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Bell Laboratories
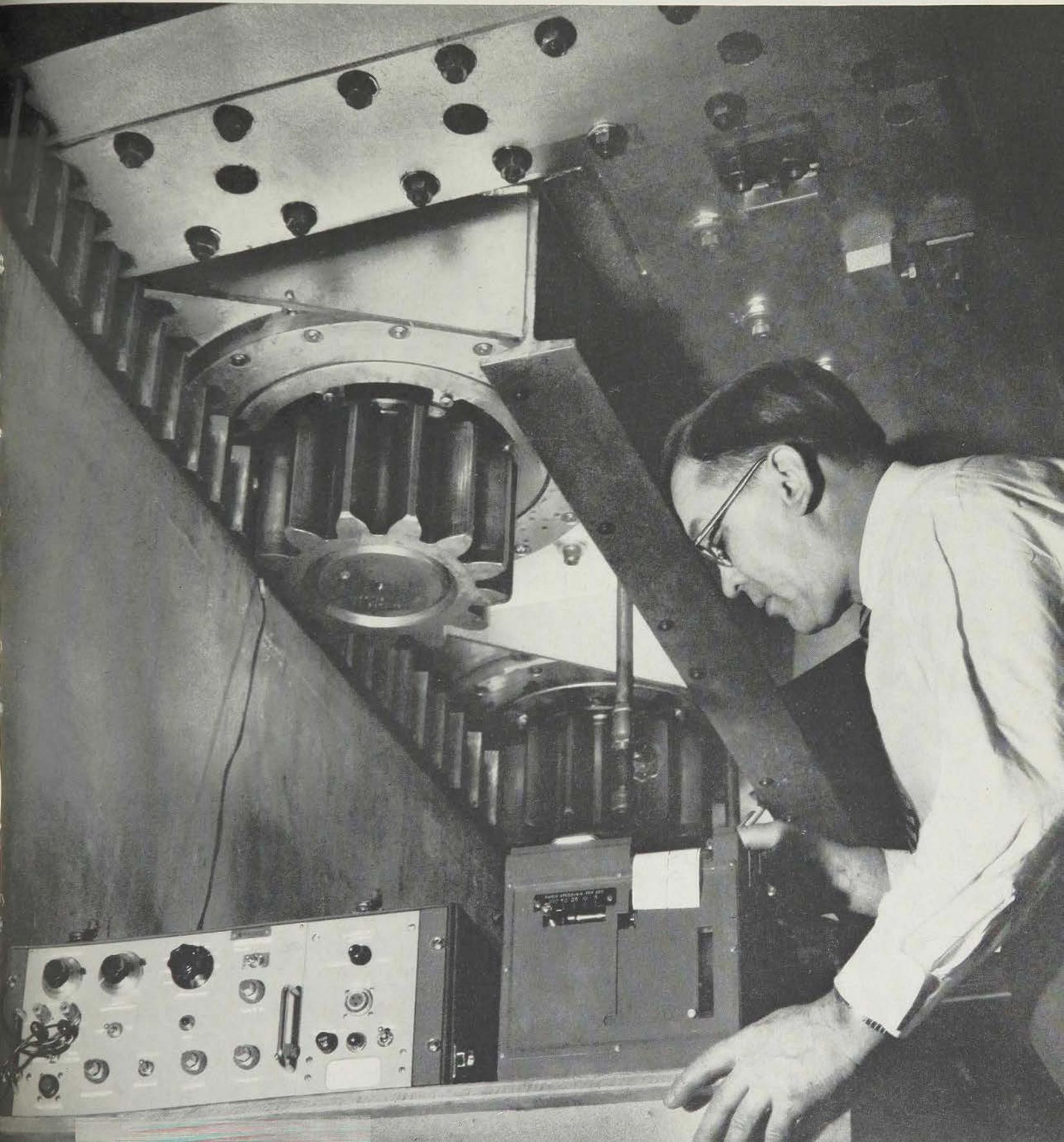
RECORD

Contents

Cover   *In the pit under the Telstar horn antenna, Emil Knab makes a recording of the strain on the bull ring gear teeth as the antenna is rotated. The application is typical of the versatility of strain gages. (See page 398)*

One of the most recently established branch laboratories, Columbus has complete responsibility for design and development of No. 1 and No. 5 Crossbar systems, and for some basic development work on ECO.

The Columbus Branch Laboratory

F. A. Korn

EARLY LAST YEAR, H. I. Romnes, President of the Western Electric Company, spoke before a conference of engineers and architects at the Ohio State University. His subject was "The Management of Change." In referring to scientific breakthroughs, Mr. Romnes emphasized that progress in our technology depends not only on the basic invention but also on many people who figure out how to manufacture the items at prices people can afford. A log jam at this point in the flow of technological creativity could be just as serious as a drought at the source. To avoid such a log jam in providing products for the Bell System, product development engineers and manufacturing engineers had been brought closer together recently—at the manufacturing location.

The close working relationship between Bell Telephone Laboratories and Western Electric Co. engineers at branch laboratory locations, as discussed recently by M. H. Cook (RECORD, *November*, 1961), provides a mutual understanding that quickens the pace at which new products are introduced into manufacture. The manufacturing engineer obtains a clearer understanding of design intent and of performance objectives. At the same time, development engineers become more aware of the potentialities and the limitations of manufacturing processes. Thus, the evaluation of a product becomes a joint effort of development and process engineers, in which each does his job better because of the other, and the whole job gets done faster.

One of the most recent branch laboratories established is that at the Western Electric Works in Columbus, Ohio. The production effort at Columbus is devoted almost entirely to large crossbar switching systems, including most of the major components such as wire spring relays, crossbar switches and resistors. The 1A line concentrator —which uses crossbar components and techniques —is also important in Columbus production.

Crossbar switching systems have been a major product of Western Electric since their inception during the late 1930's. Manufacturing and engineering control for this new type of product was first allocated to the Hawthorne (Ill.) Works, starting with the No. 1 crossbar system. The crossbar tandem system soon followed. Development of the No. 4 system, which is designed for toll switching, was undertaken at Bell Laboratories just before the war; manufacturing control of this system was allocated to the Kearny, N. J. Works, mainly because of the division of products by Hawthorne and Kearny Works (Hawthorne had local systems and Kearny had toll). After the war, the new, more flexible No. 5 crossbar system

Exterior view of Columbus Office building; laboratory space is on three floors at left end.

was designed, with control allocated to Hawthorne.

The tremendous increase in demand for telephone service at the end of the war, coupled with the program for converting from manual to dial operation and for improving service, caused production of crossbar equipment to skyrocket. (An indication of the volume of production in this area can be gathered from the table shown on page 394 which gives the number of frames of the various types of crossbar systems manufactured since 1950.) Anticipating growth, Western Electric undertook a long range study of the Bell System's needs for this type of product and decided to erect three modern crossbar manufacturing plants at Omaha, Columbus and Oklahoma City. In the over-all plan for these manufacturing facilities, engineering control for the manufacture of the No. 1, No. 5 crossbar and crossbar tandem system was assigned to Columbus. Transfer of Western Electric's control and production of the No. 4 toll crossbar system from the Kearny Works to the new crossbar plants mentioned is now under way. By late 1962, this control will be completely transferred to Columbus and the product allocated between Columbus

and Oklahoma City. At that time, Western Electric's control over all large modern crossbar systems will be centered at the Columbus Works. Also, the Equipment Standards group of Western Electric, which prepares manufacturing information and drawings for the shop and for the line engineers from Laboratories drawings and specifications on the various crossbar systems and ECO, is also located at Columbus. The Columbus Works has also been assigned control for the large scale production of the new Electronic Switching System (RECORD, *January* 1962).

The Branch Laboratory at Columbus was given complete responsibility for all design and development of the No. 1 and No. 5 crossbar switching systems as well as for components such as the crossbar switches and relays which are the basic building blocks of these systems. The movement of Laboratories crossbar tandem system development people to Columbus was considered when the Columbus branch was established. However, because of the status of certain urgent projects in this area, it was not considered advisable to move the group until later. The crossbar tandem group, as well as the Laboratories development group

CROSSBAR SYSTEMS ANNUAL PRODUCTION In Thousands of Frames				
Year	No. 1 & Tandem	No. 5 Crossbar	No. 4 Toll	Total
1950	9	3	1	13
1951	7	5	1	13
1952	9	7	2	18
1953	9	12	2	23
1954	6	17	2	25
1955	8	22	2	32
1956	11	30	3	44
1957	13	33	4	50
1958	10	24	2	36
1959	9	21	2	32
1960	10*	33	2	45
1961	13*	37	3	53
1962**	14*	42	3	59
1963**	14*	42	4	60

*Includes Automatic Number Identification.

**Figures for 1962 and 1963 are Program Planning Estimates.

responsible for the No. 4 type toll crossbar system, are now expected to be moved to Columbus in mid-1963. At that time the Laboratory organization, therefore, will have responsibility for practically all the components which manufacturing engineering controls, and for the systems in production at the Columbus Works. Also, since the Columbus Works has manufacturing engineering control for the Electronic Switching System, the Branch Laboratory has included a group responsible for some basic development work relating to this system.

When the Columbus Laboratory was established, complete design responsibility for the major components and the related systems—from start to finish—was delegated to it. This resulted from the long standing need for closer liaison between all the systems development and engineering groups in the switching field than had heretofore been maintained by telephone communication and frequent visits back and forth between locations.

The Columbus Works is located on a site of approximately 250 acres in a rural residential area about 8½ miles east of the center of the city. The Works has a large office building of three floors with a smaller fourth floor for executive offices. The office building contains more than 250,000 square feet of space and is connected by two corridors to the manufacturing area, which is located directly behind it. The manufacturing area is a one-story facility of approximately 1,275,000 square feet—about equal to 22 football fields. The area is highly flexible and can be readily rearranged as the production of highly complex telephone switching equipment demands. There are also a number of other buildings of smaller size. The total number of people employed at the Works is now approximately 4500.

Early planning for the Columbus Branch Laboratory was started at about the time the building plans were being made. At the present time, approximately 77,000 square feet of space has been assigned for Laboratories use. About four-fifths of this space is in the office building. It is located in the West, or extreme left section of the building on all three floors, and the North West section on the second and third floors. This space is used for offices, small component development laboratories and for staff facilities such as the drawing and administration files, drafting room and development model shop. The larger crossbar systems laboratories require space with high ceilings, and these, together with related shop facilities, are located in the manufacturing building.

At present, the organization of the Columbus Laboratory is divided into six major areas:

1. An apparatus development department which is responsible for the design of crossbar switches, message registers and most of the usual relays generally used in telephone systems. It also has responsibility for development and problems relating to solderless wrapped connections and welded connections.

2. A department responsible for the development of common control circuits for the No. 1 and No. 5 crossbar systems, including circuits such as senders, registers and markers. It also is responsible for conducting laboratory tests of all circuits of these systems. This department also plans the complex laboratory systems installations as well as the installation of field trials when necessary and prepares Bell System Practices.

3. A department with responsibility for non-common control circuits for No. 1 and No. 5 crossbar systems such as links, trunks, and
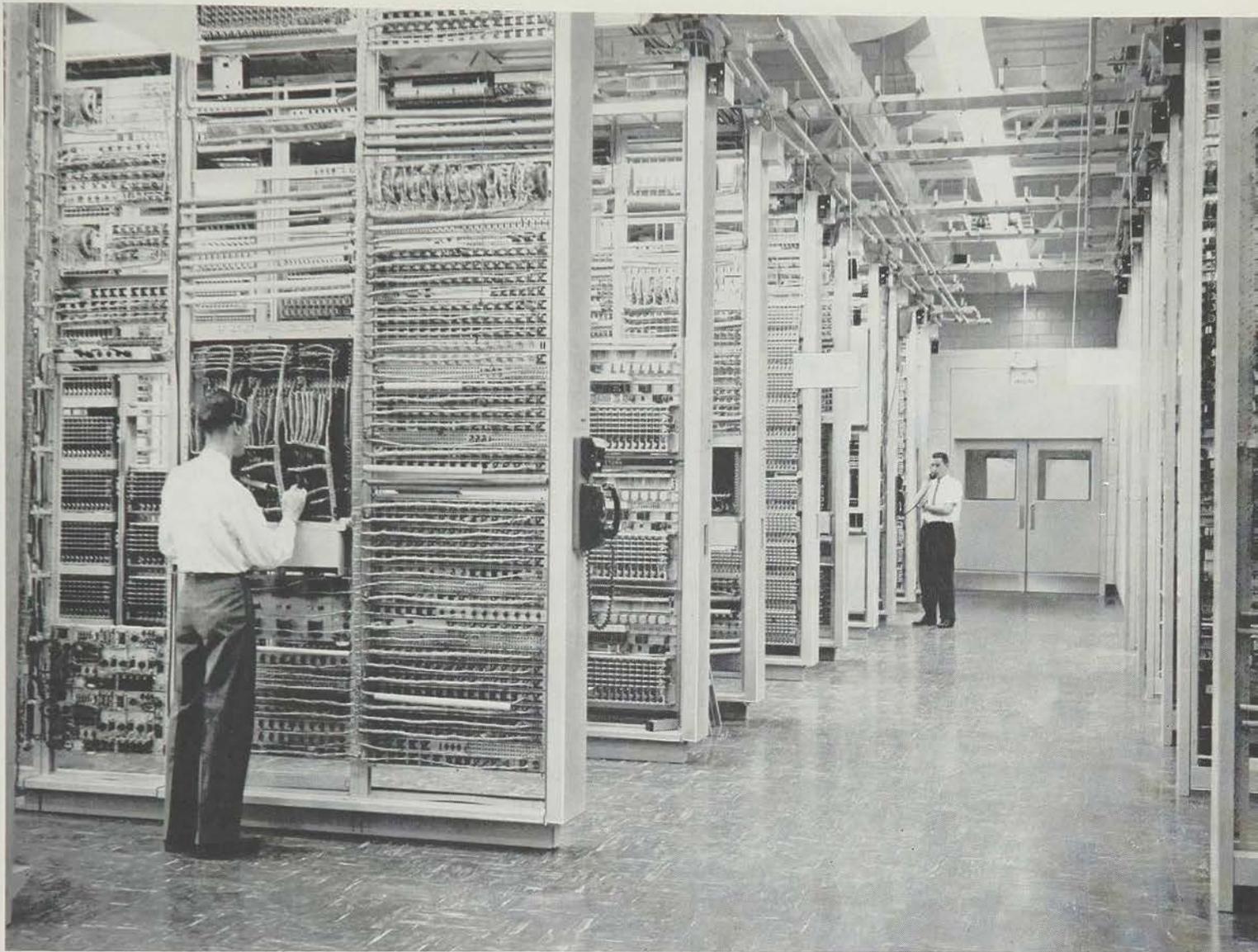
Complete No. 1 and No. 5 crossbar systems can be checked out in this crossbar laboratory at Columbus.

connectors. This department is also responsible for equipment development activities and for a number of special projects, including the 1A line concentrator and central office switching equipment used for "BELL BOY" service.

4. A section concerned with circuit development work on the crossbar tandem and 4A toll crossbar systems. This unit is the "advance guard" of those who will transfer to Columbus in mid-1963, and is composed largely of people who recently transferred from operating telephone companies to the Laboratories.

5. A section responsible for fundamental development work on certain components to be used in the new electronic central office, such as the connector and printed circuit wiring packages.

6. A staff organization with responsibilities for other than direct technical development operations. At Columbus, this includes the editing and drafting group, drawing and specification files, development shop, reproduction facilities, order service, stock room, clerical, typing, stenographic, secretarial and other supporting activities. The personnel of this organization is almost entirely Western Electric people on loan to the Laboratories.

There are several specialized laboratories in which these groups work. Among them is one equipped for obtaining data and conducting basic tests on magnetic designs for relays and other electromechanical apparatus. This laboratory is fully equipped with the latest instruments for such studies. Another laboratory has facilities for conducting tests on crossbar switches and a variety of older types of relays, including those

Library is maintained jointly by Laboratories and Western Electric; it stocks 1800 volumes.

used in the Bell System but made by outside manufacturers. A third laboratory is devoted to studies of wire spring relays, the basis of modern switching systems. (Western Electric built more than 14 million of these relays during 1961.)

A connections laboratory is used for conducting tests on solderless wrapped connections and welded connections, as well as for studies to determine how quality standards can be safeguarded. A precision measurements laboratory with special temperature and humidity controls is equipped with instruments for detailed dimensional analysis.

A number of laboratories are devoted to test procedures, both operational and life-test. One is designed for testing with frames and other similar facilities and to permit continuous operation of components under test and to minimize related noise. This laboratory has facilities for conducting environmental tests of large components and was used for testing the remote unit of the 1A line concentrator under such conditions of varying temperature and humidity as might be encountered when mounted on a utility pole. Another laboratory has facilities for conducting shock, vibration and life-tests on components and small equipment units.

The large crossbar systems laboratories are located in the manufacturing area; in one of these, complete No. 1 and No. 5 crossbar central offices can be checked out. Included are most of the various kinds of circuit and equipment units

designed for these systems, with the ability to test new service features as these are developed for use by the operating telephone companies. This laboratory includes bench testing space and a power room with adequate capacity for operating not only the No. 1 and No. 5 crossbar systems laboratories but also the crossbar tandem and No. 4 toll laboratories which will be installed in the near future. The completeness and adequacy of the laboratories and offices can be seen in the accompanying photos.

In addition to offices and laboratories, Columbus has a self-service stock room, reproduction facilities, and a model shop with an assortment of light machine tools and facilities. There is also a separate wiring shop with facilities for building local frame cables and for assembly, wiring and the fabrication of equipment units for testing in the systems laboratories. Another facility in the office building is a classroom area which is used for training purposes and conferences.

An essential adjunct to a development organization is an adequate technical library. As in several other branch laboratories, the library at Columbus is maintained jointly by the Laboratories and Western Electric and is operated by a professional librarian and an assistant, shown at left. In addition to some 1800 volumes of technical works and 280 periodicals, it has access to all publications on file at any of the other locations and can obtain any of these on short notice. Furthermore, at Columbus, the large and extensive libraries at Ohio State University and the Battelle Memorial Institute are readily accessible.

