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Bell Laboratories RECORD

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Bell Laboratories **RECORD**

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Contents

Cover *Inside a DEW-Line "radome," showing part of search antenna and protective geodesic cover. Story on DEW Line begins overleaf.*

Foremost among the contributors to the technology that evolved the Distant Early Warning Line are the Western Electric Company and Bell Telephone Laboratories. These organizations have been chiefly responsible for the development and installation that has led to the effective detection and communication systems for the DEW Line.

G. R. Frantz

Development of the DEW Line

The DEW Line is a radar warning system that extends from the eastern coast of Canada to the northwest tip of Alaska. An additional section is now under construction along the northern coast of the Alaskan peninsula, extending to the Aleutian Islands. These two sections are connected by the Alaskan Aircraft Control and Warning System — a group of radar-warning stations which provide air defense for Alaska itself and early warning for the United States and Canada. The accompanying map (page 4) shows the position of the DEW Line and the other significant warning networks, the Mid-Canada Line and the Pine Tree Line.

The objective of the warning system is, of course, to detect winged aircraft reliably, whether such aircraft are flying a few feet above the surface or at high altitudes. Having detected such targets, the system must then report the tracks accurately and promptly to air-defense headquarters in this country and in Canada.

The Alaska-Canada section of the DEW Line was placed in operation on schedule (July, 1957) and is now reporting aircraft penetrations. The sea flanks are covered by airborne and U. S. Navy picket-ship radars. Future developments in technology will result in continuous improvement in this radar net.

The Warning Line was conceived by the Summer Study group—which in 1952 met at the Lincoln Laboratory, Massachusetts Institute of Technology, to consider the problems of the evolution and further development of the air defense of North America. This group of scientists was composed of representatives from various government agencies, military commands and a number of private organizations, including Bell Telephone Laboratories.

As the first step in carrying out the recommendations of this group, Western Electric was asked in December, 1952, to undertake the construction of a trial segment of the Line along the northern coast of Alaska. This experimental line was to be used for a field trial of detection and communication systems under Arctic conditions. Operating toward a critical deadline, Western Electric arranged for procurement of supplies, design of buildings and air strips, transportation of equipment, and actual construction of the stations.

Bell Laboratories was asked to plan the electronics system and to arrange a series of important tests — tests designed to demonstrate the technical feasibility of a detection line in the far north. Laboratories groups therefore procured special communications equipment,

A typical DEW Line site. On either side of the spherical radome housing the automatic search radar are the two sixty-foot antennas. At left can be seen the pair of thirty-foot parabolic antennas.

equipped available search radars with automatic alerting equipment, and planned extensive tests and test instructions. Special "fence" type equipment was also procured — automatic units for detecting aircraft in the areas that would otherwise be gaps between larger stations.

With the assistance of Lincoln Laboratory and other organizations, these jobs were ready on schedule. By July, 1953, the equipment necessary for seven stations was loaded at Seattle for the voyage to the north shore of Alaska.

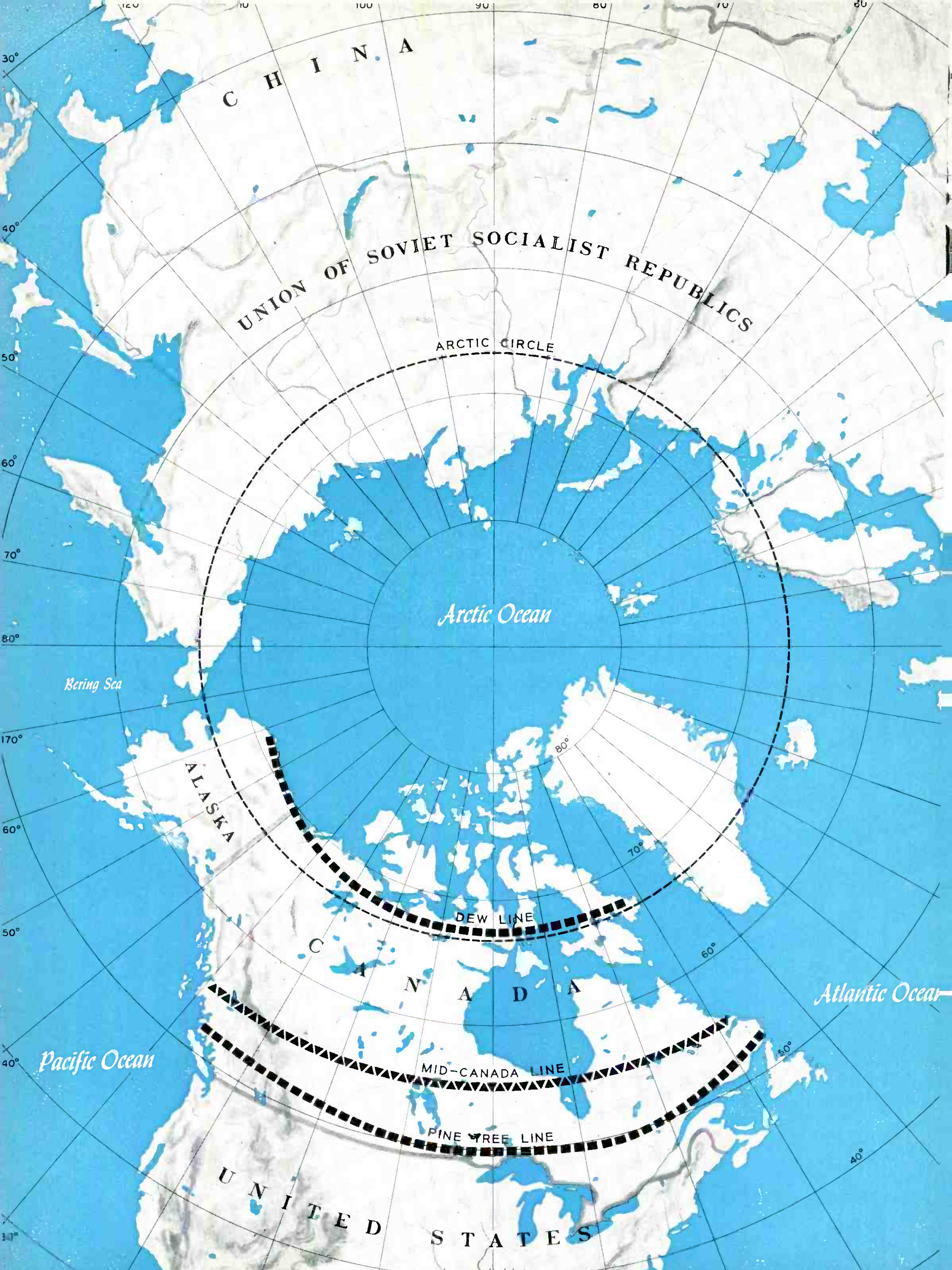
The experimental stations consisted of a main station, two auxiliary stations, and four intermediate stations. The main station had detection equipment, lateral (east-west) communications, and rearward communications to a base station near Anchorage, about 650 miles from the Line. The auxiliary stations, spaced about 90 miles on each side of the main station, had detection equipment and lateral communications. The intermediate stations, which did not require continuous attendance by operating personnel, used the "fence" equipment to fill in the gaps between main and auxiliary stations. As a result, the over-all system had stations about every 30 miles.

