saw Maser.*

Gordon, E. I., and Ashkin, A., *Transverse Wave Interactions on Electron Beams.*

Gordon, E. I., see Ashkin, A.

Klüver, J. W., *A Coupler for an M Type Parametric Amplifier.*

Lambert, C. A., and Dayem, A. H., *Noise Near the Potential Minimum of an Open Circuit Diode.*

Louisell, W. H., see Cook, J. S.

Mims, W. B., see Forrester, P. A.

Rigrod, W. W., *Power Flow and Stored Energy in Thin Electron Beams.*

Yariv, A., and Cook, J. S., *An Investigation of Tunneling Noise in Esaki Diode Microwave Amplifiers.*

INTERNATIONAL CONGRESS ON MICROWAVE TUBES, Munich, Germany

Ashkin, A., *A Microwave Adler Tube.*

Ashkin, A., see Gordon, E. I.

Gordon, E. I., *A New Transverse Traveling-Wave Tube.*

Gordon, E. I., and Ashkin, A., *Beam Cooling and Up-Conversion.*

Klüver, J. W., *An M Type Fast Cyclotron Wave Coupler.*

Scovil, H. E. D., *Solid State Traveling-Wave Masers.*

SYMPOSIUM ON MOLECULAR STRUCTURE AND SPECTROSCOPY, OHIO STATE UNIVERSITY, Columbus, Ohio

Liehr, A. D., *Semiempirical Theory of Forbidden Intensities in Aromatic Systems.*

Pappalardo, R., *Absorption Spectrum of Cu^{2+} in Different Coordinations.*

Pappalardo, R., and Wood, D. L., *Spectrum of YB^{3+} in Yttrium Gallium Garnet.*

Snyder, L. C., *Computer Simulation of the Electron Spin Resonance Spectra of Aromatic Ions and Radicals.*

Snyder, L. C., *Jahn-Teller Distortions of Molecules: A Molecular Orbital Description of Cyclobutadiene, Cyclopentadienyl Radical, and Benzene Positive and Negative Ions.*

Sugano, S., and Varsanyi, F., *Zeeman Effects of the Purely Cubic Field Emission Line of $MgO: C_r^{3+}$ Crystals.*

Varsanyi, F., see Sugano, S.

Wood, D. L., see Pappalardo, R.

NATIONAL SCIENCE FOUNDATION COLLOQUIUM ON MEASUREMENT OF ELASTIC PROPERTIES OF SOLIDS, ST. LAWRENCE UNIVERSITY, Canton, N. Y.

Mason, W. P., *Effect of Magnetic Fields on Elastic Moduli.*

Mason, W. P., *Elastic Properties of Crystals.*

Mason, W. P., *High Amplitude Dislocation Effects.*

McSkimin, H. J., *Measurement of Elastic Properties Under High Pressure.*

McSkimin, H. J., *Wave Propagation in Solids and Survey of Measuring Techniques.*

OTHER TALKS

Ahearn, A. J., *Mass Spectographic Detection of Impurities in Liquids*, A.S.T.M. Comm. E14 on Mass Spectroscopy, Atlantic City, N. J.

Anderson, P. W., *Generalized B.C.S. States in Liquid Helium Three*, Conf. on Many-Body Problems, Utrecht, The Netherlands.

Anderson, T. C., *Crystal Controlled Primary Frequency Standards — Latest Advances for Long Term Stability*, 1960 Conf. on Standards and Electronic Measurements, Nat'l Bureau of Standards, Boulder, Colo.

Anderson, W. W., and Hines, M. E., *Wide Band Resonance Isolator*, Prof. Gp. on Microwave Theory and Techniques, San Diego, Calif.

Bachelet, A. E., see Collins, C. A.

Baker, R. G., see Compton, K. G.

Ballman, A. A., see Laudise, R. A.

Batdorf, R. L., *An Esaki Diode in InAs*, I.R.E. Device Research Conf., Pittsburgh, Pa.

Berry, R. W., and Schwartz, N. *Thin Film Components Based on Tantalum*, Fourth National Conv. on Military Electronics, Washington, D. C.

Collins, C. A., and Bachelet, A. E., *New Television Network Switching Facilities*, Atlantic City, N. J.

Compton, K. G., and Baker, R. G., *The Use of Electroplated Metals in Static Contacts*, Seminar on Contacts, Pennsylvania State Univ., University Park, Pittsburgh, Pa.

Darlington, S., *Guidance of Lunar Probes*, Univ. of California, Berkeley, Calif.

Darlington, S., *Data Smoothing and Circuit Theory*, Univ. of California, Berkeley, Calif.

Early, J. M., *Transistors*, Workshop on Solid State Electronics, Purdue Univ., West Lafayette, Ind.

Elmendorf, C. H., *Transmission Systems Design*, Design Engineering Seminar, Pennsylvania State Univ., Pittsburgh, Pa.