Educational opportunities in the Columbus Branch Laboratory are also quite favorable. Newly recruited engineering graduates attend Ohio State University in the Branch Laboratories Education Plan (BLEP) and work toward a Master's degree. In addition, this university is convenient for those who wish to continue advanced studies under the Graduate Study Plan. The BLEP Program serves in lieu of the first two years of the Communications Development Training Program (RECORD, *November,* 1960) at headquarters locations. Beginning in the Fall of 1963, it will be supplemented by Bell System technology courses to be given locally. Those in the BLEP Program are normally transferred to some other branch or to headquarters on a rotational assignment during certain summer months.

In a new program, a second rotational assignment in another laboratory department at the branch will be given to the BLEP students. The Ohio State University also offers a varied selection of liberal arts and some technical courses in the evenings. In addition to these opportunities

in formal education, a number of Out-of-Hours courses are given each year by members of the technical staff.

The branch laboratories system brings with it certain problems in communications, to which are applied all possible services, including expeditious mail and parcel service. In addition, direct telephone tie lines are provided between Columbus and Murray Hill and also between Columbus and Indianapolis. Speakerphone facilities in one of the conference rooms at Columbus aid in interlocation telephone conferencing. Teletypewriter service is also available. Travel between locations supplements these methods of communication.

The Columbus Laboratory started in mid-1959 with just under 100 people. By January 1, 1962—just two and one-half years later—it had grown to 297, about three times its original size. It is still growing. By the end of 1963, after the move of the crossbar tandem and toll crossbar people is completed, it is estimated that this Laboratory will increase to more than 500 people.

One of the outstanding advantages in the branch laboratories arrangement is the ability to reduce intervals involved in the manufacture of new products. This is very important where urgent schedules for service must be met and also in those cases where competition is involved. An advantage in the Columbus Branch Laboratory situation which is very important in reducing manufacturing preparation intervals is the close association with the Western Electric equipment standards engineering group that is responsible

Strength test apparatus is typical of modern instrumentation installed throughout laboratory.
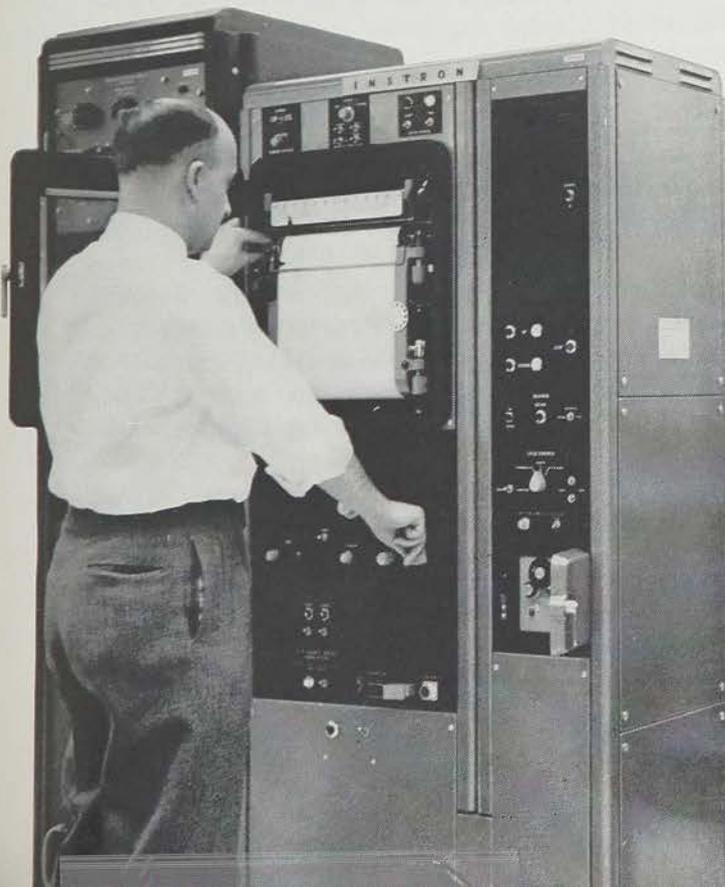
for converting Laboratories design information into wiring diagrams, cable running sheets, and other information required by the shop. Also, close cooperation is feasible with the Engineer of Manufacture engineers who are responsible for the design of test sets to check out the final product. Of course, this is in addition to the contacts with those who are directly responsible for the manufacturing operations.

A number of procedures are followed to expedite the completion of developments. For instance, meetings are held at the start of a development with the various branches of the Laboratories and Western Electric to explain the importance of the project, its schedules and any unusual procedures required. Engineering level contacts are also made with all organizations. As development progresses, and when the project is particularly sensitive to price change, all contacts are kept fully informed in reviews of price status. Western Electric manufacturing drawings are begun on a piecemeal basis and Western Electric authorizations for manufacturing preparation are sometimes requested before Laboratories design information is released. This is possible with the informal contacts so prevalent at the branches.

When copies of Laboratories design information become available, Western Electric begins many phases of manufacturing preparation. Preliminary copies of Western Electric drawings are sometimes used in building models for Laboratories testing and for field trials. Because of this advance preparation, some phases of manufacture will actually have begun by the time Laboratories official drawings and specifications are issued. Laboratories testing under environmental conditions when necessary continues during the early stages of manufacture.

The telescoping of Bell Laboratories-Western Electric schedules requires for its success certain conditions and actions which are out of normal routine. For instance, specific design requirements and economic factors affecting salability are determined as early as practical, particularly when risks involved are higher than normal. Also, intensive analysis of designs is required, with less dependence on laboratory tests.

The above measures have been tried and tested successfully on the 1A Line Concentrator project at Columbus, and are being extended to other developments to as great an extent as appears practical. Perhaps the most important attribute is implicit confidence between Bell Laboratories and Western Electric personnel, vital to an operation where one group begins large scale operations from the other's preliminary information.

*Today's strain gages can measure forces
resulting in deformations of as little
as a few microinches or as great as 20
percent of a material's original dimensions.
These applications meet the stringent
requirements of modern science, but the
concept dates back more than 300 years.*

Strain Gages

John Buckelew

THE DISCOVERY that metal wires change in electrical resistance when subjected to strain or elongation was made by Lord Kelvin in 1856. Kelvin's discovery plus Hooke's law, which relates the proportionality factor between stress and strain, form the basis of today's analytical techniques involving the electric resistance strain gage.

In reporting the failure of a material or structure, the established method uses increments of stress, or force per unit area. This standard of failure has a disadvantage, however, in that stress cannot be measured directly. Thus, we cannot measure the force which is exerted on a material, but only the resulting consequences of that force. Strain is the variable measured. In the simplest case—uniaxial stress—stress and strain in a material are directly related by the material's modulus of elasticity. Therefore, to obtain stress values, the strain is measured and this is multiplied by the modulus of elasticity for the material involved.

A typical strain gage installation is shown on page 399. The gage consists of a wire or foil resistance element mounted on either an epoxy or paper base. This unit is bonded to the surface of the test specimen with one of a variety of adhesives. If the test is conducted in a humid environment, the installation is waterproofed. A strain gage operates on the principle that strain —that is, displacement or deformation—is transmitted from the surface of the test specimen through the adhesive layer to a strain-sensitive filament. This causes a change in the electrical characteristics of the filament which, after amplification and calibration can be described in microinches of strain, or, what is sometimes called microstrain.

Resistance strain gages can measure strains from a few microinches to 20 percent of their original length. They can operate in liquid helium and at more than 700 degrees F and can detect strains from zero frequency to more than 50,000 cps; their upper limit has not yet been determined. Strain gages mounted to rotating machinery can withstand loads up to 60,000 gravitational units, and signals have been obtained from them at close to 100,000 revolutions per minute. They can be used in almost any application where stress is a measurement problem.

The two major uses of strain gages are to measure strain directly in a part, and to use the gage as a sensing element of a transducer. When strains are measured directly, the results are not quite as accurate as those obtained with a transducer. One reason for this is that the gage factor,

which relates the change in resistance to the change in gage length, is not determined for each gage. The manufacturer uses a statistical method for assigning the factor, which results in a tolerance of one percent. Instrument errors and variations in mounting techniques may add another two or three percent error. When a gage is used as part of a transducer, however, its resistance change is calibrated with known weights. For example, if a gage is cemented to a short metal column, for use as a load-measuring transducer, an accuracy of about one percent is possible because such devices can be individually calibrated. Strain-gage-based transducers can measure force, torque, pressure, and many other similar variables.

The design of these devices varies. For force measurements, the sensing unit is generally a cantilever beam, a flexible ring, or a solid column with strain gages bonded to the surface. For torque measurements, a compliant shaft may be used with strain gages mounted at an angle of 45 degrees in relation to the shaft's centerline; and for pressure measurements, a diaphragm is used with a strain gage having a helical shaped foil element.

The transducing process, or method by which the physical variable (displacement or deformation) is changed to an electrical variable, depends on the gage filament strain sensitivity and eventually the gage factor. The strain sensitivity is solely a property of the filament material and is equal to the unit resistance change in the filament divided by a unit change in length. The gage factor, however, is the result of a number of variables including strain sensitivity. It is equal to the unit change in resistance of the gage divided by the unit strain that is transmitted from the specimen surface to the filament material. It is dependent on such things as the filament carrier, the adhesive used to cement the filament wire to the carrier, the adhesive used to bond the gage to the specimen, and the filament geometry.
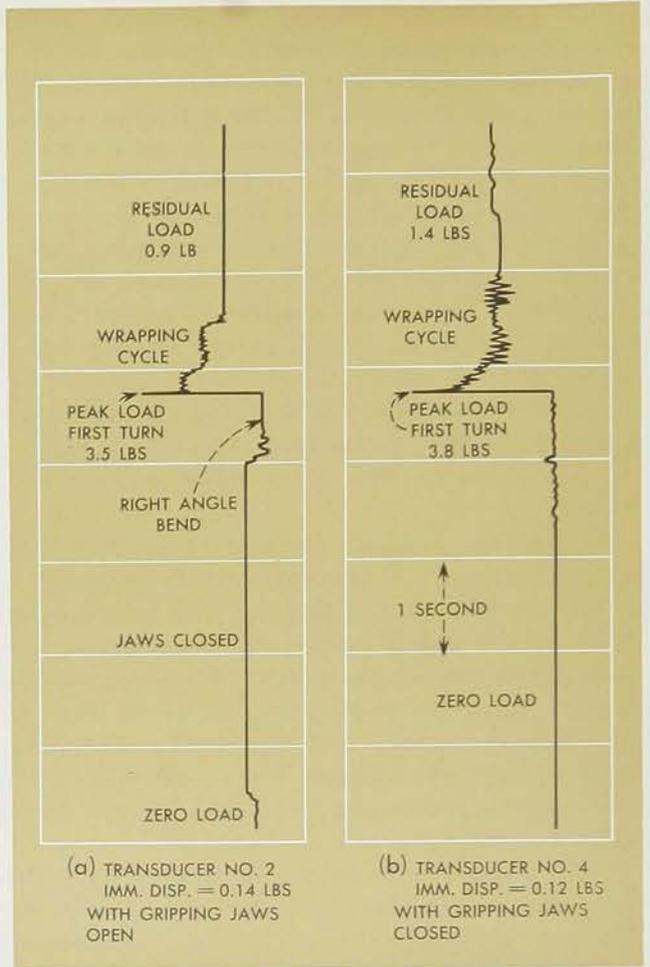
Various filament materials are used in strain gages. One of the most popular is a copper-nickel alloy called constantan. Gages of this material have a gage factor of about two and are used primarily for low-frequency and static strain work. Another filament material is a nickel-chrome-iron alloy known as Isoelastic, which is used primarily for dynamic strain measurements. Isoelastic has a gage factor almost twice that of constantan but is quite sensitive to temperature variations, and so not suited for long-term static work where temperature is not controlled.

The carrier, or base, is a material used to sup-
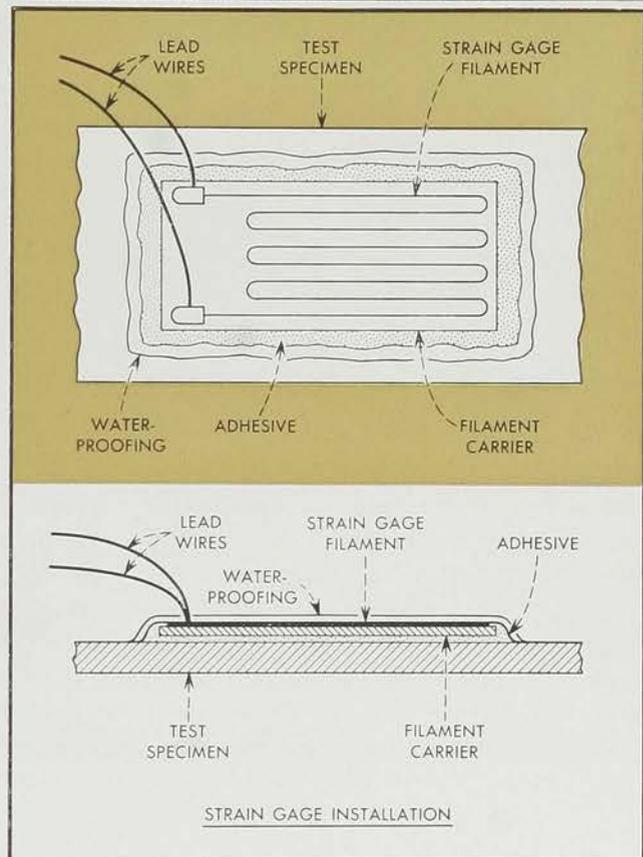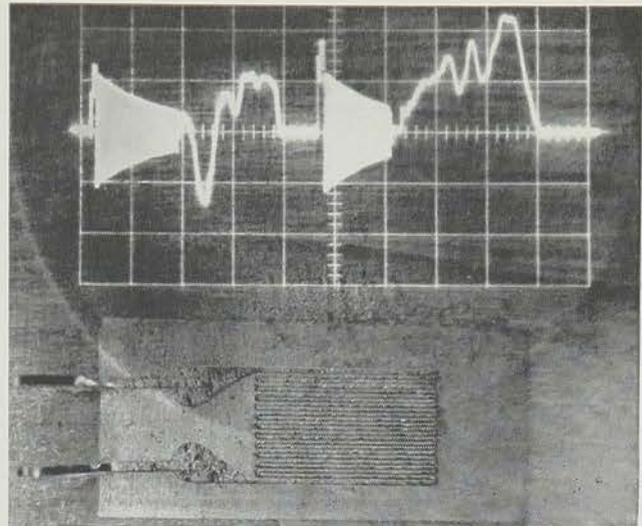
High-frequency vibrations of a cantilever beam instrumented with foil strain gages of the type shown in the lower part of the photograph. Bottom diagram shows a typical strain gage installation.

port the filament wires. It facilitates handling, and insulates the gage from the specimen. Many materials are suitable for carriers, including paper, phenolic, epoxy, mica, and metal. A paper carrier is generally used for temperatures up to 180 degrees F. Other materials are used for higher temperature work, and their use often involves more difficult bonding procedures.

(a) TRANSDUCER NO. 2	(b) TRANSDUCER NO. 4
RESIDUAL LOAD 0.9 LB	RESIDUAL LOAD 1.4 LBS
WRAPPING CYCLE	WRAPPING CYCLE
PEAK LOAD FIRST TURN 3.5 LBS	PEAK LOAD FIRST TURN 3.8 LBS
RIGHT ANGLE BEND	1 SECOND
JAWS CLOSED	ZERO LOAD
ZERO LOAD	

(a) TRANSDUCER NO. 2
IMM. DISP. = 0.14 LBS
WITH GRIPPING JAWS
OPEN

(b) TRANSDUCER NO. 4
IMM. DISP. = 0.12 LBS
WITH GRIPPING JAWS
CLOSED
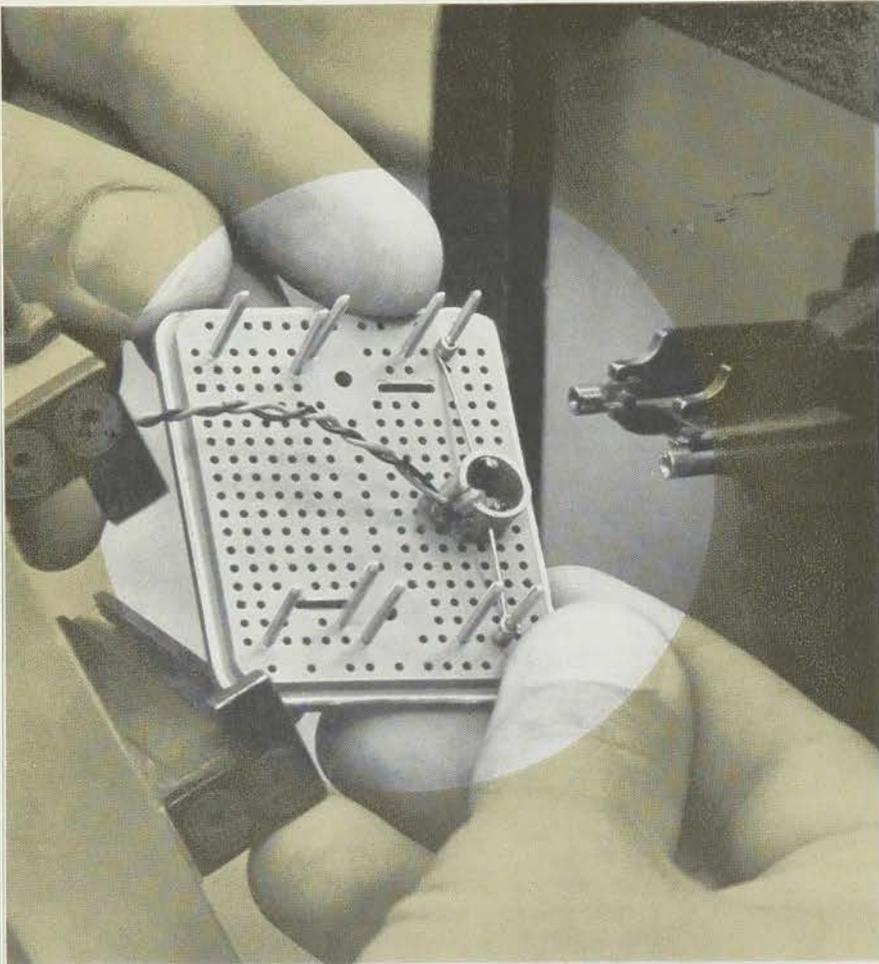
Plastic module showing strain gage transducer mounted in place after a test run. Parts of the wire-wrapping machine can be seen in background. Chart (right) shows load picture for each step in cycle.