Western Electric completed installation of electronic equipment during the fall and winter of 1953, and tests began early in 1954. As expected, some of the equipment performed according to plan, and some was found to require improvement. For example, the Laboratories specified a redesign for the search radar to improve both its accessibility and performance. One result was automatic equipment for monitoring the performance of the system. This monitor sounds an alarm when the power falls below a particular value or when noise becomes excessive. For the other detection system the Laboratories specified improved performance under conditions of vibration, small fluctuations in power supply, variable propagation and moving clouds. Furthermore, to improve the performance of the person operating the console, suggestions were made to supply him with equipment for transmitting messages automatically.

In general, the tests successfully demonstrated that a simplified, largely automatic system could be operated by a limited number of well-trained technicians, despite rigorous climatic conditions and difficult supply routes. The Air Force concluded, therefore, that a DEW Line extending completely across the Arctic was practicable, and late in 1954 asked Western Electric to build the complete line. As prime contractor, Western Electric recruited specialists from the entire Bell System and made arrangements with construction companies and with hundreds of suppliers and subcontractors.

An important part of the project was selecting the route — a tremendous undertaking. Individual sites were chosen and the stations were laid out using criteria specified by the Laboratories. These criteria, besides the usual requirements for radars and communications, included many others imposed by the nature of operations in the far north: for example the need for fresh water, access to the sea, and surfaces for air strips.

In designing the detection and communication system, Laboratories engineers drew upon recent


CHINA
UNION OF SOVIET SOCIALIST REPUBLICS
ARCTIC CIRCLE
Arctic Ocean
Bering Sea
ALASKA
DEW LINE
CANADA
MID-CANADA LINE
PINE TREE LINE
Pacific Ocean
Atlantic Ocean
UNITED STATES

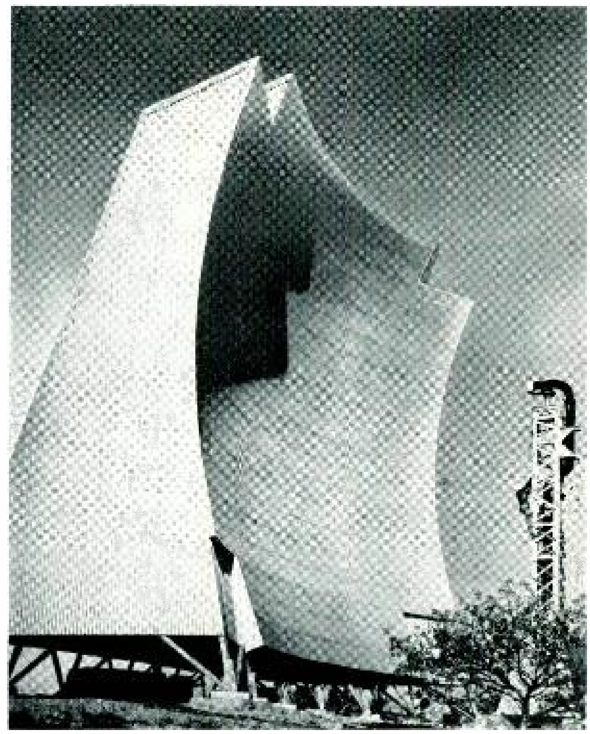
advances in the art and upon their experience with the experimental network. The basic plan called for automatic search radars at auxiliary stations about 100 miles apart, with intermediate stations as "gap-fillers" employing another type of detection system. The detection information is passed laterally along this line, via UHF "beyond-the-horizon" circuits, to the main stations which have all the facilities of auxiliary stations. They also provide communications via VHF transmission to the mid-Canada line.

In addition to these basic systems for detection and communication, each station has fixed-station, mobile-radio equipment for communication with vehicles and with intermediate sites: ground-to-air communication equipment in HF, VHF and UHF bands; low frequency beacon; and HF radio equipment for emergency use.

Some of the electronic items are standard commercial or military units purchased by Western or supplied by the Government. Other equipment, however, required special development — for example the detection units, lateral communications equipment, the control console for a station, and certain special test gear. For these, Bell Laboratories monitored the design and production or, in the case of the control console, actually designed the equipment and prepared for its manufacture by Western Electric.

The control console presented a particularly difficult design problem, since it is the interconnection point of all the diverse communication and detection systems. Because of the complexity of the system, however, great emphasis was placed on ease of operation. Consider, for example, how the console operator at an auxiliary station uses a unit termed a "message composer." When the operator hears an alarm telling him that an aircraft is penetrating the network, he looks at his display equipment. From this he gets the aircraft's course, altitude and speed. He then places this information in the message composer by setting appropriate dials. It is transmitted along the lateral communication system to the main station to be plotted along with data from other auxiliary stations.

At the main station, the plotting board enables the operators to filter out the "friendly" tracks, to correlate data from the various radar stations, and to determine on which tracks information should be transmitted to higher headquarters to the south. From these headquarters,



DEW Line terrain sometimes presents difficult or unusual transmission problems. Here, the lateral system uses higher-powered, sixty-foot antennas.