Gupta, S. S., *Order Statistics for Gamma Distribution and Relation Life Testing*, Cornell Univ. Ind. Engineering Seminars, Ithaca, N. Y.

Gupta, S. S., *Selection Procedures for Normal Populations*, Cornell Univ. Ind. Engineering Seminars, Ithaca, N. Y.

Hannay, N. B., *A Review of the Mass Spectrographic Analysis of Solids*, A.S.T.M. Eighth Annual Meeting on Mass Spectroscopy, Atlantic City, N. J.

Hines, M. E., see Anderson, W. W.

Jaycox, E. K., *Emission Problem Clinic*, Eleventh Annual Symp. on Spectroscopy, Chicago Section, Chicago, Ill.

Jonas, L. A., *High Voltage Eliminator for Teletypewriter*, A.I.E.E. General Meeting, Atlantic City, N. J.

Karlin, J. E., *Consumer Acceptance Research Human Factors Engineering—Research on the Telephone System*, Univ. of Michigan, Ann Arbor, Mich.

Klüver, J. W., *Parametric Amplification of the Fast Cyclotron Wave*, Royal Inst. of Technology, Stockholm, Sweden.

Kronish, I. A., *The Nike-Hercules Guided Missile System*, School No. 18, Iselin, N. J.

Laudise, R. A., and Ballman, A. A., *The Solubility of Quartz Under Hydrothermal Conditions*, Lehigh Univ., Bethlehem, Pa.

Law, J. T., *p-Layers on Vacuum Heated Silicon*, Electrochemical Soc. Conf., Columbus, Ohio.

Leamer, F. D., *The Technical Institute in America*, A.S.E.E. Meeting, Purdue Univ., Lafayette, Ind.

Lee, C. Y., *Various Models and Examples of Automata*, Summer Conf. Course, Univ. of Michigan, Ann Arbor, Mich.

Leutritz, J., Jr., *Pretreatment Determination of Moisture Density to Facilitate Retention Assays of Oil-Type Preservatives*, 1960 Annual Meeting Amer. Wood-Preservers Assoc., N. Y. C.

Loomis, T. C., *Semi-micro Methods of X-Ray Analysis*, Symp. on X-Ray Spectrochemical Methods, Stevens Inst., Hoboken, N. J.

Lundberg, C. V., *Electrical and Moisture Diffusion Properties of Polyurethane Foam*, Western Electric/Bell Telephone Laboratories Casting Resin Conf., Merrimack Valley, North Andover, Mass.

Mason, W. P., *High Amplitude Internal Friction and Its Relation to Fatigue in Metals*, Acoustical Soc. of Amer., Providence, R. I.

Mason, W. P., *Influence of Lattice Parameters on the Properties of Crystal Resonators*, Fourteenth Review of Technical Progress, U. S. Signal Corps Freq. Control Div., Atlantic City, N. J.

Merrill, F. G., *Frequency and Time Standards—A Status Report*, 1960 Conf. on Standards and Electronic Measurements, Nat'l Bureau of Standards, Boulder, Colo.

Moore, E. F., *Programming Concepts, Automata, and Adaptive Systems*, (Five Lectures), Univ. of Michigan, Ann Arbor, Mich.

Morrison, J., *A Review of Test Methods for the Detection and Analysis of Solid Materials*, A.S.T.M. Committee F1, Boston, Mass.

Murphy, R. B., *On the Meaning of Precision and Accuracy*, Sixty-Third Annual Meeting of A.S.T.M., Atlantic City, N. J.

Olmstead, P. S., *Road to Understanding*, A.S.Q.C. Annual Conv., San Francisco, Calif.

Olmstead, P. S., *Statistical Evaluation*, A.S.Q.C. Annual Conv., San Francisco, Calif.

Rodgers, R. F., *Some Basic Factors Affecting Readability and Reproducibility of Microfilm*, Nat. Microfilm Assoc. Conv., N. Y. C.

Scaff, J. H., *Coming Developments in Metals Technology*, Forty-fourth Annual Meeting Nat. Ind. Conf. Board, N. Y. C.

Schreiber, H., *Pulse-Height Discrimination in X-Ray Spectrochemical Methods*, Symp. on X-Ray Spectrochemical Methods, Stevens Inst., Hoboken, N. J.

Slichter, W. P., *Nuclear Magnetic Resonance Studies of Rubber-Like Polymers*, Naugatuck Chemical Co., Naugatuck, Conn.

Smith, W. L., see Warner, A. W.

Spencer, A. T., *Bonding Polyolefins to Copper Alloys Bearing Chemically Formed Oxide Films*, A.C.S. Division of Paint, Plastics and Printing Ink Chemistry, Cleveland, Ohio.

Storks, K. H., *Opportunities for Modern Analytical Chemists*, Symp. on X-Ray Spectrochemical Methods, Stevens Inst., Hoboken, N. J.