The design of the filament grid varies, depending on whether the gage is intended to measure strain in tension and compression, torque, stress, or pressure. The sensitive element is generally a foil or a wire. There are two-element gages for measuring torque, three-element gages for strains of unknown direction, spiral gages for diaphragms, and many others.

The success of a strain-gage installation depends a good deal on the adhesive which holds the gage in place. A thin and strong adhesive layer produces the most favorable result. As in the case of carrier materials, the choice of a particular adhesive depends primarily on the temperature of the part to be measured.

Strain gages were recently put to an interesting application in the Electromechanical Laboratory where they were used as part of a load transducer. Measurements were made of the static and dynamic forces acting on electrical components (such as resistors) when they are automatically mounted on a module using wire-wrap-

ping techniques. For this type of mounting, both lead wires were wrapped around square metal pins protruding from a plastic module. The photograph above shows this module and the transducer designed to measure the forces.

As shown in the photograph, the transducer consisted of a thin steel ring. A foil gage was bonded to the inside wall. The physical load was applied to the ring by two wires attached through holes in the ring wall. These load wires simulate the conventional lead wires of a component. The output signal of the transducer was calibrated by applying known loads. Then, the transducer was placed inside the automatic wire-wrapping machine and allowed to undergo the wrapping forces of a regular component. The wrapping cycle consisted of a number of steps: first, gripping jaws closed on the component load wires, second, the wires were bent at right angles, third, they were positioned over the wrapping terminals and finally they were wrapped around the terminals. The load for each step was recorded on

a chart also shown above. With this technique, it was possible to measure accurately the magnitude and duration of the wrapping forces.

As an outgrowth of this work, similar measurements were made of the loads developed when mounting components using electric-, air-, and manually-powered hand-held wire-wrapping tools. The results of the test showed that the air-powered tool exerted the lowest peak forces on the component and the electrically-powered tool was next. The hand-powered tool loaded the component with the most severe forces.

In another application, strain gages were used to measure strain levels encountered when printed-circuit boards were subjected to vibration. A variety of boards with different weights of components were mounted on a vibration table. Strain gages were bonded to the boards, and the strain was measured at various frequencies and vibration levels and also at the natural frequency of the board. Fatigue tests of the printed-circuit boards were then made in separate flexing machines to determine the suitability of the design.

The versatility of strain gages was demonstrated when they were used in a dynamic ball-bearing torque monitoring machine shown at the right. The device consisted of a gyro motor having a stator inside the rotor with the bearings under test separating the two items. Shafts attached to the stator were mounted in precision bearings in pillow blocks. In making torque measurements, the rotor was brought up to speed, as determined by a speedometer. The power to the rotor was cut off and the torque was then recorded for the first 10 seconds of coast-down time. As the torque in the gyro-motor bearings increased, during the life test run, the tendency of the stator shafts to rotate with the rotor increased. This motion was restricted by a spring steel cantilever beam which was clamped on one end at right angles to the stator shaft extension and limited in travel by a knife edge at the other end. As the torque in the bearings increased and the stator shaft tried to rotate, the cantilever beam deflected. This deflection caused a strain in the beam which was measured with strain gages.

One final example of an interesting strain-gage application involves their use in building a load cell to measure the weight carried by the trucks of the Telstar satellite antenna. These trucks support the antenna and allow rotation in azimuth. The transducer consisted of a steel column $2\frac{1}{2}$ inches in diameter and 5 inches long. Four strain gages were used; two were mounted
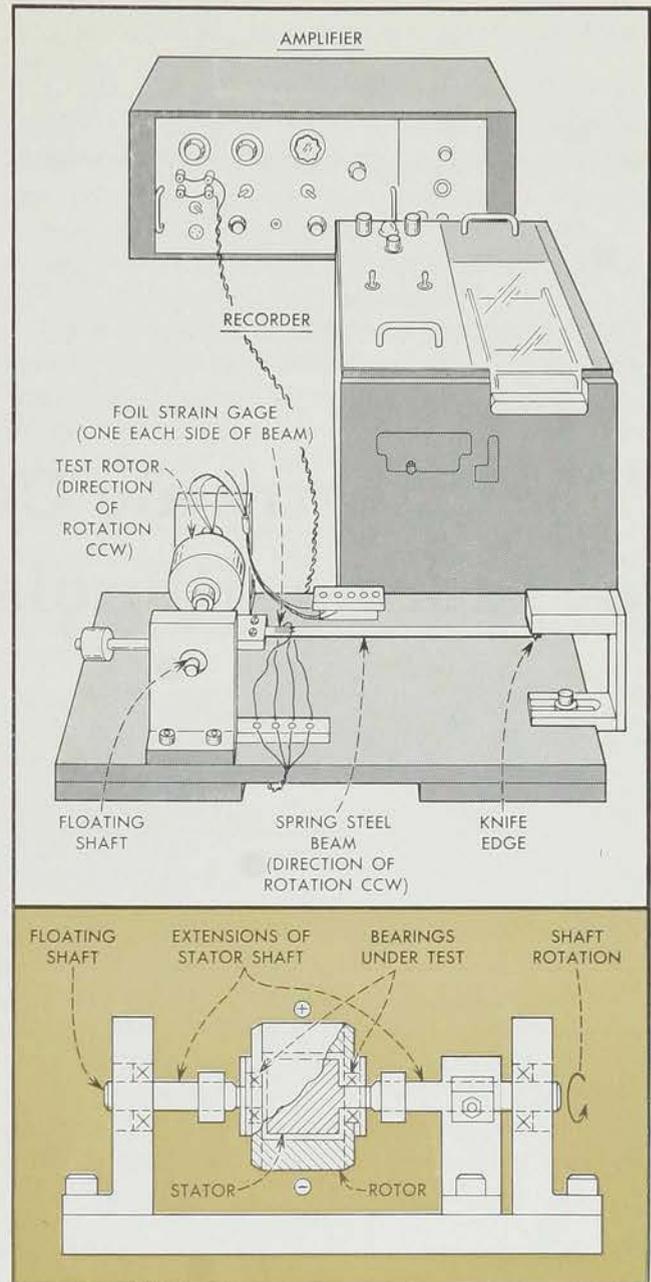
Testing arrangement used for monitoring torque of gyro bearings over their expected lifetimes.

in the axial direction (along the length of the column) and two in the tangential direction. (This configuration takes advantage of the lateral deflection of the beam resulting in additional gage sensitivity.) The transducer was placed on one end of a jack under the truck, and the truck was raised until the wheels just cleared the track or rail. Loads of about 60 tons were measured.

Strain gages provide a relatively simple and inexpensive tool for making highly accurate measurements. Their application is limited only by the user's imagination.

All of the experimental equipment used in the trial of the ECO at Morris, Ill. has been dismantled, but the results of this experiment will affect the entire spectrum of tomorrow's communications technology.

The Electronic Central Office at Morris, Illinois

E. G. Neumiller

THE DESIGN of the Electronic Central Office was predicated on the knowledge that time can be sliced into infinitesimally tiny portions, and that certain actions can be accomplished within these time spans. For example, in the 12 seconds it takes the average person to dial a seven-digit number, the electronic central office (ECO) can perform millions upon millions of separate tasks. Even compared with today's electromechanical switching which interconnects millions of telephones, the ECO represents an increase in speed of 1000 times.

One of the most important steps in designing a commercial version of the ECO was the successful trial of the system in Morris, Illinois. The ECO experiment began in June of 1960. About 400 customers participated during the two-and-one-half year trial of the ECO. The purpose of the trial was not only to test the ECO's performance but also to study the service features of the system and the reactions of the telephone customers, ultimately leading to the commercial electronic central office, No. 1 ESS.

Major components of the experimental ECO at Morris consisted of a scanner, signal distributor, barrier-grid stores, flying-spot stores, switching networks, central control, standby transfer and administration center.

The scanner, at millisecond intervals, detected the condition existing on a customer line or trunk. For example, the scanner detected a customer picking up the handset of his telephone. When he dialed, it detected each of the pulses returned by his dial, and the scanner also detected the conclusion of a call. In this way, the scanner "gathered" information. The signal distributor acted to "distribute" information in an opposite manner to the scanner. When, for example, it was necessary to pulse out digits to an electromechanical system, the signal distributor actuated a relay to do this, thus coupling the high-speed ECO system to a slower-speed system.

A barrier-grid store provided a short-term, or "scratch pad" memory. This was an electrostatic storage tube in which were recorded such things as the number dialed by a customer, the progress of a call, and the state (idle, ringing, or talking) of each customer's line. A flying-spot storage tube was the long-term, or semi-permanent, memory. It used photographic plates to store such information as the office telephone service program, the office test program, "translation data" (which contained such data as that necessary to convert a directory number to an equipment location), the type of ringing required, whether a call was for another office, and so forth.

Switching networks containing neon-filled gas tubes were used to connect customers with dial tone, ringing tone, and with other customers and circuits. The line-concentrator switching network was connected to customers' telephone lines, while the distribution switches were connected with tones, trunks and other circuits.

The central control acted as the "brain" of the ECO, making decisions to control the flow of orders to various parts of the system. For example, an order from program memory to connect two customers was directed by the central control to those parts of the system necessary to do the job.

To permit trouble-free telephone service, a standby transfer was ready immediately to replace a component temporarily in "trouble" with another standing by for service. An administration center extracted information concerning operation of the system, and this was printed out on the office teletypewriter. This center was also used to type in changes in system operation and other instructions, as required.

In appearance and performance, the ECO at Morris had little in common with present telephone switching systems. The 23,000 neon-filled gas tubes comprising the switching network worked silently. There were no long high racks of relays but simply several rows of gray cabinets packed with electronic components.

The gas-tube switching network made it necessary to replace the conventional 20-cycle ringing with tone frequency signaling, and a special telephone set which accommodated the tone frequency feature. The tone ringer could be tuned to any one of the eight ringing frequencies transmitted from the electronic central office. Thus, a customer on a party line had his telephones tuned to one frequency and they rang only when he was being called. A 20-pulse per second dial (twice as

Equipment cabinets of the Electronic Central Office. R. P. Falkinburg tests circuits in the ECO's administrative center, while B. G. Hemmendinger checks operation of the gas-tube switching network.
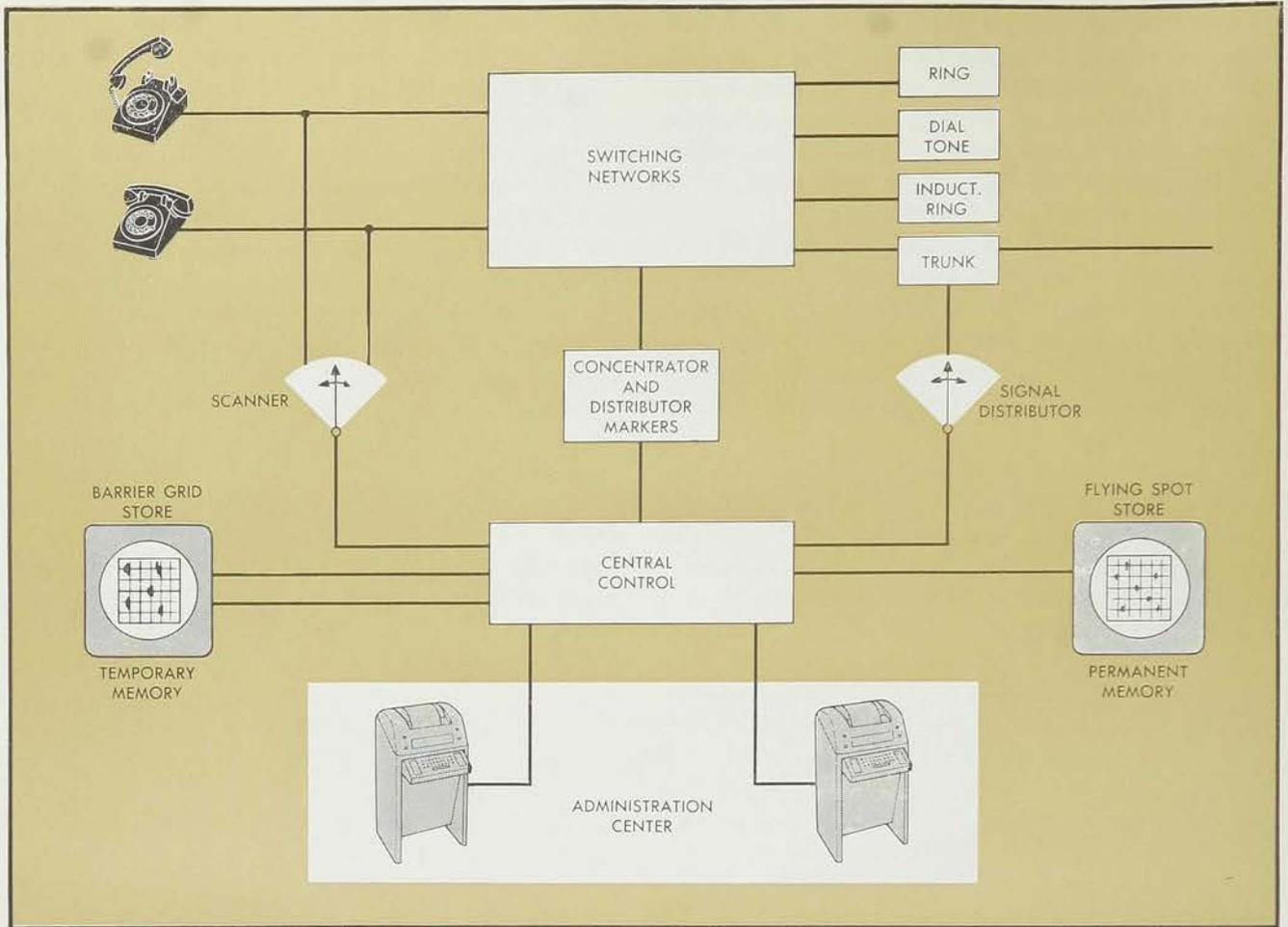
This schematic diagram shows the basic components of the experimental electronic central office.

fast as normal) was installed with each telephone.

The standard station protector did not fully guard the low-current tone-ringing telephone set, so a zener diode was mounted at this protector to guard against damaging voltages lower than those controlled by the carbon blocks.

ECO trial lines terminated at the vertical main frame of a No. 5 crossbar system together with the lines of the other Morris customers. Through crossconnecting "jumpers," the trial lines were wired to concentrator line terminals on the horizontal main frame. Twenty-five line concentrators in the electronic central office were equipped to serve a maximum of 1000 lines. The actual number of lines connected to a single concentrator was determined by estimating customer traffic patterns and then assigning lines so as not to exceed the traffic-handling capacity of each concentrator.

Calls between customers served from the Morris No. 5 crossbar unit and customers served from the ECO unit were handled as though the trial unit were a separate central office. Calls from other offices were switched through the No. 5 crossbar unit. However, all Morris customers, No.

5 crossbar and ECO, had telephone numbers starting with the same prefix: WHitney 2. Use of a separate office code (such as WHitney 4) would have required a change in telephone numbers when customers joined the trial and again when they left. A single office code permitted use of current telephone directories, and resulted in flexibility for adding or removing customers during the trial.

Both the No. 5 crossbar unit and the ECO were arranged to check their "translation" records to determine whether a call was to be terminated within the unit itself or whether it had to be outpulsed to the other unit. The No. 5 crossbar completing marker did this by checking the called number in the number group frame wiring, while the ECO used its translation records in the memory storage system. Two incoming trunk groups handled all calls to the ECO unit. One group handled all calls from the Morris No. 5 crossbar unit; the other handled long distance calls (either direct-distance-dialed calls placed by customers outside of the local area or those handled by the Morris switchboard operators) and also calls

from the local service area community dial offices. An operator handling incoming long-distance calls did not have to know from which unit the call came. She routed all such calls to the No. 5 crossbar and that equipment automatically routed the call.

The ECO had a group of outgoing trunks for calls to No. 5 crossbar customers and another group for calls to seven nearby communities included in the Morris local service area. Four digits were outpulsed for No. 5 crossbar calls while seven digits were pulsed to route calls to the seven community dial offices. All outward long-distance calls from Morris, whether they originated in the No 5 crossbar unit or in the ECO, were handled by operators. Consequently, separate outward trunk groups were provided from each unit to the Morris long-distance switchboard.

In addition to the line concentrator trunks, interoffice trunks and operator trunks, a number of other trunks were terminated on the ECO distribution network. They included tone trunks for dial tone, busy signal and re-order signal, ringing trunks, and test trunks.

In late 1959, the Illinois Bell Telephone Company prepared a list of 500 telephone customers considered desirable as participants in the initial phase of the trial. These candidates satisfied a number of requirements established jointly by the Laboratories and the Illinois Company. Trial candidates were selected from this list, and the Morris Commercial Manager invited these customers to take part in the trial. They were advised in advance when telephone installers would arrive to connect their ECO telephones.

On June 1, 1960, seven Illinois Company employees and three Laboratories engineers were given ECO service, and two weeks later 20 regular customers were added. This first group of customers had two lines—one for the trial telephone, the other for their regular telephone. For the next five months they received ECO service four hours a day, between the hours of 5 p.m. and 9 p.m. During this time, calls could be originated from either telephone. When the electronic unit was "turned down" for testing during the other hours of the day, these customers received telephone service from the No 5 crossbar system and calls made to their ECO number were automatically routed to their regular telephone. Whenever ECO service was not available, a recorded announcement on the ECO line told the customer when the next service period would start.