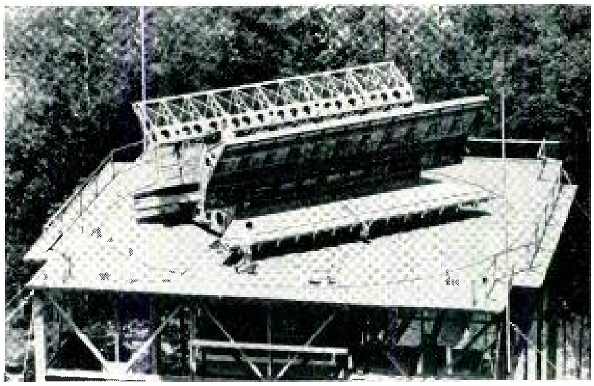
the main stations receive such important information as identification codes and flight plans.

Equipment developed by other organizations was to operate reliably for long periods under Arctic conditions. Antennas and other exposed equipment were designed for temperatures ranging from −65 to +65 degrees F, and for wind velocities up to 150 miles per hour. The exposed equipment is able to operate under conditions of snow, rain or salt-laden air, and it can withstand heavy coatings of ice or snow. The indoor equipment, however, is not subjected to conditions significantly more rigorous than those normally expected for indoor, ground-based electronic systems. Indoor designs emphasized automatic operation, trouble-free performance, accessibility of components for maintenance, and ease of operation.

The automatic search radar is a dual system with two antennas operated "back-to-back," each normally supplementing the other. During maintenance or emergency periods, either antenna may be arranged mechanically to provide coverage while the other half of the system is out of operation.

This antenna, shown in the photograph at the

LEFT: *the three lines are positioned for complete radar coverage and dependable communications.*



The automatic search radar, shown here before the radome has been erected, uses two antennas of a special design, operated back-to-back.

top of this page, is a scaled-up version of an earlier Bell Laboratories design used on another system. The radar proper is an extensive redesign of the system used on the experimental line, which was a good system but one designed for portability and therefore not ideally suited for permanent installation.

The radome enclosing the antennas is built of Fiberglas and plastic sections that are specially shaped in accordance with a "geodesics" design. This rigid type of radome was chosen as a result of tests made by Lincoln Laboratory on the summit of Mount Washington. Full-sized radomes were tested in Labrador and Greenland.

The "fence" detection system, as mentioned earlier, fills the gaps between radar stations. The various parameters of this system were developed after Laboratories engineers carefully analyzed the problems encountered on the experimental line. Particular emphasis was placed on reliability and freedom from false alarms in the automatic alerting features of this system. Special antennas were furnished to give direction of aircraft movement and to eliminate indications of slowly moving objects, such as birds.

The lateral communication system operates "over-the-horizon" in the frequency range of 800 to 1000 mc. This system provides up to 24 voice channels along the line, some of which are used for teletypewriter service. In general, one-kilowatt transmitters are used with two 30-foot diameter parabolic antennas, but certain difficult links use 60-foot antennas and 10-kilowatt transmitters. These antennas are shown on page 5 and at the right. The same types are used in White Alice—the Alaskan communication systems (RECORD, *August*, 1958).

The VHF rearward communication system is of an ionospheric scatter type that uses a certain layer of the ionosphere to reflect radio waves, and it provides several teletypewriter channels in each direction. High-power transmitters are employed with two antennas having space diversity. That is, the antennas are attached to one receiver which uses the better of the two signals. They depend upon reflection from the ground to establish a lobe aimed at a region in the ionosphere midway between the transmitter and the receiver. The angle of this lobe depends on the length of the path, and the angle is obtained by installing the antenna at the proper height.

During the first half of 1957, extensive evaluation tests of reliability of communication circuits, detection capability, and data-handling methods were made. No major flaws were found in the system concept or performance, and the Alaska-Canada portion of the Line is in full operation at the present time. Further tests are currently being conducted during operation by Bell Laboratories and the Western Electric Company, and also by Air Force agencies. In general, the performance has been successful to date with no more than the usual number of problems expected from any new system.

The lateral communication system transmits one thousand watts from 30-foot parabolic antennas.

Researchers, concerned with the properties of semiconductors in studies of transistor action, have measured the piezoresistive effect in such materials as silicon and germanium. Unexpectedly, this effect was so pronounced that it permitted the construction of very sensitive devices for measuring strain—devices that have nearly all the qualities of an ideal gauge.

W. P. Mason

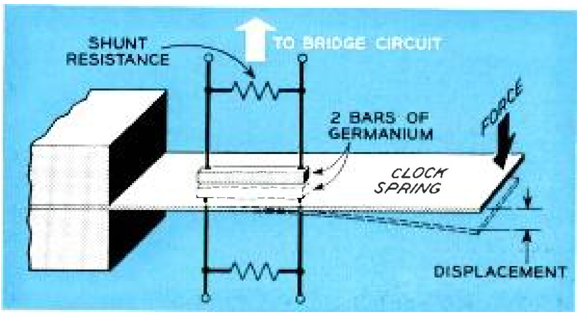
Semiconductors in Strain Gauges

One of the most important and most interesting problems in mechanics is the conversion of mechanical motion into an electrical signal. In the broadest sense this is, of course, a fundamental feature of the telephone or of any other microphone-like device: mechanical motion of a diaphragm, ribbon, or some other vibrating material results in a fluctuating current. But a microphone is only one of a wide range of mechanical-electrical converters or transducers. Others are used in phonograph pickups, in crystal filters, in roughness indicators, and in many types of gauges for measuring such quantities as tension, compression, acceleration, pressure, shear forces and torque.

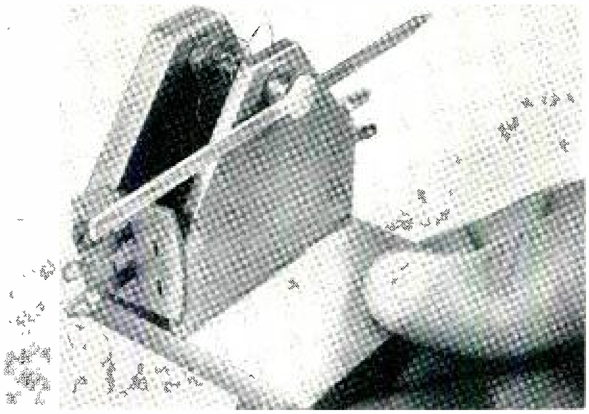
In this article we are concerned particularly with this last category of measurement devices, since certain semiconductors — hitherto used chiefly in the fabrication of transistors and diodes — have been found to possess a number of remarkable properties when used in gauges. Before we discuss these semiconductors specifically, however, it is helpful to gain perspective by reviewing briefly some of the problems of this branch of mechanics.