Schwartz, N., see Berry, R. W.

Smith, W. L., see Warner, A. W.

Van Uitert, L. G., *Factors Influencing the Luminescent Emission States of the Rare Earths*, Luminescence Symp. of Electronics Division of Electrochemical Soc., Chicago, Ill.

Walker, L. R., *Topics in Spin Waves*, Westinghouse Electric Corp., Pittsburgh, Pa.

Warner, A. W., and Smith, W. L., *Quartz Crystal Units and Precision Oscillators for Operation in Severe Mechanical Environments*, Fourteenth Annual Freq. Control Symp., Atlantic City, N. J.

Wasserman, E., *Thermochromism and Linear Radicals*, New York Univ. Chem. Dept., N. Y. C. General Electric Research Laboratory, Schenectady, N. Y.

Wehe, H. G., *Miniature Lacquer Film Capacitors*, Vacuum Metalizer Association, Bermuda.

Weiss, M. M., *X-Ray Generation by Microwave Generators*, Inst. of Ind. Medicine, New York Univ. Post-Graduate Medical School, N. Y. C.

THE AUTHORS

A. C. Keller, author of "The DDD Relay", has attended Cooper Union, Yale University and Columbia University. He holds degrees of BS, EE and MS and is a licensed professional engineer in New York State. At present, he is Director of Switching Systems Development having previously been Director of Component Development and Director of Switching Apparatus Development. He holds patents in the fields of electromagnetic and electromechanical devices, sound recording and reproducing equipment, loudspeakers, Sonar, switching apparatus, electronic heating equipment, sputtering equipment and complete telephone systems. During World War II Mr. Keller received two Navy citations for his work in sonar systems and devices. At present, he is a consultant for the Department of Defense in Research and Engineering and the chairman of a Working Group. He is a member of seven national engineering and scientific societies and is listed in "American Men of Science," "Who's Who in the East," and "Who's Who in Engineering."

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W. A. Budlong, a native of Tampa, Florida, is a graduate of the University of North Carolina. After receiving his masters de-

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gree in physics from the University of Delaware, he joined the Laboratories in 1953 and graduated from the Communications Development Training Program. Since 1955 he has been concerned with electronic switching systems, especially their control by stored programs. As a result of this work, he has more recently been engaged in the simulation of electronic switching systems on a digital computer. Mr. Budlong is a member of the I.R.E. and the Association for Computing Machinery. He is the author of, "Simulating Electronic Switching with a Computer," in this issue.

W. C. Michal has never worked for any company except Bell Laboratories. He began his career in 1930, and has worked in the New York, Murray Hill, and Allentown locations. In 1936 he

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began work on the development and design of copper varistors. In 1940, Mr. Michal received the degree of B.E.E. from the College of the City of New York. His responsibilities were extended to include design work on silicon-carbide varistors. After thermistors were developed at the Laboratories, he helped design thermistor rods, discs, and networks. Mr. Michal was transferred to the Allentown Laboratory in 1955, and it was here that he conducted a development program on the design and processing of diffused-silicon diodes he describes in his article—"A Diffused-Silicon Varistor"—in this issue.

P. W. Wadsworth

P. W. Wadsworth, a native of Cazenovia, New York, first joined the Bell System upon graduation from high school and worked for one year with the Long Lines Department of the American Telephone and Telegraph Company. After receiving his B.S. degree in electrical Engineering from Ohio Northern University in 1927 he joined Bell Laboratories. Throughout his career Mr. Wadsworth has been primarily concerned with circuit design of toll switching and signaling systems and he has been granted a number of patents in the field. For several years he did circuit design on voice-frequency circuits of toll systems including transatlantic radio terminals, ship-to-shore and harbor-craft radio. During this period, as one of a group that designed and installed the radio equipment of the *S.S. Leviathan*, he made a transatlantic crossing with the ship to observe the operation of the equipment. During World War II, he transferred to the underwater sound project and worked on the design of the acoustic torpedo. More recently he has been concerned with circuit development for a special service switchboard to permit person-to-person dialing, and for special toll and signaling systems, including the Emergency Reporting System. In this issue Mr. Wadsworth describes the concentrator system for emergency reporting.

P. P. Koliss, author of "A New Main-Frame Connector" in this issue, joined Bell Laboratories in 1939. During his first ten years at the Laboratories he was a member of the Switching Apparatus Development Department. In 1949 he transferred to the Outside Plant Development Department. A native of Massachusetts, Mr. Koliss received his B.S. and M.S. degrees in electrical engineering from Worcester Polytechnic Institute. At present he is at the Baltimore, Maryland, location of Bell Laboratories where he is in charge of a group responsible for the development and design of terminal and protection apparatus. Mr. Koliss is a member of A.I.E.E. and Sigma Xi.

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