The electronic central office was placed in full 24-hour service on November 11, 1960. At that time, the original 30 customers had their regular telephones removed and thus became the first telephone users to receive local telephone service entirely from an electronic central office. During the weeks that followed, additional customers were added to the trial. At the peak of the trial, more than 400 customers were receiving full-time ECO service. The Illinois Bell Telephone Company installed as many as 10 ECO telephones a day with their regular installation force. The weekly average of customers added varied widely depending on such things as the complexity of the installation, test programs being carried out in the office, and the number of craftsmen available.

Trial customers were given the opportunity to sample six special services of the type envisioned for electronic central offices of the future. These special service features included code calling, abbreviated dialing, series completion, fixed transfer, timed transfer, and dialed transfer.

Code calling permitted a customer to use his extension telephones for intercommunication service. It worked this way: The customer dialed the digit "1" to inform the ECO that he was requesting this special service. Then he dialed a second digit (any digit, from "1" to "8") and hung up. Immediately, the ECO rang all the telephones on his line with series of tones followed by a silent interval. This was repeated over and over again until the ECO detected an answer on the line. The series of tones was the same as the second digit dialed; for example, if the customer dialed "15", the ECO would send a series of five tones. The ringing stopped when someone picked up an extension phone or the phone at the calling station. Upon answer, two or more extensions on the line could intercommunicate, and the line was held busy to other incoming calls.

Abbreviated dialing made it possible for a customer to reach frequently called 7-digit numbers by dialing only two digits. The customer first dialed the digit "1" to tell the ECO that he was requesting this special service. (In the Morris ECO, the digit "1" was used for code calling, as well as for abbreviated dialing. This meant that a customer could have only one or the other service at any one time. In commercial systems this code conflict is being eliminated.) The customer then dialed a second digit from "1" to "4". The second digit told the ECO which one of four Morris telephones the customer wished to reach. Prior to this, the customer gave the telephone company four telephone numbers he wanted to correspond to whatever second digit he selected. These numbers could be in either the ECO or the No. 5 crossbar office or both. Upon receipt of the second digit, the ECO consulted the abbreviated-dialing

Administrative center at Morris ECO. Daniel Danielson speaks on the test telephone.

list in its translation lists, checked the number of the calling telephone, and set up the call to the directory number found in the list.

The customer having series completion service had calls to his telephone automatically routed to another telephone if his telephone was busy. If the second telephone was also busy, the calls could be further routed to a third telephone. When the ECO found a called line busy, it checked its memory records to see if the line had series completion service. If it had, the ECO attempted to complete the call to the first alternate telephone it found on the stored series completion list. If that line was also busy, it tried the second alternate telephone. If the completion could not be made to telephones on the list, a busy signal was returned to the calling customer.

Fixed transfer enabled a customer to transfer his incoming calls at various times to a number previously given to the Telephone Company. When a customer wanted this service, he dialed "5583" and hung up. The ECO recognized this code and recorded the transfer condition in its memory records. Calls to the customer's telephone were routed to the preselected alternate Morris

telephone. Even though his telephone was on transfer, the customer could continue to make outgoing calls. When the customer wished to restore service to normal, he dialed "5584" and hung up. This erased the transfer record in the ECO memory.

With timed transfer service, the customer called the telephone company business office and requested that his incoming calls be transferred to another telephone during the specified period. The business office called the customer back to verify the request so as to prevent fraudulent use of the service. A transfer order was then placed in the ECO memory, using the administration center teletypewriter. The time to start and stop the transfer service was also recorded. Only during the specified interval would calls be transferred; at other times, calls would be routed to the customer's own telephone. During the transfer period he could still make outgoing calls.

The most flexible form of transfer service was the dialed transfer which enabled a customer to have his calls transferred to any telephone in the exchange by dialing a coded series of digits. For example, he dialed "5585" and the last four digits

of his own telephone number and the last four digits of the Morris telephone number to which his calls would be transferred. When he hung up, transfer was put in effect by the ECO. Again, he could still make outgoing calls. To restore his service to normal the customer dialed (from his own telephone *only*) "5586" and the last four digits of his own telephone number. He then hung up and the transfer was canceled out of the ECO memory records.

A special service was furnished without cost to a customer if he wished to try it out and had sufficient occasion to use it. These services were added to the system program several months prior to the start of the trial to demonstrate the new service potential of the ECO, and also the ease and simplicity of adding such services with a stored program system. It required only 800 additional stored program words to provide them.

ECO service proved to be very popular with those given one of the services. Code calling, abbreviated dialing, and dialed transfer received the most plaudits from interviewed users.

The maximum number of Morris customers who could be given the six services at any one time is shown in the Table above. Only a few customers at a time could be given some of the services because a fixed limited amount of temporary memory was available in the Morris ECO to give the service; in future installations, extra memory capacity can be added if necessary to meet the demands for service.

Customers were removed from the trial ECO system beginning in January, 1962, with the final customer being converted back to No. 5 crossbar service on January 24, 1962. During the period the trial system was in service, much valuable information was obtained. The objective of the trial was to test system performance under field conditions so as to determine the feasibility of new switching techniques, the attitude of customers to the services provided, and the type of maintenance facilities and operating personnel needed.

The new switching techniques were found to be entirely feasible. An over-all appraisal of the quality of service given to trial customers indicated that the system was capable of providing dial service that compared favorably to that provided throughout the Bell System. Also, customer-reported trouble ratios compared favorably with Bell System averages for No. 5 crossbar dial equipment in spite of the experimental nature of the electronic equipment.

The higher speed dials (20 pulses per second) and the tone ringers furnished with the station set met with very favorable customer response.

SPECIAL SERVICES	CAPACITY
Code Calling	400
Abbreviated Dialing	125
Series Completion	48
Fixed Transfer	16
Timed Transfer	13
Dialed Transfer	16

Customers stated that electronic service was fast, convenient, modern and a sign of progress.

Experience gained by Laboratories engineers who designed and maintained the office stimulated a number of improvements in circuit design, programming, and maintenance techniques. These experiences are being further reflected in design of future systems. Useful information was gathered on the type of personnel required to operate an ECO system. The success of the Morris trial ECO has been evident from the favorable reactions of customers and operating company personnel. Moreover, it has provided valuable information for use in designing switching systems of the future.

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H. D. Cahill

Maintaining the ANI System

THE CONTINUED EXPANSION of customer dialing over long distances has led to a recent development known as Automatic Number Identification or ANI. (RECORD, *June,* 1960.) This system, which serves No. 1 crossbar, panel, and step-by-step switching offices, uses electronic equipment to identify a calling customer's number automatically and to transmit this number to Automatic Message Accounting equipment at a central office which produces a tape record for billing purposes. The central office, which is a tandem or toll point, is commonly referred to as a CAMA, or Centralized Automatic Message Accounting, office.

At present, the Bell System uses centralized recording without ANI features in many areas. But these arrangements are only semi-automatic, requiring the CAMA operator to intervene and ask the calling customer for his number. The operator then keys the number into the recording equipment. With the new ANI circuits, however, these identifying and recording functions are performed automatically, thereby furnishing the customer improved service. At the same time, he obtains the greater accuracy inherent in machine operation.

A system that automatically identifies directory numbers for billing records must be accurate and free from troubles that interfere with the normal flow of traffic. To achieve these ends and to enable maintenance personnel to detect the approach of possible circuit failures, Bell Laboratories engineers developed new testing and maintenance facilities for ANI. These include overall testing, trouble-recording, and line-verification.

The first of these facilities—the testing equipment—can "seize" the principal ANI circuits from a common test frame and permit tests to be applied manually to circuits or parts of circuits. The test frame may also operate fully automatically in a manner designed to test all of the principal circuits periodically. By operating keys on the frame, a maintenance man can control the applied tests in accordance with a particular program.

Laboratories engineers designed a test frame, called the Outpulser, Identifier, Trunk Test frame (OITT). It consists of a bay of equipment which includes relays, switches, and timing devices. A key-and-lamp panel is mounted on the frame. The keys control the various tests to be made and the lamps indicate the progress of a test call or trouble conditions if the test fails. The frame is also equipped with a writing shelf and "pigeon holes" for storing useful testing data.

As its name implies, the OITT frame tests outpulsers, identifiers, and trunks. Before proceeding further, it may be helpful to discuss briefly what these circuits are and how they work together. A transmission circuit, called the ANI trunk, connects a local panel, No. 1 crossbar, or step-by-step office with a CAMA office. A called number is outpulsed through this trunk circuit digit by digit. At the proper time, the CAMA equipment signals the trunk circuit to obtain the calling number. The trunk circuit thereupon seizes an outpulser which, in turn, seizes an identifier. This latter circuit identifies the line number of the calling party and registers it in the outpulser. The outpulser then releases the identifier, and the ANI circuit transmits the calling number to the CAMA office. Equipment there records the calling number on AMA tape.

The actual identification is done through recognition of a 5800-cps tone signal generated by an oscillator and applied for a short interval through
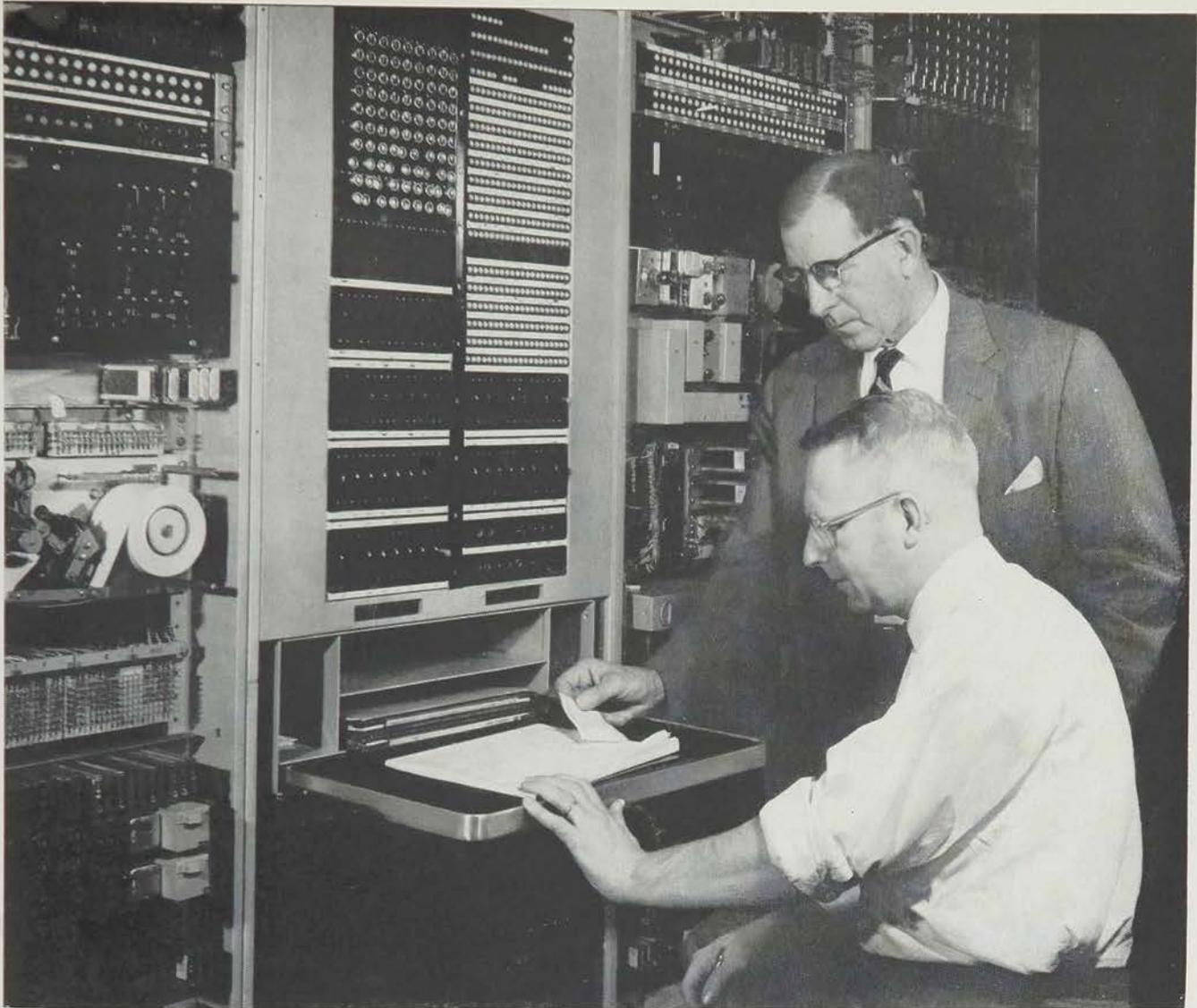
M. R. McCann (seated) and H. D. Cahill at OITT frame examine trouble ticket from ANI System test.

a lead to the ANI trunk circuit. The identifier signals the oscillator when this tone is needed. The tone comes back to a lead of the calling customer's line. From there it passes through a capacitor-resistor network to "bus-bars." These are arranged for the calling number to be obtained by successive scanning of four sets of leads, representing the thousands, hundreds, tens, and units digits of the calling line number. The identified thousands digit serves also to represent the central office in which the calling customer's line is located. Under control of the identifier, the bus-bar system is scanned by ten "amplifier-detectors," representing digits 0 to 9. These amplifier detectors register the directory number obtained from the four sets of leads scanned. Amplifier-detectors are electronic devices designed to detect a tone and amplify it, and register their findings in the outpulser.

ANI circuits may be grouped into two general classes—common control and noncommon control. In carrying out the testing program, the OITT circuit uses this natural division. For example, trunks circuits (noncommon control) are seized and tested automatically. Outpulsers and identifiers (common control) are seized and tested manually.

We will first describe trunk testing. There are two basic types of trunks in each of the three switching systems served. In panel and No. 1 crossbar, the trunk circuits are either multifrequency (MF) or panel call indicator (PCI) trunk circuits. They derive their name from the type of pulsing they use to transmit the called number between the local and CAMA offices. Step-by-step trunk circuits use either dial pulsing (over a metallic loop) or a composite signaling arrangement known as "E and M lead" signaling.

The trunk test circuit has access to each trunk through the crosspoints of a crossbar switch, and it seizes the trunk circuits in a definite order of progression. This progression is determined by a single lead, labeled "TT" in the diagram shown below. Five TT leads are wired to each switch crosspoint, and a total of 100 crosspoints on each switch permits one crossbar switch to serve 500 trunk circuits. Progression from trunk circuit to trunk circuit is done by relays. These are arranged to test first the trunk circuits whose individual TT leads are wired to the five contacts closed by a particular magnet on the crossbar switch. A set of five relays operate sequentially, activating an individual contact within the closed crosspoint. When five trunk circuits have been seized and tested, the first magnet releases and a second magnet operates. Select magnet zero remains operated, so that the next five trunk circuits to be tested will come from the same row of crosspoints. The set of five sequential relays function again to seize five more trunk circuits, one at a time. When the last trunk circuit on this row is tested, other relay combinations cause the trunk circuits wired to the second row to be seized one at a time. Thus by progressing both horizontally and vertically under control of relay patterns, one switch may serve up to 500 trunk circuits.

If a trunk circuit is busy handling a service call, the test circuit may either wait for it to become idle or pass it by. A particular circuit may also be selected and tested manually. This is done by keys that operate the proper magnets and sequential relays for automatic progression.

Having seized a trunk circuit, the test circuit proceeds at once to make a variety of tests to determine whether the trunk circuit can operate properly on service connections. During this period, relays are tested for marginal conditions and timing functions are checked. Sequential functions also are checked, especially those required to bring into action at the proper time other circuits needed to identify the calling number and to transmit that number of the CAMA office.

The diagram on the opposite page shows in simplified form the test connection after an idle trunk has been seized. Test relays in the trunk circuit controlled over lead TT disconnect the trunk relay equipment from the outgoing cable pair and connect the originating and terminating trunks to the test circuit. At this point, the test frame is connected to both ends of the trunk and can apply the tests described above in a predetermined order. The diagram shows two leads designated "T" and "R" connecting to the outpulser. These leads plus three others are used to check the identifying functions.

Arrangements for two-party lines require two bus fields. Consequently, the outpulser, and later the identifier, must be told which field to scan. In No. 1 crossbar and step-by-step offices, the trunk circuit supplies this information. In panel offices, however, the trunk circuit directs the outpulser to test the line to determine which party is calling. To do this, the test circuit simulates either of the two stations, and then checks to make certain that the testing has been done correctly.

During number identification, an oscillator applies a tone to a trunk lead. On trunk test calls, this tone returns to the test circuit and then goes through a receiving network that takes the place of the regular network used on service calls. At the proper time, the identifier scans this artificial network, and "detectors" find a test number corresponding to pre-set digits. This four-digit number is registered in the outpulser and the identifier is released.