Of the many materials that can be used as electromechanical transducers, the two most important groups are the piezoelectric materials (mechanical motion produces a voltage) and the piezoresistive materials (mechanical motion produces a change in resistance). Magneto-strictive materials — wherein a mechanical motion causes a change in a magnetic field, which then generates a voltage in a surrounding coil — are another possibility, but these have certain disadvantages that limit their use in many applications. The voltage generated in a magneto-strictive device is proportional to the time rate of change of the magnetic field; thus the generated voltage is proportional to the velocity of displacement rather than to the actual displacement. Furthermore, magnetostrictive materials are subject to eddy-current losses at moderate and high frequencies, which alter the relationship between velocity and voltage. Hence such materials are not advantageous for measuring force, torque or acceleration.

With any of these types of materials, the ideal would be to have a device that is very sensitive to small forces, responsive both to static forces and to periodic forces over a wide band of frequencies, operative over a wide range of temperatures



Displacement gauge constructed with crystals of germanium. Such gauges are up to two orders of magnitude more sensitive than common types.



The torsional transducer: torque is applied to the arm on the free end of a germanium crystal; the other end is firmly cemented to a backing plate.

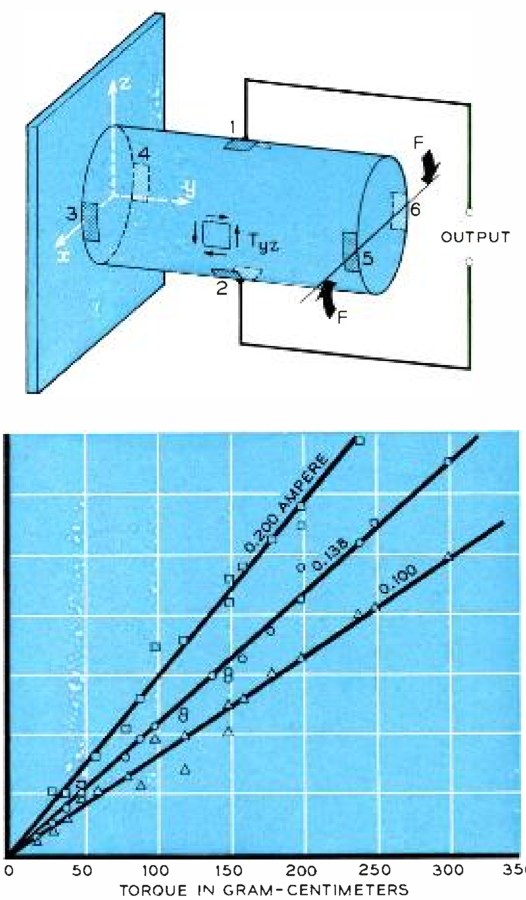
and humidities, and stable with time. It is also advantageous if the device is easily fabricated and is small enough to add only a negligible weight to that of the object being measured.

In general, piezoelectrics like quartz and ADP (ammonium dihydrogen phosphate) perform well at high frequencies but are inadequate for static or low-frequency forces because leakage current masks the response. In addition, they lose effectiveness at high temperatures and high humidities. Also among piezoelectrics, the newer ferroelectric ceramics like barium titanate (RECORD, *August*, 1949; *September*, 1955) have better temperature and humidity characteristics, and they have the advantage that they can be formed into irregular shapes. They tend, however, to change with time, and they may depolarize under high stress. (*For an application of the barium titanate ceramics to problems of acceleration and shock, see* RECORD, *March*, 1956.) There is much need, therefore, for more stable and more sensitive materials that operate over wider ranges of frequency, temperature and humidity; and semiconductors have most of these advantages.

Many metals and alloys exhibit a change in resistance with strain, and a length of metal wire, usually the alloy constantan, is the sensing element in the most common types of strain gauges. In the simplest case, the gauge could be attached to a long rod that is to be measured, and for stress, weights could be added at the bottom of the rod. With increasing stress, current passed through the gauge would change as a result of the changing resistance of the wire. A bridge circuit is placed across the sensing wire, and a value of strain is read from a calibrated dial.

The sensitivity of such a gauge is described by its gauge factor, given by the expression dR/RS where R is the resistance of the unstrained piezoresistive element and dR is the change of resistance with strain S. As an example, if the piezoresistive material in the unstrained state has a resistance of 50 ohms but increases in resistance by 0.01 ohm at a strain of 0.0001 unit per unit length, the gauge factor would be 0.01/(50 x 0.0001) or 2.

Most commonly used metal-wire strain gauges have gauge factors between 2 and 4. Somewhat higher values are obtained with platinum wire, and values up to 20 are noted for nickel. By contrast, germanium is so much more sensitive that gauges using this material have factors up to 150, and silicon permits factors as high as 175. F. T. Geyling and J. J. Forst of the Laboratories have used germanium for a displacement gauge so sensitive that the factor limiting the sensitivity is the normal vibrations of a building. A shunt resistance had to be placed across the ger-



Configuration of the torsional transducer. Graph shows calibrations at different biasing currents.

manium to eliminate the effect of these vibrations, after which the device was still about fourteen times as sensitive as the usual wire-type gauge. With mounts that are resistant to shock and vibration, the full sensitivity (about eighty times that of a wire gauge) can be realized.

Thus, germanium, silicon and other semiconductors permit strain gauges that are about two orders of magnitude more sensitive than older types. But this is merely one of their advantages. Equally important for many applications is the fact that semiconductors can measure static and low-frequency stresses, as well as higher-frequency stresses up to the resonant frequency of the material.

In these new gauges, stress forces can be quite large, since semiconductors are generally strong materials. They can also be used to measure hydrostatic forces merely by immersing the gauge in the fluid. Further, since most semiconductors are structurally and chemically stable, their characteristics should not change appreciably with age or under conditions of high humidity. Operating temperatures with germanium range to 600°K, and with silicon to 1000°K. These limits are set by the "intrinsic" temperatures of the elements, above which they lose their piezoresistive characteristics. Above the intrinsic temperature, thermal agitation is the main cause of resistivity and is not affected by stress. Certain intermetallic semiconductors, like gallium arsenide, with an intrinsic temperature of 1400°K, should be even better in this respect.

These semiconductor crystals have another advantage not possessed by wire-type gauges — namely that they respond to torsional and shearing forces, and thus can be used directly to measure torque. R. N. Thurston of the Laboratories has constructed the torsional transducer shown in the drawing and photograph on the opposite page. This is a cylindrical crystal of germanium cemented to a solid support at one end, with electrodes numbered 1 to 6 attached as shown in the drawing. With a proper biasing voltage, current is caused to flow from electrode 3 to electrode 5 and from electrode 6 to electrode 4. Electrodes 1 and 2, attached midway along the cylinder, are normally at neutral positions, but when a torque is applied to the free end of the cylinder, a voltage is generated across them. This voltage is directly proportional to the torque, and for this reason, no balancing bridge is required. Besides its sensitivity, this transducer has the advantages that it responds to both steady-state and alternating torques, and that the angular displacement is negligible.

J. J. Forst adjusting an ultra-sensitive semiconductor strain gauge constructed with germanium.

The device uses a cylinder of germanium 0.130 inch in diameter and 0.50 inch long. The graph with the drawing of this unit is a calibration in terms of voltage generated across electrodes 1 and 2 with various amounts of torque, for three different values of biasing current.

In experimental work at Bell Laboratories, crystals were prepared and cut so that their unstrained resistance was 55 ohms — the same resistance as that of a common wire-type element. Thus, the same bridge circuit and other associated equipment could be used merely by substituting the new gauges. These advantages mean that semiconductors have nearly all the qualities needed for an ideal gauge. There are still extreme conditions for which no simple measurement device is adequate, but the new gauges offer such greatly expanded characteristics that research, development and testing groups are sure to find many uses for them.

There is another interesting aspect to these gauges, namely, that they are a good example of how pure research often results in useful, and sometimes unexpected, by-products. Extensive physical and chemical research has been conducted on the properties of semiconductors, which was the reason the piezoresistance effect was measured, and this research has resulted in a useful device in an entirely different field.

One of the most important steps in the development of the transatlantic telephone cable system was the design of a repeater that could be laid under 2.5 miles of ocean water by the use of conventional equipment aboard cable-laying ships. Such a repeater is costly and difficult to repair and must be designed and constructed with care for long life.

W. M. Bishop and W. A. Klute

Flexible Repeaters for the Transatlantic Telephone Cable

Development and engineering on flexible repeaters for the transatlantic cable system, installed in 1955 and 1956, was begun in late 1952. The schedule called for the completion of this work in the spring of 1954 to provide sufficient time for the manufacture of the required repeaters. This tight schedule was practicable because of the well documented background of engineering information available from earlier work on repeaters suitable for undersea use.

Previous work on repeaters of this type culminated in the installation of the 1950 Key West-Havana cable system (RECORD, *March*, 1952). Although this system was only about 120 miles long, the engineering was done with transoceanic cables in mind. As a result, sound basic repeater circuit, component and equipment designs of proven reliability were available for the transatlantic project. As finally developed, this circuit has three amplification stages, and the cathode heaters for the three electron tubes are connected in series. The positive voltage drop across the three heaters is used as the plate supply for the electron tubes.

As in all cable systems, the signal decreases in power with distance over the cable. Further, this attenuation of the signal occurs in a predictable pattern or "shape" of a curve plotted to show the amount of attenuation at various frequencies. Thus, the repeater must not only "boost" the over-all power, but also must compensate for the higher attenuation of the higher frequencies. This is referred to as "gain-shaping" to counteract the "cable-loss shape," so that finally, the signal is delivered with very nearly the original frequency-power distribution.

The gain-shaping necessary to match the cable loss shape is obtained in approximately equal parts from the input and output networks and from the beta circuit (used to provide negative feedback to the amplifier). The crystal across the beta circuit affords a means of evaluating the performance of individual repeaters and of identifying inoperative repeaters during the life of the system.

The Key West-Havana repeaters using this circuit handle twenty-four 4-kc voice circuits between 12 kc and 108 kc.

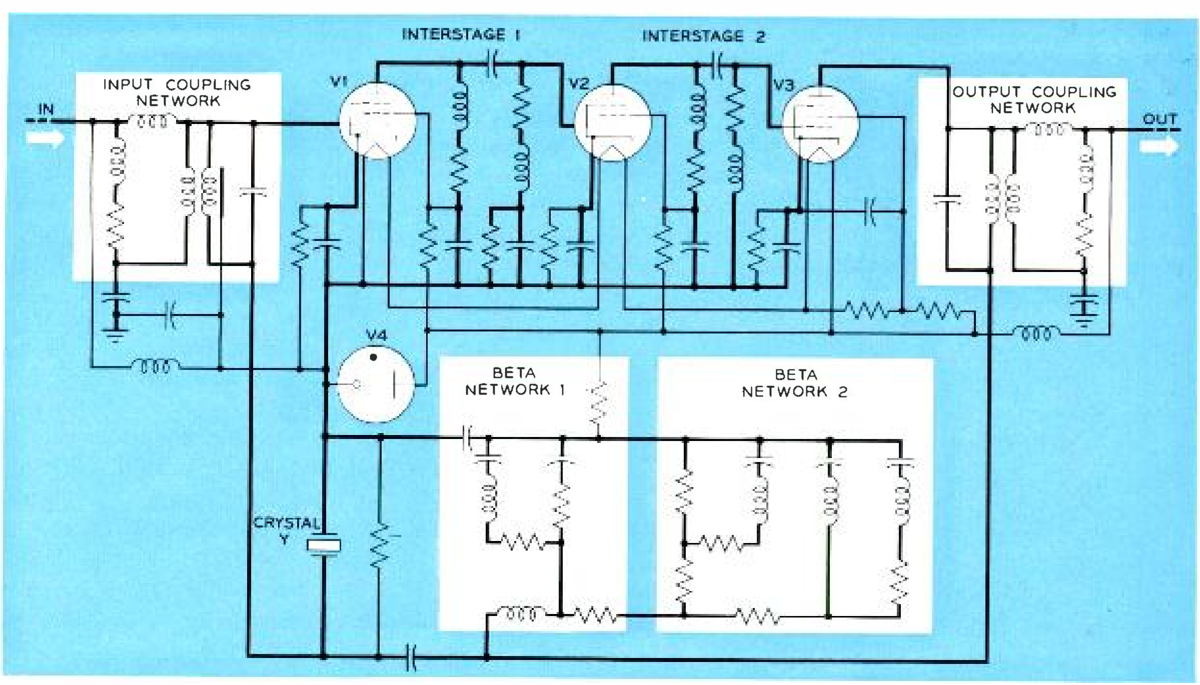
The plan for the transatlantic system specified that the repeater gain compensate for the loss of 36.9 nautical miles of cable in its ocean-bottom environment over as wide a frequency band as was consistent with accepted performance requirements. Experience gained with the Key West-Havana repeaters under operation showed that repeater design margins could be reduced. This, together with the planned use of a larger diameter cable with lower loss, constituted the more important considerations leading to increasing the bandwidth of the repeater for the transatlantic system.