The test circuit then wants to know whether the identified number can be successfully sent through the trunk circuit to the CAMA office. It does this by permitting the outpulser to function
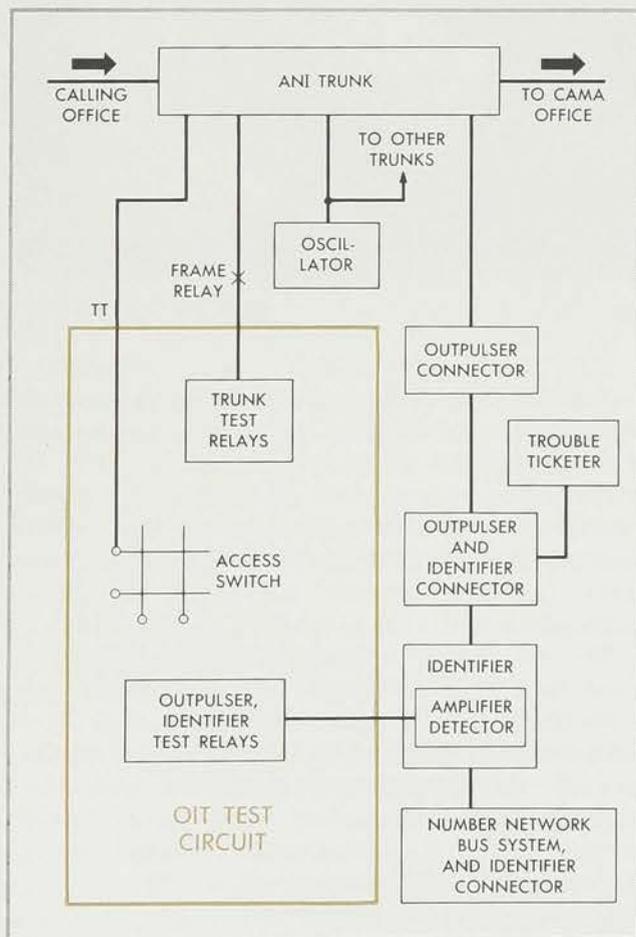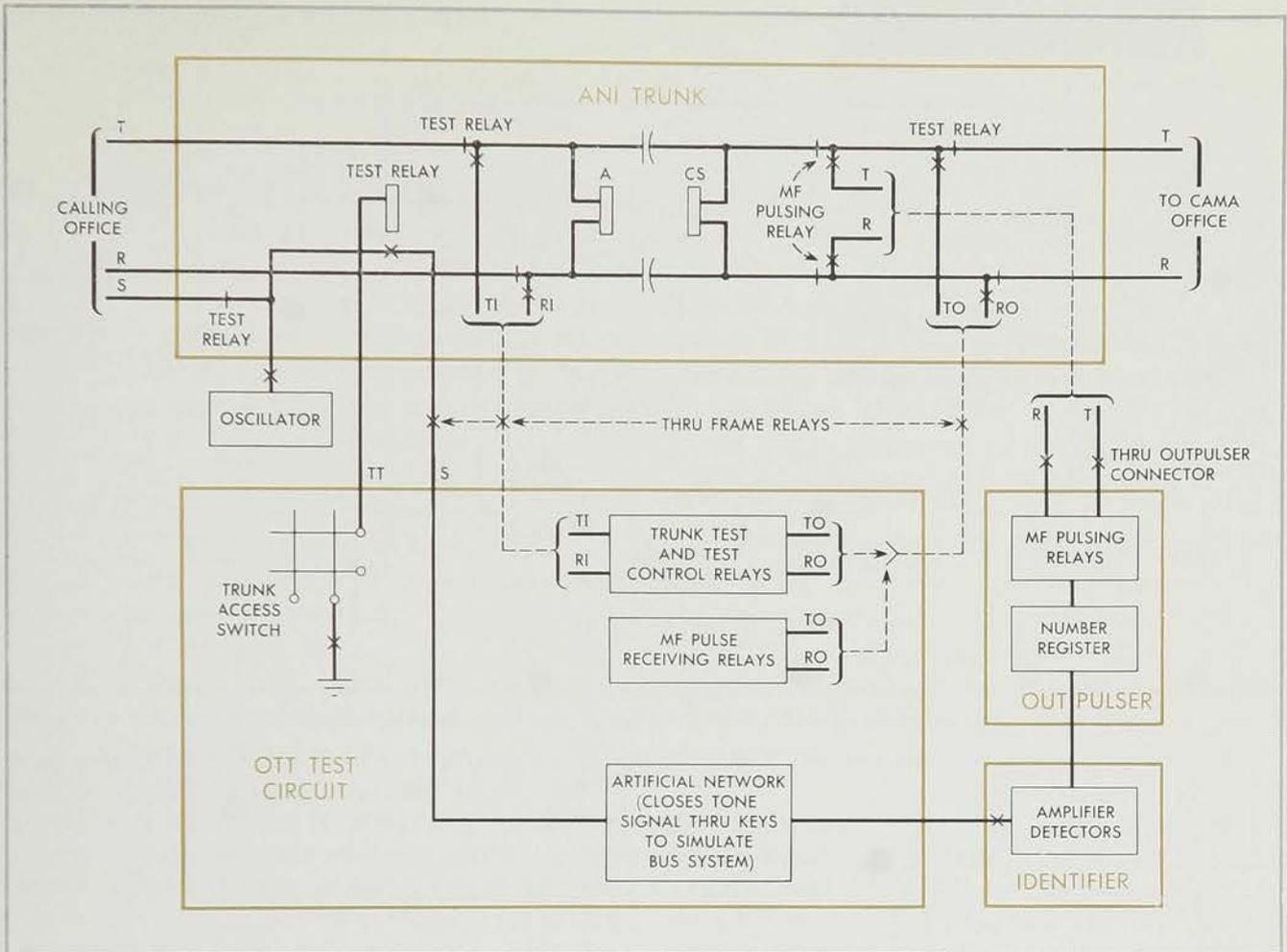

Diagram showing test connections to ANI *circuits.*

The Outpulser, Identifier, Trunk Test (OITT) frame was developed to facilitate the testing of ANI circuits. The simplified schematic above shows the connections involved in conducting ANI tests.

as it would normally for service calls. As the identified number is transmitted through the trunk circuit, it is intercepted at the outgoing end and returned to the test circuit over two of the five special leads. Here, the number is registered and checked by pulse-receiving relays. If no trouble is found, the test circuit applies other tests called for by the test control relays.

When all tests of the trunk equipment are successfully completed, the outgoing leads are disconnected from the test circuit and connected to the cable pair. A final test checks these leads for continuity and polarity into the CAMA office.

As an example of common-control circuits tested manually, certain keys on the test frame permit seizing any desired outpulser for test. Likewise, either identifier may be selected under control of the outpulser.

An outpulser may be selected for test at any time. If it is busy on a service call, the test frame waits until the call is served. In general, the outpulser is checked for its ability to register and carry out orders received from the test circuit.

Such orders are those it normally receives from trunk circuits when serving regular calls. For example, on two-party line calls, it may be told that the calling line number will be found in one of two bus fields. Or it may be ordered to make a party test to determine which party is calling. It may also be tested for its accuracy in making a party test, or in registering and pulsing out the identified number. In addition, it may be tested for its ability to stop and arrange for a trouble record if failures occur. Other tests could be mentioned too, but they are similar in character and designed to find existing trouble conditions or to detect a weakness that might cause failure.

In general, identifiers are tested for their ability to scan a bus field rapidly, to identify a designated number correctly, to register that number in the outpulser, or to demand a trouble record if a complete number cannot be found. The system also checks that the outpulser and the identifier working together will make a second trial if the first trial fails. In the case where certain digits are missing, a test may be applied to the identifier
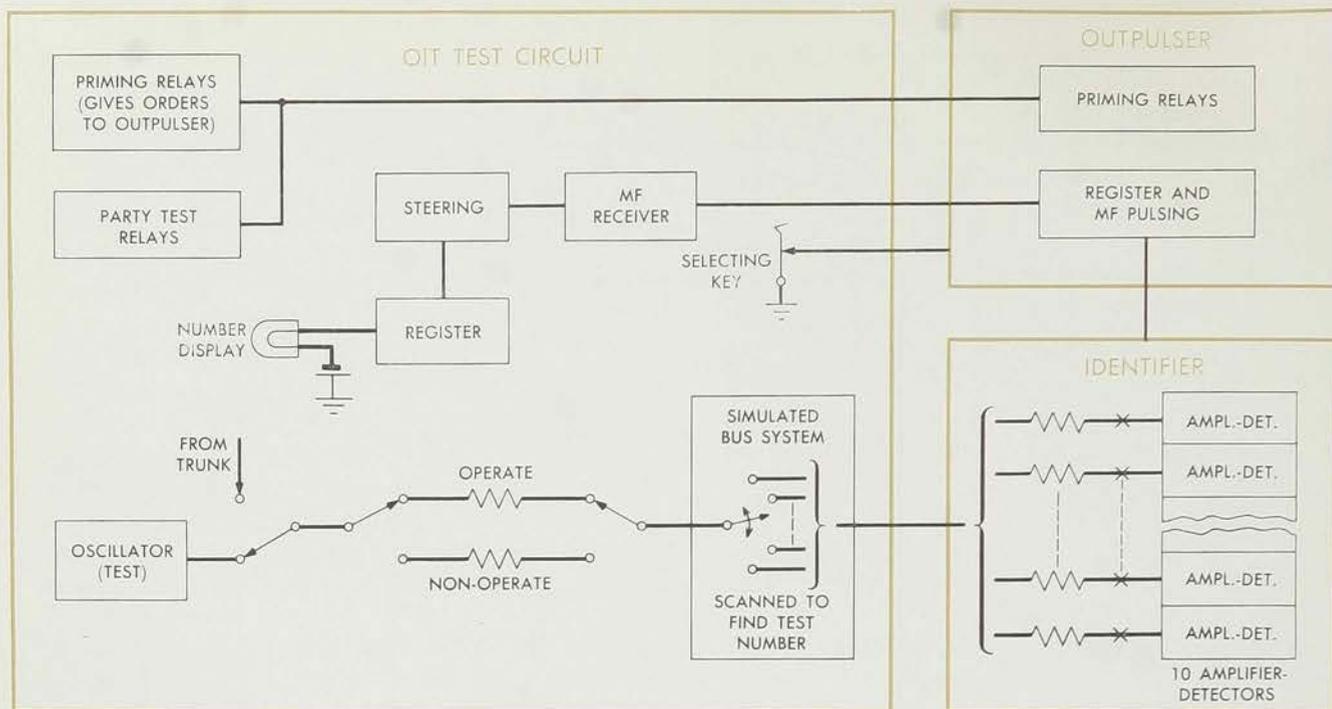
Block diagram showing connections for testing outpulsers and identifiers, prime elements for ANI.

to see that it immediately rescans the network before it initiates a trouble ticket.

During identification, marginal tests are applied to the amplifier-detectors to disclose faults or even weaknesses that might soon lead to service failures. This is done by introducing losses in the tone path, thus imposing operating conditions more severe than expected on service calls. With a separate oscillator, furnished as part of the test frame, a maintenance man can apply closely regulated signals to the amplifier-detectors. He can set up any test number on keys and thus force desired combinations of the amplifier-detectors to function.

Other tests require the identifier to scan the regular service network periodically as an aid in locating faulty wiring or a defective component. Connection to the regular bus system is done with a cord through which the tone reaches the elements of the network under investigation.

Trouble recording is controlled by the outpulser, but is performed on a frame called the "trouble ticketer frame." The main purpose of this frame is to record pertinent data on calls encountering trouble in the ANI equipment. A "message ticketer," similar to the one used in the step-by-step automatic ticketing system (RECORD, *March,* 1959), prints the trouble record in one short line of information. A ticket has space for 40 printed characters and the ticketer is arranged to print any one of the 12 characters in each space. With this arrangement, each of the spaces on the line represents specific items of informa-

tion such as type of call, identity of trunk, time of day, and progress of the call at time of trouble. A ticket is printed in about six seconds during which time the outpulser and other ANI circuits involved are released from the ticketer frame, free to serve other calls.

A third feature of the maintenance arrangements is line verification. This checks cross-connections made in the ANI system for service to new customers or when numbers are changed. In No. 1 crossbar and step-by-step offices, existing test facilities direct a test call to the line to be verified. In panel offices, this connection is made by patching at a distributing frame. After reaching the line to be verified, the ANI equipment obtains the number and displays it on lamps convenient to the observer.

A new facility in No. 1 crossbar and panel offices identifies lines that have been routed to permanent signal holding trunk circuits because of off-hook or line trouble conditions. Briefly, the method consists of patching the permanent signal trunk circuit to an auxiliary circuit that has access to outpulsers. The line in trouble is then identified in the usual way, and the number printed on a special ticket produced by the trouble ticketer.

ANI represents a further step in the direction of automation of all telephone switching and billing procedures. The testing program described, with the trouble recording and verifying facilities, insures that ANI equipment will give good service to the customer.

Brief accounts of recent technical developments
at Bell Telephone Laboratories

NEW PHENOMENON OBSERVED IN SUPERCONDUCTING TUNNEL DIODES

A new phenomenon has been observed in superconducting tunnel diodes. When these diodes are placed in a microwave field, tunneling can occur between states of unequal energy.

Aly Dayem and Raymond Martin observed this unusual electronic behavior. They placed a superconducting diode at liquid helium temperature in a microwave cavity, biased the diode with a 60-cycle ac voltage, and excited it with microwaves from 24 to 90 kmc. The tunneling current rose sharply at certain voltages, they found.

At these voltages the energy level of the electron-filled band on one side of the diode was lower than the level of the empty conduction band on the other side by an amount equal to Planck's constant times the frequency of the microwave radiation. The electrons then absorbed one or more photons (energy quanta) from the microwaves and tunneled across and up into higher energy states. In the absence of a microwave field, tunneling can occur only between levels of equal energy.

Because they absorb energy quanta in this manner, superconducting tunnel diodes can serve as detectors of microwave radiation at liquid helium temperatures.

THEUERER WINS PATENT FOR FLOATING ZONE MELTING

Henry C. Theuerer has been awarded a patent for "floating zone melting," a widely-used process for controlling the amount of impurities in materials. The patent, applied for in 1952, had been held up ten years because of interference suits filed by other applicants here and abroad.

Mr. Theuerer's invention, which is capable of reducing impurities in silicon to one part in ten billion is a form of "zone melting," a process claimed in an earlier patent issued to William G. Pfann, also of Bell Laboratories.

In zone melting as popularly practiced, a container of material is passed slowly through heaters which melt short zones of the material. The molten zones move through the material, redistributing impurities or sweeping them to one end. The technique has been very successful in controlling the impurity distribution in germanium and other materials. However, high-melting-point materials such as silicon are easily contaminated by the container.

In the floating zone method there is no contact between the molten zone and a container. A rod of silicon or other material is held vertically and a ring heater moved upward around it. The molten zone is kept in position by surface tension.

The floating zone technique has been used to process high-melting-point metals such as molybdenum, tungsten and niobium as well as semiconductors and superconductors.

*Miniaturization doesn't apply only
to glamorous solid state devices—
even the workhorse electromechanical
relay is now available in a
rugged miniaturized form.*

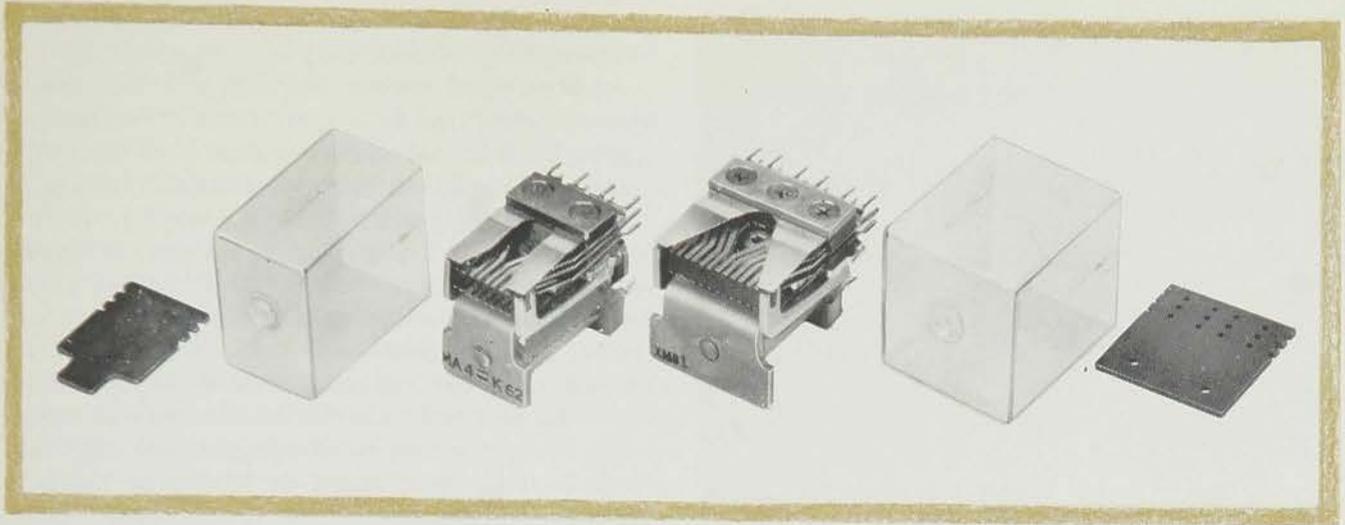# Miniature Relays for
Key Telephone Systems

W. W. Werring

THE CURRENT TREND towards miniaturization in communication equipment is normally associated with semiconductor devices and integrated circuits. However, even the standard telephone components are also being scrutinized with an eye to reducing their physical dimensions.

For example, one major effort of the Bell System has been to reduce the size and increase the ruggedness of the equipment installed on customer premises in key telephone systems. One of the major components in this equipment is the wire spring relay. A smaller and lighter relay which would occupy only about one-tenth of the volume of the general purpose wire spring relay, without sacrificing any of the reliability characteristics of Bell System apparatus, would prove very helpful in these systems. No existing relay

satisfied these requirements. Also, such relays had to be manufacturable at low cost, and in large numbers without excessive preparation time and expense.

As a result of this effort, new miniature electromechanical relays, designated as codes MA and MB, were developed on an urgent schedule, and are now in manufacture by Western Electric. As is often the case, the availability of new smaller devices has resulted in their use in other applications where small size and weight are important, in addition to their initial use in key telephone equipment.

The new MA and MB relays are capable of four and six sets of transfer contacts respectively. Both relays are enclosed in clear plastic covers. The dimensions of the MA relay are

MA (left) and MB miniature relays shown with their plastic cases and backs removed.

1¹⁄₁₆ x ¾ x 1¼ inch; of the MB, 1¹⁄₁₆ x 1 x 1¼, as shown above.

The basic structure of the new relays is of the well known end-on armature type, an efficient magnetic design. The capabilities of this basic magnetic structure allow the same core and coil to be used in both relays, although the yoke, armature and spring pile-up are wider in the larger MB relay.

The coils of the new relays are wound on molded nylon spools, as shown at lower right. Recent improvements in coil winding machines and advances in winding techniques have made it possible to manufacture these finished, spool-wound coils more cheaply than the "filled" coils so long a standard in Bell System relays. This is particularly true in the coil sizes and wire sizes needed for a miniature relay. Such coils also permit more winding turns in a given space.