The development of the electrical circuit to broaden the frequency band began with the basic Key West-Havana circuit. Initially, development effort was concentrated on the revision of the input and output coupling networks. These networks were scaled up in frequency from their original range of 12 to 120 kc to the range of 20 to 200 kc. The final design of each of these networks matched about one third of the attenuation of 36.9 nautical miles of cable. In addition, the output circuit was designed to present a load to the third tube of the repeater that was satisfactory from the standpoint of modulation performance. Also, the circuit permitted the tube to be operated at close to its maximum power capability at full drive.

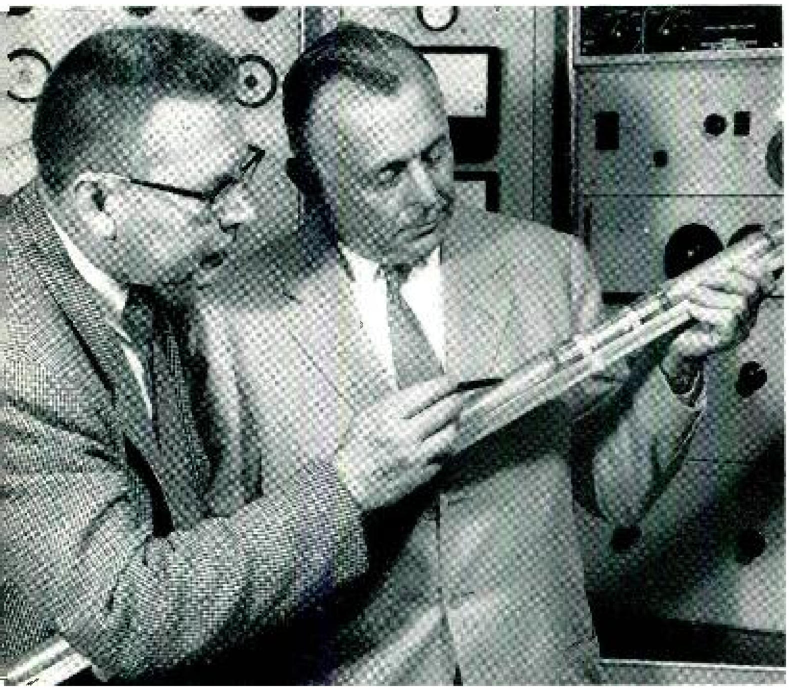
The interstage networks were then revised. These were also scaled up in frequency from the Key West-Havana designs. Also, the effective parasitic capacitance was reduced approximately 4 mmf. This reduction resulted in the lowest values obtainable from the processes used to manufacture components. The reward was an increase of approximately 2 db in the forward gain of the amplifier and about 1 db in the maximum available feedback.

The beta circuit was the last circuit to be developed. This network, in addition to supplying one third of the required transmission shaping, was used to equalize all the small deviations of amplifier gain from cable loss. Any attempt to make each of these shaping networks exactly match one third of the attenuation slope over the frequency band would have introduced additional components in each network with associated layout problems. The beta circuit was therefore modified to compensate for deficiencies in the other shaping networks. Next, the simple beta circuit was modified to be applicable to the new frequency band, and additional elements were added to obtain the desired compensation for the cable. Residual deviations were sinusoidal in shape and hence were minimized by the addition of tuned circuits.

A schematic of the final amplifier circuit for the transatlantic system is shown on this page. It is not markedly different from the one used for



The circuit used for the transatlantic repeaters. It compares with the Key West-Havana circuit except that the present design has a more elaborate beta circuit plus a gas tube for protecting the power circuit. Repeater design consists of the amplifier circuit assembly and repeater container.



W. A. Klute (left) and W. M. Bishop examine an amplifier section. This view shows the unsheathed amplifier with adjacent sections attached to each other; they are connected electrically by bus tapes.

the Key West-Havana amplifier, but the beta networks have three more tuned circuits and some additional resistors.

The repeaters employing this circuit provide thirty-six 4-kc voice circuits between 20 and 164 kc. In addition, maintenance facilities for the system (order wire and printer circuits) are available below 20 kc. The fault-localization facility (crystal band) is provided above the message circuits in the range of 170 kc.

A gas tube has also been added to the circuitry. Its purpose is to provide a current path in the event an electron-tube heater opens. The remainder of the repeaters will then continue operative for test purposes. The potential across the gas tube is approximately 50 volts when the heaters are normal and rises to well above the firing voltage of 150 volts in the event of an open heater. When the tube is fired, the voltage across it drops to about 10 volts.

Over-all mechanical design of the repeater, as with the circuit design, closely followed that used in the Key West-Havana project. Modifications were necessary, however, partly because of changes in the electrical requirements of the circuit and components, and partly to take advantage of new developments in design. Furthermore, extensive re-engineering of the repeater was required because it was to be manufactured on a production basis by the Western Electric Company. This involved the preparation of new manufacturing information in the proper form for factory use.

The mechanical design of the repeater consists of two major parts — namely, the amplifier circuit assembly and the container, including the remaining components of the repeater.

The amplifier circuit assembly consists of 67 electrical components grouped in 15 rigid sections, plus a short terminal section at each end, which brings the number of sections to 17. Eight of the sections contain individual components such as power-filter capacitors or electron tubes. One section contains a desiccator. Eight sections contain the remaining electrical components. This makes a structure about 84 inches long with an outside diameter of 1.5 inches. The adjacent sections are attached to each other mechanically by axial helical steel springs to give the structure the desired mechanical flexibility. They are connected electrically by bus tapes which have slack loops between sections to provide flexibility.