The spools are injection molded and the terminals are a drive fit in molded holes. The coil wire is brought out through appropriate slots and wrapped directly on the coil terminals. A number of coils are then soldered at one time in a dip soldering operation. This coil will ultimately be wound and finished completely automatically, thus avoiding the costly hand finishing and terminating operations required with the filled-coil construction.

The contact "pile-up" is built up from flat springs and insulators, which avoids the expense and long manufacturing preparation time associated in the past with molded pile-ups. Twin contacts are provided to insure contact reliability and the pile-up is card actuated to provide maximum assurance against contact locking. The contact force is nominally 10 grams per pair of twin contacts, comparable to the standard estab-lished by the general purpose wire spring relay. The combination of contact materials used is the same as that in the wire spring relay—palladium on both contacts, with a thin surface layer of gold over the palladium of the moving twin contacts. The thickness of palladium of both contacts and the dimensions are such that the contacts have an erodible volume about 1/3 that of the general-purpose wire spring relay.

The electrical sensitivity of the miniature relays in ampere turns is fairly comparable to that of the wire spring relay with the same number of springs. For example, the four transfers require an operate power of about 0.275 watt; the six transfers require 0.35 watt.

The operate time of the miniature relays compares favorably with that of the wire spring relay when operated at the same power level. However, because of the vast difference in allowable power dissipation, the large relay can be operated at power levels that are beyond the capability of
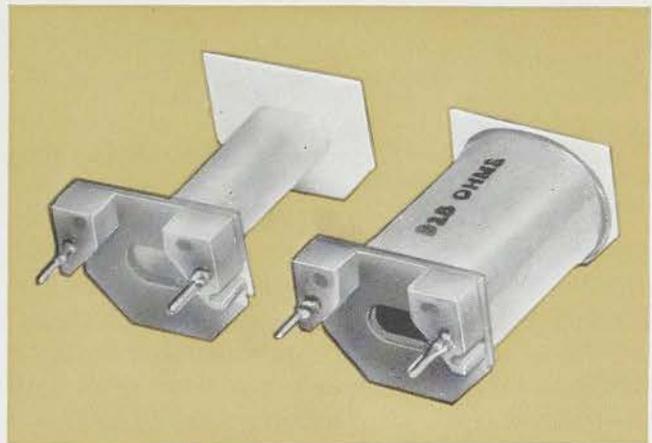
Coils of the miniature relays are wound on molded nylon spools (left). Finished coil is at right.
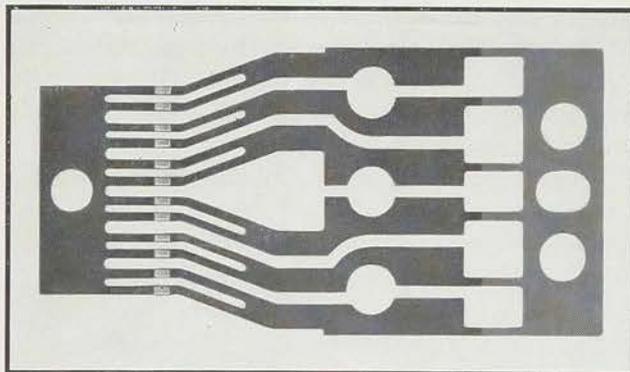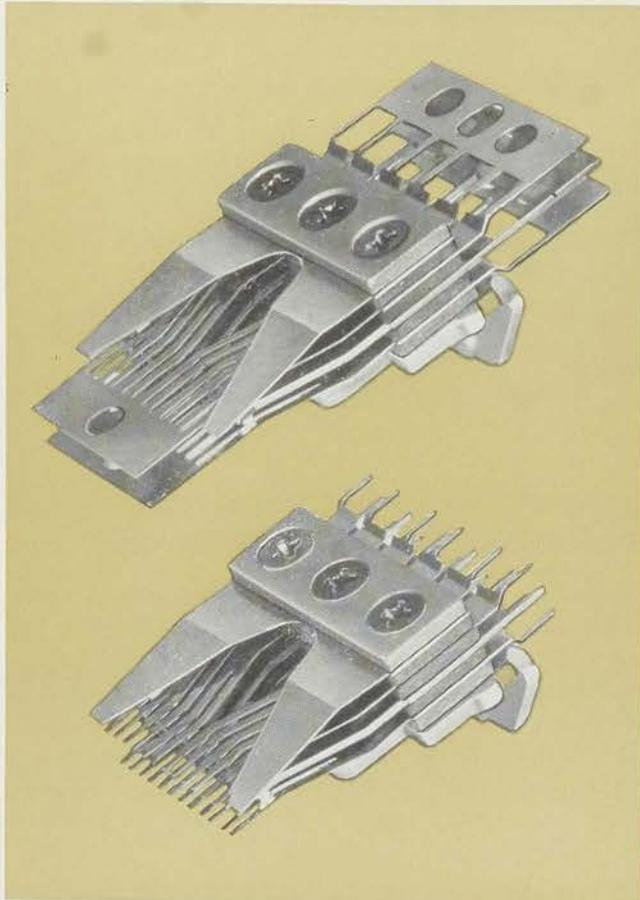
Springs of a layer are punched from single sheet. Assembled pile-up (top) still has connecting pieces attached; in finished pile-up they are trimmed off.

the miniature relay. The MA relay with four transfers will operate in about 20 milliseconds with a power of 0.5 watt, and in about 15 milliseconds with an applied power of 0.75 watt. The operate time may be as fast as 5 milliseconds when operated with a 2 watt input. The relays are capable of dissipating 3 watts under normal or continuous operation and 4 watts under trouble conditions.

The release time on open circuit ranges from 2 to 4 milliseconds with the full complement of springs. A slower release time, up to 25 milli-seconds, may be obtained by use of a winding of bare copper over the core.

As mentioned earlier, the MA and MB relays have a capacity of four and six transfers respectively. Both "break before make" transfers and "make before break" or "continuity" transfers are possible by changes in the coding of the actuating card. Various combinations of these, together with simple "makes" and "breaks", can be provided, up to the limit of the four or six spring positions. In these alternate configurations, contact springs are provided only in those positions specified; the terminals, on the other hand, are always provided because they hold the relay to the circuit board by means of the soldered connections.

The use of printed circuit boards with the new relays is intended to eliminate readjustments or other maintenance in the field. Replacement of the wiring board is the only field repair method expected. Under this concept, the plastic cover is removable only with difficulty, although it is not sealed. The intent is to discourage unauthorized tampering with the relays in the field.

The magnetic circuit of the miniature relay is quite efficient. This results partly from the low joint reluctance between core and yoke and low hinge-gap reluctance between armature and yoke, combined with near optimum pole face area for the critical pole gap. This results in a low value of "closed gap reluctance" and insures less magnetic interference between adjacent relays.

It is important, of course, that any new design meet the functional requirements of the system in which it is to be used. However, it is equally important that it be manufacturable at a satisfactory cost. In the development of the MA and MB relays, the advice and cooperation of the Western Electric manufacturing engineers was enlisted at an early stage. As a result, the final design of these relays includes a number of departures in the construction of flat spring pile-ups which are particularly adapted to low-cost manufacture, ultimately even by automatic methods.

The individual parts of a miniature relay are necessarily small and, in some cases, frail. Under conventional assembly techniques for older types of flat spring relays, many parts would probably be handled with tweezers, some parts would be distorted, and the assembly process would be costly. Also, it would be almost impossible to achieve the accuracies in alignment and location needed both in manufacture and in operation of the relay. In the MA and MB designs, as in the wire spring relay, the pile-up consists of only three layers of springs: the middle layer is composed of

heavy stationary springs, while the top and bottom layers are movable flexible springs. During manufacture, all springs of a layer are partially punched from a strip of stock with connecting pieces left at each end as shown at left. Accurately located holes are provided in the connecting ends, for use in locating and aligning the springs in all subsequent operations, such as contact welding or pretension forming. Finally, the holes are used for locating the springs during the final assembly of the pile-up on its mounting bracket. After the completion of the pile-up subassembly, the extra connecting and locating portions of the spring blanks are clipped off. In this way, not only are fewer and larger parts handled, but all location and alignment relationships are directly established mechanically from the same datum positions.

With this type of spring design, it is possible to process strips of spring punchings for a number of relays as a single unit through operations such as contact welding and forming. Thus, the design of the pile-up largely avoids the handling of individual small parts even for these miniaturized relays, and opens the possibility of automatic handling and assembly by Western Electric.

In the final assembly of the relay two major subassemblies—the coil, core, and armature assembly and the pile-up assembly—are associated and fastened together with a single screw. After assembly, a simple mass adjustment to obtain the best alignment of the operating card with the contact springs may be made, if necessary, by bending the armature legs. However, the accuracy of the pile-up can be such that similar accuracy in the production of the armature minimizes the need for this adjustment.

Almost 1400 engineering models of this design are now undergoing field trials in a key telephone system. Considerable quantities have been manufactured this year, and large scale manufacture is scheduled for 1963. Eleven codes have been issued for the MA type and seven codes in the MB type.

There is, of course, no suggestion that these miniature relays can generally replace the large general purpose relays used in central office switching circuits—the complete capabilities of the large relay inherently exceed those possible in the miniature. However, the new small relays are of a balanced design based on the accumulated experience of the Laboratories in this field, and provide effective relay performance, commensurate with their size. These miniature relays are apparently filling a need in our switching apparatus and their availability has stimulated renewed interest in miniaturization system design.

Bell System Assisting in NASA's Project Relay

The Bell System is participating in NASA's Project Relay by providing launch vehicle guidance, a radiation measurement package in the Relay satellite itself, and use of the Andover, Me., earth station.

The Delta launch vehicle that will carry the Relay satellite into orbit will be guided by the Command Guidance System designed by Bell Laboratories for the Air Force and manufactured by Western Electric. This system was used on July 10, 1962, to guide Telstar, the Bell System's communication satellite; and it has scored well over 100 successful missile and satellite guidance operations (RECORD, *November,* 1962).

The intended orbit for the Relay satellite will be elliptical with a perigee of 800 nautical miles and an apogee of 4500 nautical miles. The Command Guidance Facility at Cape Canaveral is operated for NASA by Bell Telephone Laboratories.

The Relay satellite includes among its radiation measuring instruments a package designed and built by Bell Laboratories under the direction of Walter L. Brown, Head of the Semiconductor Physics Research Laboratory. This package is made up of two detectors that are very similar to two of the detectors in the Telstar radiation package, but which profit from the Telstar experience.

A solid-state proton detector, very similar to Telstar's low-energy proton detector, counts the protons in each of five energy ranges between 2 and 27 Mev (million electron volts). An electron detector counts the electrons in four energy ranges between 1 Mev and 2 Mev. It is similar to the Telstar detector except that a metal absorber has been added to the front of the device to raise the range of energies detected.

A refinement on the Telstar measurement will be made possible by "gating" the measurements with a magnetometer so that measurements of the two detectors are recorded only when they are pointed to within ten degrees of perpendicular to the earth's magnetic field. This will simplify interpretation of electron flux measurements.

Bell Laboratories will assist NASA in analyzing the radiation data measured by these detectors.

The Bell System's earth station for communicating by way of satellites at Andover, Me., will be used to carry out communication experiments with the Relay satellite just as it was used in the Telstar project. It has broadband capability that will permit transmission of two-way telephony and television via the Relay satellite.

Highly-Sensitive Microphone Uses Transistor as Base

A new type of microphone that acts as its own amplifier and is at least 4 times more sensitive than the carbon telephone transmitter, the most sensitive microphone now in use, has been invented by scientists at Bell Laboratories.

The new microphone can be made very small and light—about the size of a tiny button—and has many potential applications, such as a telephone transmitter, in tiny hearing aids, in blood pressure measuring devices for use inside the heart, or in phonograph pickups. The principle of its operation can also be applied in such devices as mechanical strain gages, seismographs and accelerometers.

The new transistor microphone was invented by M. E. Sikorski and P. Andreatch, Jr. of the Mathematical and Mechanical Research Center. A. Grieco of the same center and H. Christensen of the Electron Device Technology Laboratory contributed to the work. R. Edwards of the Semiconductor Device Laboratory has also done work in the field of stress effects on transistors.

The microphone contains no electromagnet coils or carbon granules. Its main parts are a diaphragm, a sapphire stylus and a junction transistor, as shown in the diagram opposite.

Sound waves in the air set the diaphragm to vibrating, causing the stylus to move up and down. The point of the stylus presses against the emitter region of the transistor, creating stress. This stress is then transmitted through the emitter to the two junctions in the transistor, causing changes in the resistance across the junctions. The change in the resistance of the emitter junction is analogous to the application of a sig-nal to the base-emitter circuit in a transistor amplifier: An amplified signal in the collector-emitter circuit is obtained.

The transistor microphone uses 20 to 100 times less electric current than a carbon mike, and its efficiency (ratio of ac power out to dc power in) is up to 100 times higher than a typical carbon mike. The new transistor microphone has the following characteristics as compared with a typical carbon granule microphone as well as an earlier semiconductor microphone that made use of the piezoresistive effect:

The transistor microphone is more sensitive

	MICROPHONE	
	SENSITIVITY (in mv ac rms for a 1 dyne/cm², pressure at 1 kc)	EFFICIENCY (ac power out / dc power in) (at 10 dynes/cm² pressure)
Transistor microphone	63 mv *	11%
Carbon granule microphone	16 mv	1x10⁻¹%
Piezoresistive microphone	2x10⁻⁵ mv	1.4x10⁻⁶%

*This value corresponds to a reduced impedance level of 100 ohms. A signal of 1.1 volts was obtained at a standard operating impedance level of 30,000 ohms. This is a 69 times larger signal than for the carbon microphone.

(approximately four times on the voltage basis) and gives a higher signal-to-noise ratio (54 db) than the carbon microphone. Harmonic distortion is less than 3 per cent at 1000 cps and a sound pressure of 3 dynes/cm². Its frequency response is limited by the design of the diaphragm and the stress transmitting system.

The idea that a transistor could be used as a pressure transducer is not new. It was previously proposed that if pressure were to be applied to the point contact of a point-contact transistor, the point would deform, varying the area of its contact with the emitter surface. Thus, contact resistance would vary in proportion to the applied stress. Such a transducer was not developed because its efficiency was not very high.

As mentioned above, the new microphone uses a junction transistor; pressure applied to a point on the surface of the emitter is passed through the emitter region and across the two p-n junctions of the transistor. In a simplified picture, the stress across the emitter junction changes its resistance and therefore the current flowing in the transistor changes.

This modulation of the current may be due to various mechanisms such as changes in the carrier mobilities, the energy gap, and the lifetime of the carriers. At large strains, recombination centers, due probably to dislocations, may be created in the semiconductor material under the indenter. This would affect the lifetime of the carriers.

Since the emitter-base junction is nearer the point of application of the force than the collector-base junction, the stress on it is greater and the conduction through it is affected to a larger extent.

The electrical output is comparatively large. For example, in the experimental transistor microphone a sound pressure of 1 dyne/cm² at a frequency of 1 kc resulted in a voltage signal of 63 mv (rms). The noise (in the frequency range of 600 to 4000 cps) accompanying the 63 mv signal was 0.12 mv; thus the signal-to-noise ratio was 54 db. Although the signal was measured at an impedance of 30,000 ohms, the above figures have been reduced to 100 ohms impedance level for comparison purposes.

The experimental transistor microphone is based on a common, diffused-base transistor in which the collector region is n-type silicon. The base is a p-type film which was diffused onto the collector; the emitter region, which was diffused onto the base, is n-type. Other types of commercially available junction transistors—micro-alloy-diffused, epitaxial-mesa, double-diffused-planar, epitaxial-planar, surface-barrier, and
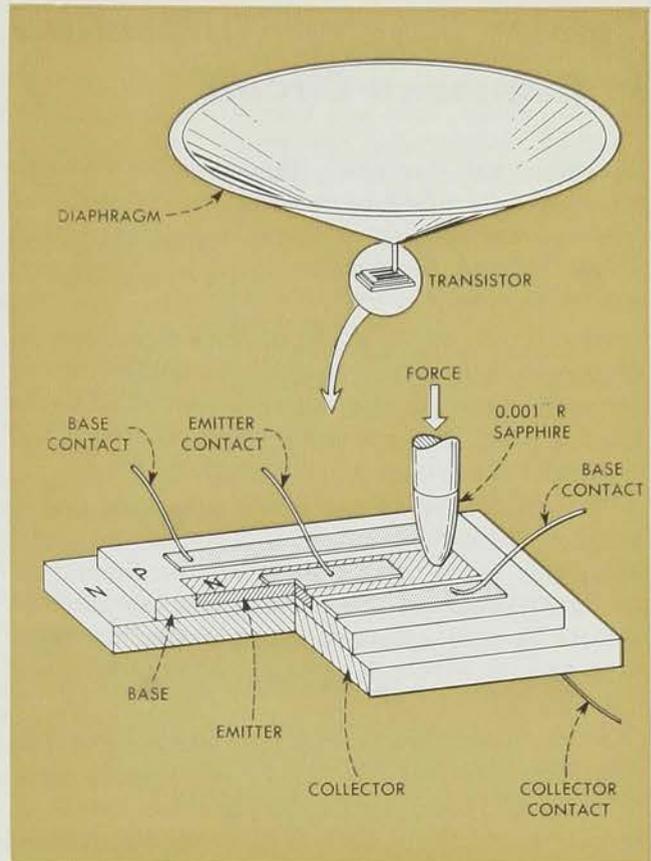
New microphone consists of a diaphragm for funneling acoustic energy to a sapphire stylus, which transmits the pressure to the emitter surface of the junction transistor.

multiple-junction transistors—can also be used. Some of these transistors have comparatively large emitter and collector regions to which stress can be applied.

The Laboratories scientists have also suggested several other methods for stressing the transistor junctions. For example, the transistor can be affixed directly to a diaphragm without need of a stylus. Or, a deformable semiconductor sheet or wafer may be used as a diaphragm and the transistor junctions diffused directly into or epitaxially grown onto it. Devices using these concepts may be more rugged, reliable, and more easily fabricated.

Various other modifications and extensions of this invention are apparent. For example, with appropriate circuitry, the transistor transducer can be used as a pressure-responsive switch. As the pressure reaches a critical point and changes the voltage across the junction, a compensating or corrective circuit can be activated which will trigger an alarm signal.

Also, transistor microphones made of materials such as GaAs or other III-V compounds, might result in even greater sensitivities.

Telstar Develops Difficulties in Command Circuit

Telstar has developed difficulties in its command circuit. After more than four months of continuously successful operation, it won't take orders to turn its communications receiver and transmitter on and off.

Efforts are being made by Bell Laboratories engineers to find the cause of the trouble in the command function and to circumvent it. It seems certain that the communications receiver and transmitter are in good operating condition.

The difficulties do not affect telemetry transmission, which continues to operate properly. Telemetry sends back reports on the amount of radiation in space, the condition of the satellite and its electronic components, temperature readings, and the effects of radiation on solar cells and transistors.

All the experiments originally planned for Telstar have been carried out. In addition to more than 250 technical tests covering every aspect of transmission, there have been some 400 demonstrations. These demonstrations have included multichannel telephony, telegraphy, data, telephoto and other facsimile transmissions. Trans-Atlantic television has been demonstrated 47 times and on five of these occasions the transmission was in color.

Scientists and engineers have watched for the first sign of failure, for this in itself would provide information for improving future satellite reliability. They will continue to investigate the cause of difficulty in the command circuit. The circuit, which was used in the experimental Telstar but likely will not be used in commercial satellites, controls several functions in Telstar. One of these is the broadband receiver and transmitter, which is turned off when not in use to avoid exhausting the batteries. The telemetry transmitter, however, draws little power and has been left on since erratic command performance was first discovered.

The first sign of difficulty was observed by the Andover, Me., ground station on November 19. On subsequent passes during the next few days, response to command was intermittent. The command circuit last worked properly on the 1,242nd orbit on Friday, November 23.

Princess Phone Gets Own Bell

A new model of the Princess telephone went into production at Western Electric's Indianapolis Works last month. The new Princess is the same as its older counterpart in outward appearance, but quite different on the inside.

For the first time, the Princess will have a miniature bell ringer inside the housing. (The original model required the use of an auxiliary ringer.)

The bell for the new Princess fits on the left side of the telephone base plate. The plate has been made heavier, and is slotted to allow greater ringer volume. To make way for the bell, a number of other internal components of the phone had to be redesigned so that all would fit within the existing housing. The job was done by a manufacturing-design team of Bell Laboratories and Western Electric engineers at Indianapolis.

The new Princess received enthusiastic customer response in a field test recently completed in Denver, Colorado. Western Electric's Indianapolis Model Shop provided 100 sets for the trial.

From initial deliveries to the Bell telephone companies this month, regular production of the improved Princess is expected to total 800,000 units for 1963.

A miniature ringer has been built into the left side of the housing of the new Princess telephone.

news in brief

Gallium Arsenide Diode Used As Low-Temperature Thermometer

A p-n junction diode made of gallium arsenide may be the most generally useful device for low-temperature measuring yet devised. A paper by B. G. Cohen and A. R. Tretola of the Solid-State Device Laboratory and R. V. Goordman and W. B. Snow of the Semiconductor Device Laboratory, presented at a recent Electron Devices Meeting in Washington, D. C., described the GaAs p-n diode whose breakdown voltage varies nearly linearly with temperature over the entire range from room temperature down to 1.4 degrees K. Thus it is possible to read temperature as voltage taken from a potentiometer connected across the diode.

Such a device makes a unique cryogenic thermometer combining the advantages of high accuracy, wide range and physical simplicity. No other low-temperature measuring device has all three of these advantages. Thermocouples, for example, not only do not have as good resolution at low temperatures, but also require a reference temperature. Metal resistance thermometers have good resolution and accuracy, but are large and require complicated equipment to operate. The good resolution of germanium resistance thermometers is offset by their very restricted temperature range. Silicon diodes are less sensitive and less linear than those of GaAs.

Zinc-diffused gallium arsenide diodes have a sensitivity of 3.5 millivolts per degree K at room temperature and 1.5 millivolts per degree K at around 1.4 degrees K. In this low-temperature area a resolution of ±0.01 degree K is possible when the current is held steady to ±0.02 per cent.

The GaAs thermometer will be useful as a general laboratory tool for measurement and control. It may also be used as a temperature monitor in refrigerated devices such as low noise amplifiers — masers and parametric amplifiers. In the parametric amplifier the GaAs diode —the heart of the amplifier— might literally be used to take its own temperature.

The diode is small — a cylinder 0.3 cm in diameter and 0.5 cm long with an active area of 2×10^{-5} cm²—and uses little power —10 microwatts. Thus it has little effect on the temperature in the neighborhood of the measurement.

Data-Phone Extended To Facsimile Transmission

The ability to send drawings, maps, charts and documents over regular telephone lines was recently announced by the A.T.&T. Co.

A new data set which will make possible facsimile transmission over telephone lines is expected to be available in limited quantities in the first quarter of next year, pending the outcome of product trials now under way.

The data set will extend the Bell System's Data-Phone service to the field of facsimile transmission for the first time. Until now, facsimile material could be transmitted only over special communication networks or private lines.

Data-Phone service enables various types of data to be transmitted between business machines over regular telephone lines at speeds ranging up to 2,500 words a minute. Data sets convert signals from business machines into pulses which can be sent over telephone lines. At the receiving end, data sets convert the signals and feed them to the business machines.

With the new service, anyone with a facsimile machine compatible with the new data set can dial anyone else with similar equipment and send copies of documents and other printed material at regular telephone rates.

Several companies are developing facsimile machines which will be compatible with the Bell System's data set.

This is the second type of analog data set developed by the Bell System. Already available is a series of telewriting data sets which make possible the transmission of live handwriting over regular telephone lines.

Advances In Optical Maser Technology Described At NEREM

Two developments in optical maser technology were described by Laboratories scientists at last month's Northeast Electronics Research Meeting (NEREM) in Boston.

In the first, continuous modulation of an optical maser beam was reported when the modulating crystal is constructed like a microwave cavity. J. Dane Rigden and Eugene I. Gordon of the Laboratories reported having formed a crystal of KDP (potassium dihydrogen phosphate) as a Fabry-Perot resonator—essentially a rod of the material between two highly reflecting parallel surfaces. KDP modulation at microwave frequencies of a coherent light beam was heretofore possible only with pulsed operation.

Communications scientists are interested in electro-optic crystals such as KDP because a varying electromagnetic field applied to a crystal causes the light waves passing through to be phase modulated. This modulation arises from an induced birefringence which is proportional to the modulating field. Polarizers and wave plates appropriately placed with respect to the modulating crystal convert the phase modulation into amplitude modulation.

In the new technique the transmission properties of the optical cavity are also varied at the

microwave frequency thereby enhancing the efficiency of the modulation. This permits using photodetection techniques which are relatively advanced in optical maser technology.

The Fabry-Perot construction serves to shorten the length of crystal needed for adequate phase modulation of optical radiation. Instead of passing once or twice through a long crystal, the light wave bounces back and forth many times within the modulating cavity. The enhanced modulation efficiency substantially reduces the microwave power required for modulation and thereby decreases the heating of the crystal. This permits continuous application of the modulating microwave signal.

In another paper, Alan D. White and Mr. Rigden reported that the helium-neon optical maser, recently demonstrated by the Laboratories to emit a visible beam, has been made to emit an infrared line (11500 angstroms) and the visible line (6328 angstroms) simultaneously. The technique is accomplished by using mirrors with peak reflectivity at both wavelengths.

The mirrors are coated with eleven layers of reflective material, each having a thickness of a quarter wavelength of the 11500 Å line, then with a transition layer, then with nine layers of the material at a quarter wavelength of the 6328 Å line.

IRE Honors Southworth, Ross; Names Nine from Labs to be Fellows

At its November 14th meeting in New York City, the Board of Directors of the Institute of Radio Engineers presented two of its seven awards to Laboratories engineers. One of two Medals of Honor, the highest annual technical award in the field of electronics, was presented to George C. Southworth, retired; the Morris N. Liebmann award was presented to

Ian M. Ross. Presentation of the awards will take place on March 27 at the International Convention banquet of the Institute of Electrical and Electronic Engineers (the group resulting from the January 1st merger of the IRE and the AIEE).

The award to Dr. Southworth was made "for pioneering contributions to microwave radio physics, to radio astronomy, and to waveguide transmission."

Dr. Southworth received the B.S. degree from Grove City College, Pa. in 1914 and did graduate work both at Columbia University, New York, N. Y., and Yale University, New Haven, Conn., where he received the Doctorate degree in 1923.

Prior to World War I he began experimental work at Grove City College, Pa. and during the war continued with research work at the National Bureau of Standards and at Yale University. Since 1923, and until his recent retirement from the Laboratories, Dr. Southworth was with the Bell System, associated with the transoceanic radio telephone and later with the early development of microwave techniques.

For his work in waveguides, Dr. Southworth received the Morris N. Liebmann Prize of the IRE in 1938 and the Stuart Ballantine Medal of the Franklin Institute in 1947. For his work on microwave radiation from the sun, he received the Louis Levy Medal of the Franklin Institute in 1946. Dr. Southworth is a Fellow of the IRE, the American Physical Society and the AAAS.

The award to Dr. Ross was made "for contributions to the development of the epitaxial transistor and other semiconductor devices." He is Director of the Semiconductor Device and Electron Tube Laboratory—Allentown.

At the same meeting, the IRE Directors named nine from the Laboratories to the grade of Fel-

low, the highest membership grade offered by the society. The recipients were: E. E. David, Jr., A. J. Grossman, W. C. Jakes, Jr., W. A. Malthaner, R. L. Mattingly, D. A. McLean, S. P. Morgan, A. C. Peterson, and H. E. Vaughan. J. A. Hornbeck, former Executive Director, Semiconductor Device and Electron Tube Division, and now President of Bellcomm, Inc., was also named a Fellow.

Industrial Research Institute Awards Medal To Dr. Fisk

Dr. James B. Fisk, President of Bell Laboratories, has been chosen to receive the 1963 Industrial Research Institute Medal.

The medal, awarded annually since 1945, is given for "outstanding accomplishment in or management of industrial research which contributes broadly to the development of industry or the public welfare." It will be officially presented at the annual meeting of the Institute next May in San Francisco.

This award to Dr. Fisk marks the third time that a president of Bell Telephone Laboratories has been so honored. Dr. Mervin J. Kelly was awarded the medal in 1954, and Dr. Frank B. Jewett in 1950.

The Industrial Research Institute, representing 178 companies, cites Dr. Fisk's "eminence in the inspiration and conduct of research in industry, and vision which has advanced the science and use of the nucleus and of the crystal." The citation of the Institute also honors Dr. Fisk "for enhancing the means of communion among mankind and among nations, under the oceans and through outer space; for patriotic service to the security and welfare of his country through science and engineering; for his role in higher education, and for his wise precept that science is truly the servant of man."

Laboratories Scientists in Seattle Report on Acoustics Research

A group of Laboratories scientists presented a total of twenty-four papers at the November meeting of the Acoustical Society of America in Seattle, Wash., including papers on all phases of acoustics research being conducted in the Visual and Acoustics Research Laboratory. Among them were papers on new, solid-dielectric microphones and earphones with high fidelity response, a report on the determination of significant speech sounds for use in automatic recognition of speech, as well as reports on voice-printing, velocity of sound in water and sound attenuation in semiconductors.

The new, solid-dielectric condenser earphone, which does not use the high voltage most other condenser earphones do and is small and relatively easy to make, has been invented by Gerhard M. Sessler and James E. West. They used aluminized Mylar as a dielectric.

The earphone was devised for and is being used as a laboratory tool to permit close control of psycho-acoustic experiments where faithful reproduction is important. A hi-fi fan could obtain the same advantages. In addition to private listening and faithful reproduction of sound, any pair of hi-fi earphones connected to appropriate circuitry could provide a high-fidelity stereophonic effect. The stereo effect would not be dependent on the listener's location nor on acoustical qualities of the room.

A good high-fidelity condenser microphone which does not need an external dc bias nor a closely located amplifier has also been invented. Both microphone and earphone use a solid polarized dielectric instead of a large external dc bias.

Most condenser microphones and earphones provide an almost "flat" response over a wide range of frequencies. But until now, most have needed a dc bias of about 200 volts, an inconvenience in itself because of the power supply and circuitry required, which also presents some potential peril, real or imaginary, to the user. As a result, condenser earphones have not had wide use.

The usual condenser microphone, though widely used, requires special cathode followers and preamplifiers; the solid-dielectric microphone can be connected with a long cable to any high-impedance preamplifier. This is made possible by its high capacitance, ten times greater than that of conventional condenser microphones.

The new microphone and earphone utilize an electret—a permanently polarized piece of dielectric material—to obtain the necessary bias. The dielectric used was Mylar film coated with aluminum. It was heated to 120 degrees C for 15 minutes and then cooled while being exposed to a 3500-volt field. The resulting polarization corresponds to about 200 volts external bias.

In addition to the electret, the earphone uses a push-pull circuit principle and has a response which is flat within three decibels between 20 and 15,000 cycles. In this range the harmonic distortion and intermodulation distortion are quite low. Pulse response is almost an exact replica of the applied voltage for pulses not containing frequencies above 15 kilocycles.

The microphone has a frequency response flat within three decibels from 50 to 15,000 cycles, or considerably higher if the resonant frequency of the system were increased (which, however,

would decrease sensitivity). The harmonic distortion is low and pulse response is good. No electric power is used in the microphone.

In the earphone, the back and front plates (the two metal electrodes) are the same and are perforated with an equal number of holes, which are aligned. Next to each plate is a nonmetalized Mylar foil. The two metalized, polarized foils are in the center, the metal surfaces facing each other and electrically connected, forming the third electrode. All three electrodes are electrically insulated from each other. The signal voltage is applied with opposite polarity to the two metal electrodes.

The combination of a three-electrode push-pull circuit and the use of prepolarized foils makes possible a system that operates without external dc bias and which is practically free of nonlinear distortion.

The quarter-mil Mylar foil polarization is relatively stable, showing an estimated lifetime of several hundred years.

Significant Speech Sounds

The report on significant speech sounds indicated that if machines are made for the automatic recognition of speech, they will have to be especially good at recognizing a "t" sound when they hear it.

Of all the pairs of speech sounds whose substitution for each other could result in the wrong recognition of a word (such as the "t" and "s" in "tell" and "sell") the "t" sound appears in the two most frequently recurring pairs. In these two it is the alternate to the sounds of "n" and "f".

The relative frequency of these pairs was determined by Peter B. Denes from a statistical analysis of speech in ordinary conversations. His analysis also determined the frequency of speech sounds and the frequency of sequences of sounds.

Speech recognition machines, it is assumed, would not at first possess the human ability to identify words by context and must therefore rely more heavily on a good "hearing" of individual sounds, especially those most frequent or critical.

The most frequent speech sounds were found to be the nondescript "uh," followed by "t," and "i" sound of "bit," and "n". The least common sound in conversation is the "zh" as in "pleasure."

Speech is literally "on the tip of your tongue," for the sounds most frequent in speech are articulated in the front part of the mouth, compared with other types articulated more in the rear.

Of the two most frequent types of consonant, the most frequent is the plosive, which includes such sounds as "t," "d," and "k." Next are the fricatives, or "hissing" sounds such as "s," "f,"

"sh" and "h".

The probability of one type of consonant following another was determined, and it was found that consonants articulated in similar ways rarely follow one another.

Also, Mr. Denes verified that the first-person singular "I" is used more than any other complete word in ordinary conversations, and found that it's used twice as often as the second-person "you," which ranks in sixth place.

The sample used by Mr. Denes for computer analysis included 23,000 words from books of typical conversations, books that are used to teach the English language to foreigners.

Ventriloquist is Voice Printed

In another paper, L. G. Kersta demonstrated that the voices of "Lamp Chop," "Charley Horse," and other puppet characters with highly individual-sounding voices created by ventriloquist Shari Lewis have almost identical "voiceprints." The voice-identification method he originated defeats attempts at disguise, and a group of high-school girls has been achieving identification accurate to better than 99 percent with voice samples of five words or more. Kersta also proposed a grid method of voiceprint classification.

Velocity of Sound in Water is Measured

The velocity of sound in water has been measured ten times more accurately than before, resulting in the discovery that the actual velocity is about four parts in ten thousand slower than previously believed. J. McSkimin and H. B. Holton, Mechanics Research, reported on a pulse superposition method of measurement. Sound energy is reflected back and forth through a quarter-inch path of water, and velocity is determined from an accurately measurable frequency rather than by direct timing as previously done. The new method is expected to be a valuable tool for accurate measurement of the salinity and the elastic constant of liquids.

Sound Attenuation in Semiconductors

Measurements on the attenuation of sound in silicon reported by W. P. Mason and T. B. Bateman, Mechanics Research, have verified the theory that attenuation due to electrons and holes connected with the impurity doping increases inversely with absolute temperature. Mason and Bateman reported the experiments using very high purity silicon and silicon very heavily doped with boron. The results have also provided new constants for the evaluation of semiconductor energy surfaces.

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

Abbott, H. H.—*Subscriber Line Circuit with Local Ringing*—3,059,058.

Anderson, J. R.—*Shaft Keying Arrangement*—3,056,618.

Atalla, M. M.—*Semiconductor Triode*—3,056,888.

Bachelet, A. E.—*Alarm Signaling System*—3,061,679.

Ballman, A. A.—*Yttrium and Rare Earth Borates*—3,057,677.

Boyle, W. S., and Thomas, D. G.—*Optical Maser*—3,059,117.

Brewer, S. T.—*Remotely Controlled Selective Switching System*—3,060,390.

Celentano, A. J.—*Alarm Signaling System*—3,061,678.

Chegwidden, R. A.—*Microwave Ferrite Devices*—3,059,194,

Cutler, C. C., and Pierce, J. R.—*Stabilization of Earth Satellite Repeaters*—3,057,579.

Cutler, C. C.—*Space Satellites for Use as Radio System Repeaters*—3,058,106.

Cutler, C. C.—*Remote Attitude Control of Earth Satellites*—3,060,425.