Each section includes one or more electrical and mechanical components enclosed in a plastic "container," which in turn is enclosed in a plastic cylinder. The bus tapes run in grooves between the plastic container and plastic cylinder. The latter unit must provide satisfactory insulation between the repeater circuit and the container for dc voltages up to 2500 volts.

Besides the indicated mechanical and electrical design changes of components and the addition of two new amplifier sections, another important design modification was made. Previously, wherever metallic finishes were exposed to the repeater atmosphere, tin or zinc coatings were used. In the new design, these were changed to gold plate. This was done to reduce the amount of metal "whisker" growth (RECORD, *November*, 1954) and the associated danger of cross contacts within the repeater.

As seen in the drawing on the next page, the repeater container consists of two layers of abutting steel rings each ¾-inch long. The abutting planes of the rings in the separate layers are staggered a half ring-length to eliminate any gap from the outside to the inside of the container and to keep the rings in relative alignment. The steel rings are the medium that enables the container to resist ocean pressure.

Placed over the rings is a thin-walled annealed copper tube. This tube, together with a system of end seals hermetically sealed to it, resists the entrance of ocean water into the repeater. In these respects, the repeater container for the transatlantic project is identical to that used in the Key West-Havana project.

Other than the increase in length resulting from the additional amplifier sections, the most extensive change in container manufacturing information for the transatlantic project was the introduction of a new test for leaks. The previous method (RECORD, *July*, 1951) was considered impracticable for factory use. Consequently, a new two-step method of container leak testing was developed.

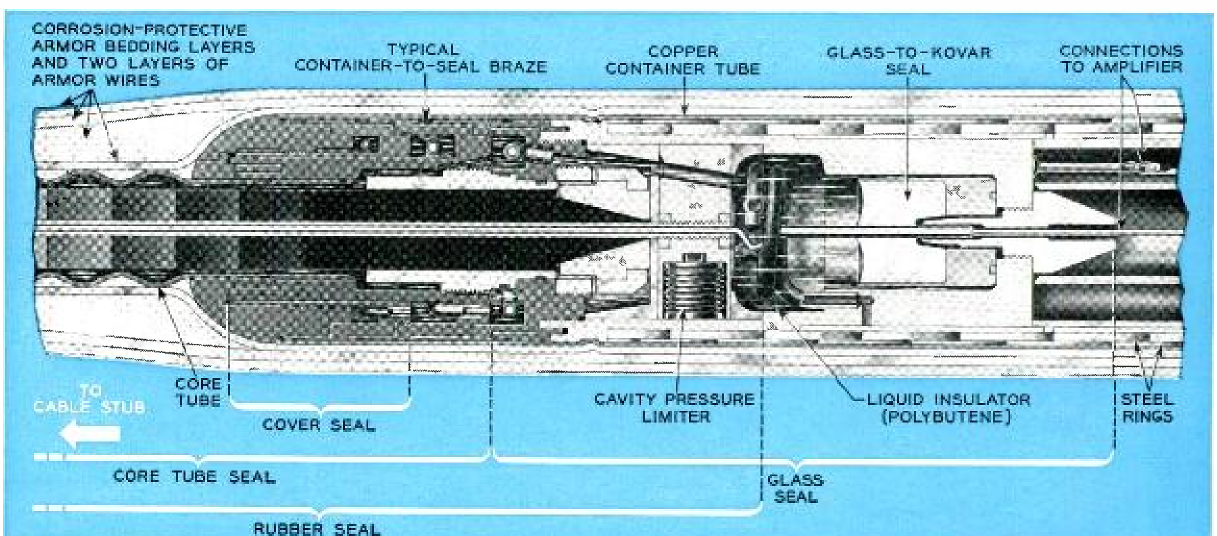
In the first step, access to the inside of the repeater is retained via a single opening, and the exterior of the remainder of the product is subjected to helium at pressures comparable to those on the bottom of the Atlantic. The opening makes it possible to analyze the internal atmosphere for helium through the use of a special mass spectrometer sensitive only to helium. The presence of any leaks is thus detected and the leak rate is determined quickly.

In the second step, after the access opening is closed, the product is again subjected to pressure for a known period. The pressurizing medium in this case is water and a solution containing a small amount of a gamma-emitting radioactive material. The solution surrounds the access-opening seal in such a way that, in case of a leak, only the solution will enter the product. The presence and the amount of the solution is determined, after a pressurizing period of a few days, by radiation detectors which receive gamma radiation through the wall of the container.