Dacey, G. C.—*Transistor Having Emitter Reverse-Biased Beyond Breakdown and Collector Forward-Biased for Majority Carrier Operation*—3,060,327.

Doucette, E. I., and Ryder, R. M.—*Protected Semiconductor Device and Method of Making It*—3,059,158.

Duvall, G. H., Hammersla, W. E., and Koliss, P. P.—*Splice Closure for Sheathed Cable*—3,061,666.

Feder, H. S.—*Switching Circuit*—3,060,267.

Frost, H. B.—*Ionization Manometer Circuit*—3,058,057.

Gibby, R. A., Kahl, H., and Mahoney, J. J., Jr.—*Apparatus for Measuring Data Signal Impairment*—3,057,957.

Gray, P. R.—*Inter-Switching Center Transfer Arrangement*—3,057,963.

Grenier, T. J.—*Shifting Reference Transistor Oscillator*—3,061,797.

Hammersla, W. E., see Duvall, G. H.

Jacobson, O. D., and Krantz, H. K.—*Switching Device*—3,056,868.

Kahl, H., see Gibby, R. A.

Kaiser, J. F.—*Normalized Sound Control System*—3,057,960.

Koliss, P. P., see Duvall, G. H.

Krantz, H. K., see Jacobson, O. D.

Mahoney, J. J., Jr., see Gibby, R. A.

Meacham, L. A., Schenker, L., and West, F.—*Telephone System Signaling*—3,060,275.

Newby, N. D.—*Magnetic Core Register Circuits*—3,061,818.

Nowak, J. S., and Ulrick, W.—*Standby Transfer Control Circuitry*—3,060,273.

Pfann, W. G.—*Internal Field Transistor*—3,059,123.

Pierce, J. R., see Cutler, C. C.

Power, J. R.—*Multifrequency Signaling Receiver*—3,057,964.

Rose, C. F. P.—*Method for Constructing a Wave Guide*—3,056,710.

Rowe, H. E.—*Timing Wave Generator*—3,057,959.

Ryder, R. M., see Doucette, E. I.

Schenker, L., see Meacham, L. A.

Stone, H. A., Jr., and Warner, R. M., Jr.—*Multiple Channel Field Effect Semiconductor*—3,061,739.

Theuerer, H. C.—*Method of Processing Semiconductive Materials*—3,060,123.

Thomas, D. E.—*Null-Type Transistor Beta Measuring Set*—3,056,924.

Thomas, D. E.—*Esaki Diode Negative Resistance Curve Tracer*—3,058,064.

Thomas, D. G., see Boyle, W. S.

Toro, J. A.—*Temperature Compensated Capacitor*—3,061,767.

Ulrick, W., see Nowak, J. S.

Warner, R. M., Jr., see Stone, H. A., Jr.

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Alberti, H., see Courtney-Pratt, J. S.

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Allison, H. W., see Fuller, C. S.

Boddy, P. J., see Brattain, W. H.

Brattain, W. H., and Boddy, P. G., *The Interface Between Germanium and a Purified Neutral Electrolyte,* J. Electrochem. Soc., 109, pp. 574-82, July, 1962.

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Anderson, R. E. D., Feldman, D. and Hake, E. A., *Telstar Satellite Power System*, Am. Rocket Soc. conf. on Space Power Systems, Santa Monica, Calif.

Atal, B. S., and Schroeder, M. R., *Perception of Coloration in Filtered Gaussian Noise—Short-time Spectral Analysis by the Ear*, 4th Intern. Cong. Acoust., Copenhagen.

Atal, B. S. see Schroeder, M. R.

Bailey, C. M., *Telstar*, Leaksville-Spray-Daper Lions Club, Leaksville, N. C.

Baker, C. P., Mollenauer, J. F., Zupancic, C., Donovan, P. F., and Kane, J. V., *Final-State Interactions, in the Reaction D (P, 2P) N.*, Intern. Symp. on Direct Interactions, Padova, Italy.

Baker, C. P., see Donovan, P. F.

Baker, C. P., see Kane, J. V.

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Barker, A. S., and Tinkham, M., *Far Infrared Dielectric Measurements of Hydrogen-Bonded Ferroelectrics*, Am. Phys. Soc., Seattle.

Bird, C., see Schroeder, M. R.

Black, H. S., *Telstar*, Cranbrook Inst. Sci., Bloomfield Hill, Mich.

Black, H. S., *Satellite Communications*, Nat'l. Assoc. of Heads of State Depts. of Agriculture, Grand Rapids, Mich.

Buehler, E., Wernick, J. H., Olsen, K. M., Hsu, F. S. L., and Kunzler, J. E., *Preparation and Properties of Cored Wire Containing Niobium(3) Tin and Vanadium(3) Gallium*, AIME Conf. on Advanced Electronic Materials, Philadelphia.

Chynoweth, A. G., see Rowell, J. M.

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Darnell, P. S., *Some Reliability Considerations for Telstar*, Washington, D. C. Chapt. IRE Prof. Group on Reliability and Qual. Control.

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

Dewald, J. F., see Peck, K. F.

Diggory, B. A., see Schlabach, T. D.

Dillon, J. F., and Remeika, J. P., *Ferromagnetic and Paramagnetic Resonance Linewidths in Chromium Chloride and Chromium Bromide*, Intern. Conf. on Magnetic and Electronic Resonance and Relaxation, Eindhoven, The Netherlands.

Donovan, P. F., Kane, J. V., Baker, C. P., Mollenauer, J. F., and Zupancic, C., *Inelastic Scattering of 10-Mev Protons from Deuterons*, Intern. Symp. on Direct Interactions, Padova, Italy.

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Fleckenstein, W. O., *Data Communication Using the Tele-*

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Garn, P. D., *Thermal Analysis*, Textile Research Inst., Princeton, N. J.

Gershenzon, M., and Mikulyak, R. M., *Electroluminescence from Gallium Phosphide P-N Junctions at High Injection Levels*, Solid State Device Conf., Durham, N. C.

Gershenzon, M., see Hare, W. F. J.

Gibson, W. M., *A Detailed Study of Mass and Energy Division In Nuclear Fission*, Rutgers Univ., New Brunswick, N. J.

Giordmaine, J. A., *Local Modes in Large Resonators*, Northeastern Univ. Laser Conf., Boston.

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Griffiths, J. E., *The Vibrational Spectrum of Methyl Germane and Trideuterol Germane*, Can. Assoc. Appl. Spectroscopy, Ottawa.

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Hill, J. W., see Courtney-Pratt, J. S.

Hoth, D. F., *The T1 Carrier System Philosophy and General Features*, AIEE, Chicago.

Hsu, F. S. L., see Buehler, E.

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Kelly, J. L., *Speech Synthesis*, Speech Commun. Seminar, Stockholm.

Kern, H. E., *Thermionic Emission and Diffusion Studies on Zirconium-Doped Nickel Cathodes*, 6th Nat'l. Conf. Tube Techniques, New York City.

Kerr, D. A., and Zenack, N. B., *Data-Phone Service as Applied to Telemetry, Alarm and Supervisory Control Systems*, AIEE, Chicago.

Kinariwala, B. K., *Timing Jitter in Digital Communication*, URSI-IRE, Ottawa, Canada.

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McCumber, D. E., *Coherence Theory for Optical Cavity Masers*, Opt. Soc. Am., Rochester, N. Y.

McLaughlan, J. W., see Courtney-Pratt, J. S.

McSkimin, H. J., *Wave Propagation Considerations for Measuring Mechanical Properties of Solids*, Symp. on Physics and Nondestructive Testing, San Antonio, Tex.

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Nast, D. W., *Tentative Characteristics of Telpak Wideband Channels*, IRE, Prof. Group on Commun. Systems, Little Silver, N. J.

Nelson, D. F., *Continuously Operating Solid-State Optical Maser*, 1. MIT, Cambridge, Mass., 2. Univ. of Michigan, Ann Arbor.

Olsen, K. M., see Buehler, E.

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Peck, W. F., and Dewald, J. F., *The Hall Effect in Semiconducting Glasses*, Electrochem. Soc., Boston.

Pfahn, A., *Properties of Fast-Decay Cathode-Ray Tube Phosphors*, 6th Nat'l. Conf. on Tube Techniques, New York City

Pollak, H. O., *The Space of Essentially Time- and Band-Limited Signals*, AIEE, Chicago.

Povilouis, E. I., see Handelman, E. T.

Prestigiacomo, A. J., see Schroeder, M. R.

Remeika, J. P., see Dillon, J. F.

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Rowell, J. M., and Chynoweth, A. G., *Tunnelling Between Superconducting Mercury and a Degenerate Semiconductor*, Am. Phys. Soc., Seattle.

Savage, A., see Miller, R. C.

Schlabach, T. D., and Diggory, B. A., *The Copper Etching Characteristics of Ammonium Persulfate Solutions*, Electrochem. Soc., Boston.

Schroeder, M. R., *The Uses of Digital Computers in Room Acoustics and Speech Research*, 1. Univ. of Gottingen, 2. Univ. of Heidelberg, 3. Technische-hochschule, Karlsruhe, 4. Seimens Labs., Munich.

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Sessler, G. M., and Schroeder, M. R., *Interaction of Sound Waves with a Gas Discharge*, 4th Intern. Cong., Acoust., Copenhagen.

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Smith, G. E., see Wolfe, R.

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Van Uitert, L. G., *Solid-State Maser Materials*, AIME Symp. on Maser Materials, Philadelphia.

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AUTHORS

F. A. Korn

Frank A. Korn, Director of the Columbus Branch Laboratory, was born and raised in Elizabeth, N. J. He is now a resident of Columbus, O. Mr. Korn joined the Engineering Dept. of the Western Electric Company (which was later incorporated as Bell Laboratories) in 1920. He has been chiefly concerned with the development of dial central office switching systems. His early work was on the panel and step-by-step systems. In 1933 he became a member of the group responsible for fundamental planning of crossbar switching systems, including No. 1 crossbar, crossbar tandem and No. 4 toll. After the war he became involved with No. 5 crossbar and was in charge of all circuit work on this system when the first office was placed into service. He became director of switching systems development in 1952, with responsibility for development work on all local dial central offices and PBX's and was appointed to his present position in 1958 when the Columbus Laboratory was organized. Mr. Korn was a member of the Editorial Board of the RECORD from 1952 to 1959.

J. W. Buckelew, a native of Jersey City, N. J., has been with the Laboratories since 1953. Prior to this time he completed a three-year machinist apprenticeship with the Westinghouse Lamp Division. From 1942 to 1945 he served in the Army Air Force as an Aerial Navigator and B'29 Flight Engineer with a rating of Second Lieutenant. After the war he attended evening sessions for a number of years at the Newark College of Engineering and Fairleigh Dickinson University. His work at the Laboratories has been mainly concerned with ball-bearings, reliability testing, and measurement problems. The article "Strain Gages" in this issue is by Mr. Buckelew.

J. W. Buckelew

Everett G. Neumiller, a resident of Short Hills, N. J., headed the group responsible for the engineering requirements for the trial electronic central office installed in Morris, Ill. He took part in developing requirements for the selection of customers and services for the trial. A veteran of 37 years with the Bell System, Mr. Neumiller was a member of the Pacific Telephone and Telegraph Company in San Francisco from 1925 to 1955, when he transferred to Bell Laboratories. His work was in central-office maintenance and engineering, and he took part in an extensive program to convert from manual to dial switching in the Northern California and Nevada area. Since joining Bell Laboratories he has concentrated on studies of central-office requirements and problems of electronic switching. Mr. Neumiller received the B.S.E.E. degree from the University of California

E. G. Neumiller

at Berkeley in 1935. He is a Lt. Colonel (Ret.) in the Ordnance Corps and the author of "The Electronic Central Office at Morris, Illinois" in this issue.

H. D. Cahill joined the Installation Department of the Western Electric Company in 1923, spending the next year on installation of new dial equipment. In 1924, he transferred to the Engineering Department, now known as Bell Telephone Laboratories, where he began his career in circuit design. In those days, manual systems were still in vogue and Mr. Cahill worked on such projects as straightforward trunking and new manual switchboards. Later, as dial systems replaced the manual switchboards, Mr. Cahill had an active part in this transition, assisting in the early design of the crossbar systems. He also assisted in developing the first

H. D. Cahill

AMA systems and more recently has been working on ANI (Automatic Number Identification).

Mr. Cahill received the B.S.E.E. degree from the University of Maine in 1923. A resident of Scarsdale, N. Y., he is the author of "Maintaining the ANI System" in this issue.

Walter W. Werring, author of "Miniature Relays for Key Telephone Systems" in this issue, is a native of New York City, and now still lives in Greenwich Village. He received his bachelor's degree in Mechanical Engineering at Cornell University in 1922, where he had been an instructor for two years. On graduating, he joined the Engineering Department of the Western Electric

W. W. Werring

Company. After early work in apparatus analysis and insulating materials, he initiated the Laboratories' development in plastic molding, and led this program for some years. He continued in the

Materials Department until World War II supervising precision measurement, photographic, welding, and X-Ray laboratories. During the war and for some time after, he was responsible for the development of the special contoured potentiometers required for the M9 and other gun directors, computing bomb sights, and Nike. He was also active in the torpedo battery project. Since then he has headed several departments in switching apparatus development with responsibilities for various relays, switching apparatus, and instrumentation. Mr. Werring is presently Head, Switching Apparatus Department. He has been active in the committee work of the ASTM and ASA.

What was Bell Telephone Laboratories doing on Monday, October 1, 1962?
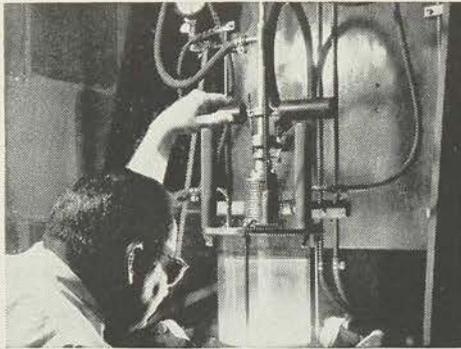
Murray Hill Laboratory, N. J. The search continued for new materials exhibiting superconductivity. Some of these materials have been used to produce very strong magnetic fields with the expenditure of very little electrical energy.
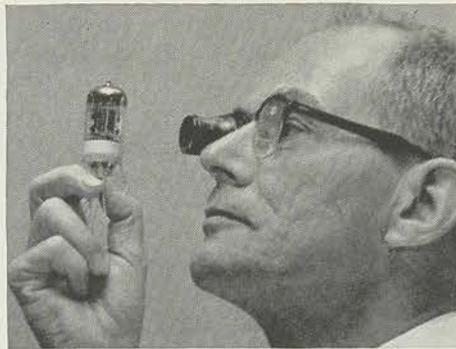
Allentown Laboratory, Pa. We were working with engineers of Western Electric, manufacturing unit of the Bell System, on the manufacture of long-life electron tubes for a new deep sea cable system.

Merrimack Valley Laboratory, Mass. We were increasing the capabilities of a new microwave system designed for low-cost telephone and television communications over distances up to 200 miles. This system is based on advances in solid state technology.


Holmdel Laboratory, N. J. We were developing an electronic switching system using new solid state devices. It will bring telephone customers a whole new range of services.


Indianapolis Laboratory, Ind. We were perfecting improved automatic dialer telephones. One model will permit the customer himself to record 50 frequently called names and numbers and then dial by simply selecting a name and pressing a button.


New York Laboratory, N. Y. We were studying the performance of a new data set which converts teletypewriter pulses into tones for transmission over regular voice circuits. Transmitting teletypewriter messages over voice circuits was introduced on August 31, 1962.
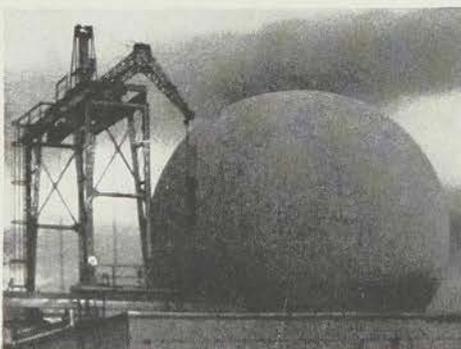
Whippany Laboratory, N. J. We were evaluating new radar technology for the NIKE-ZEUS anti-missile missile system under development for the Army. Significant improvements are further tested at four other ZEUS test sites ranging halfway around the world.
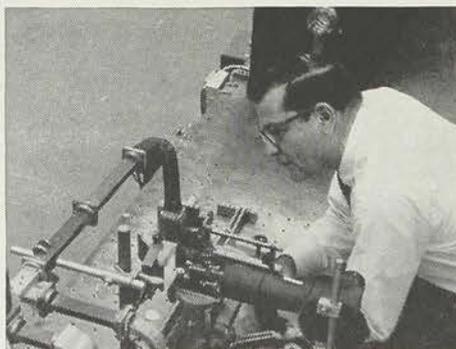
Crawford Hill Laboratory, N. J. We were experimenting with the microwave modulation of light from a helium-neon gaseous optical maser. Modulated light may someday be used to carry large volumes of information.
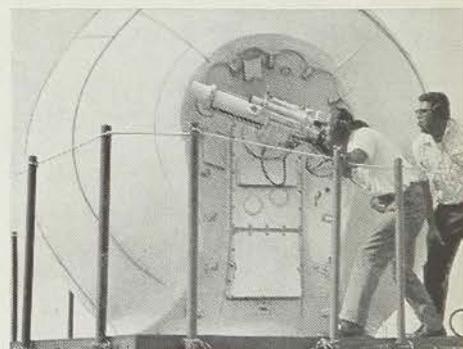
Cape Canaveral, Fla. We were preparing for the 102nd successful use of Bell Laboratories-developed Radio Command Guidance System. On July 10, it was used in the NASA launching of the Bell System's Telstar. This guidance system was originally developed for the Air Force and is operational on the Titan I ICBM.

These were some of the highlights of one day. Engineers and scientists at Bell Laboratories work in every field that can benefit communications and further improve Bell System services. Their inquiries range from atomic physics to new telephone sets, from the tiny transistor to transcontinental radio systems, from the ocean floor to outer space.

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