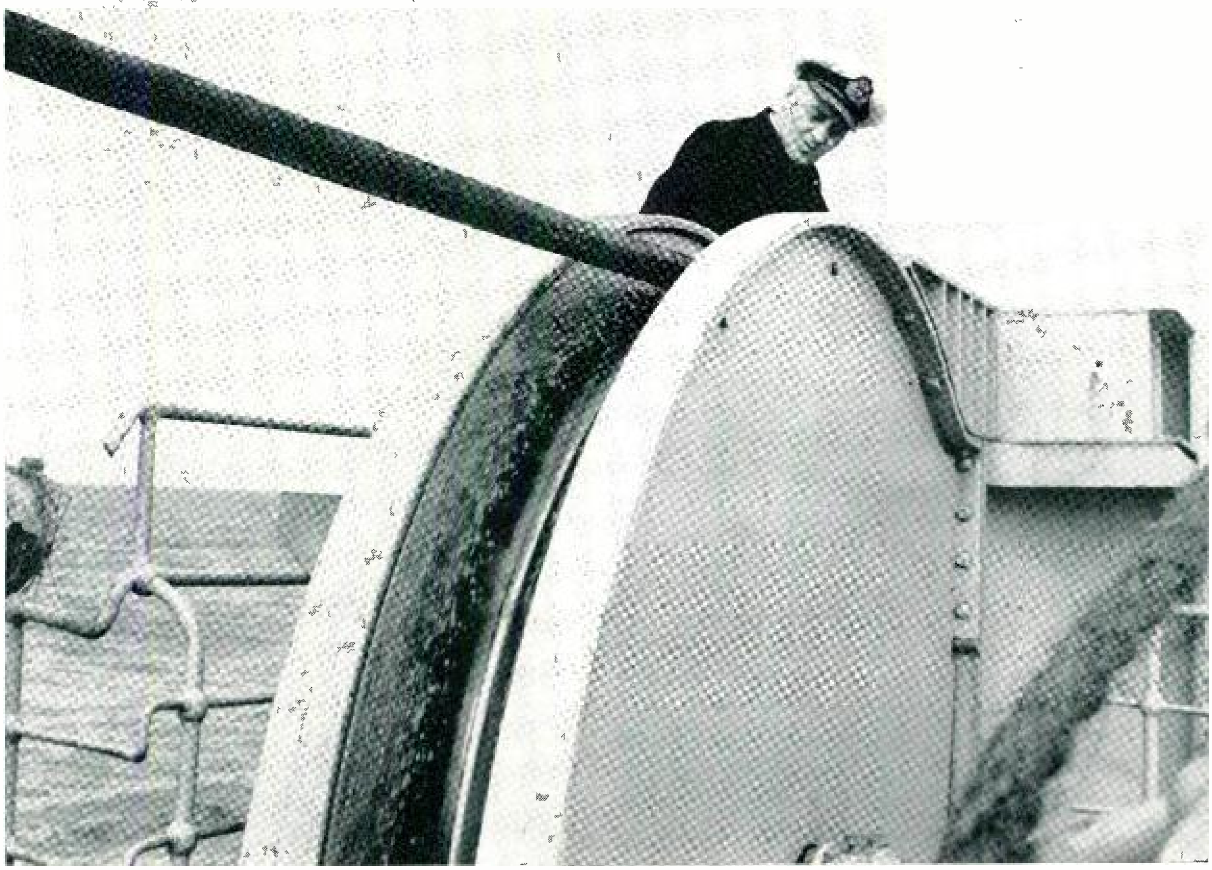
The new method has the advantage that the detectors detect only the leaking medium. The older method involved weighing the repeaters before and after pressurizing, and various factors (dirt or corrosion products and entrapped water) could contribute to errors in determining leak rate.

The transatlantic repeater shown below was manufactured under the control of the Kearny Plant of the Western Electric Company in a special shop located at Hillside, New Jersey. There, most of the mechanical and electrical components were fabricated, and all repeater assembly operations except armoring were carried out. As in most projects of this nature, however, it was necessary to perform some operations elsewhere. The electron tubes were made and extensively tested by the Laboratories at Murray Hill, New Jersey. The glass seals were manufactured by the Western Electric Company at Allentown, Pa., with the close cooperation of the Laboratories people at that location. And finally, the repeaters themselves were armored by the Simplex Wire and Cable Company, located at Newington, New Hampshire.

Although the repeaters for this project were manufactured by the Western Electric Company, the basic conditions, procedures and tooling followed closely those used by the Laboratories for the earlier project. This resulted largely from



Internal construction of an undersea telephone cable repeater. Repeater enclosure is terminated at each end with a system of seals: glass-metal, a plastic seal, and lastly a 7-foot long seal formed within a copper tube which is an extension of repeater housing. These resist sea-bottom pressures.



The transatlantic cable shown here paying out off the stern of the cable-laying ship H.M.S. Monarch. The fifty-one repeaters had to be flexible enough to go over this wheel on their way down to the rugged Atlantic ocean bottom where they lie at intervals of 37 nautical miles.

three considerations. The first and most important was the reliability requirement on the product. This required extreme care in workmanship and near clinical cleanliness during manufacture to minimize the danger of repeater failure due to contamination. Such a failure would result in costly repair operations. The second consideration was the size of the project. Since the required quantity of any specific component was in the tens or hundreds rather than in the millions, laboratory-like methods were practicable. Third, the unusual nature of the product, and the severe test requirements and urgency of the project, all made it desirable to adhere as closely as possible to methods which long investigation and experience had proved satisfactory.

As might be expected in a project of such scope and importance, many people were involved. The successful operation of the transatlantic submarine telephone cable system was the result of valuable contributions made by a large group of international workers on this project and by others who took part in the invaluable earlier experimental work on the flexible repeater.

Synthetic Quartz In Pilot Production At Western Electric

Details of a pilot plant for the production of synthetic quartz crystals were revealed in a paper given at the American Institute of Chemical Engineers meeting in Cincinnati on December 10. The paper was prepared by R. A. Laudise of the Chemical Research Department, one of the Bell Laboratories scientists who brought the Laboratories-developed hydrothermal process to the pilot-plant stage, and R. A. Sullivan of the Western Electric Co., who supervised development activities for the pilot-plant.

These production facilities, believed to be the most advanced type to date, are now being used for growing large crystals in limited quantities at Western Electric's Merrimack Valley Works in North Andover, Massachusetts. Production of this type compares with the production of synthetic rubber and synthetic fibers like nylon and rayon.

The Bell System is a large user of quartz for filters, oscillators and frequency standards, and has been interested in synthetic quartz processes for some time. This interest has resulted from the increasing difficulty in obtaining large crystals of natural quartz, and from the generally unstable quartz market. Synthetic quartz also provides a number of physical advantages over natural quartz, in addition to its availability in any quantity and size.

Scientists at Bell Laboratories have investigated the hydrothermal process on a laboratory scale for several years, and have grown quartz crystals about ¾-inch square by 1½-inches long and larger. The processing equipment has been scaled up for pilot plant investigation, and quartz crystals up to two to three inches in each cross-section dimension and five to six inches long have been grown in this equipment. Operations have not been directed toward growing the biggest possible crystals, but toward determining the optimum processing parameters.

In the hydrothermal process, a long narrow cylinder capable of withstanding high pressures, called an autoclave, is partially filled with an alkaline solution, usually sodium hydroxide. Small pieces of readily available natural quartz are then placed in the bottom of the vessel to provide the nutrient. Future production might use even less costly and more readily available material, such as high-quality sand, as the nutrient. Seed plates cut from either natural quartz, or previously grown synthetic crystals, are hung from a rack in the upper section of the autoclave. After sealing, the vessel is heated to the required temperature and maintained under a constant temperature differential from bottom to top for the requisite processing time. This period has varied from a week to several weeks, depending on the experiment being performed.

One of the main problems which appeared in scaling up the pilot plant equipment was that of finding a suitable closure for the autoclaves. The laboratory vessels were simply welded tubes supported by capped, high pressure piping. A repetitive closure was required for the larger autoclaves, and a satisfactory closure was developed which gives a tighter seal as the pressure inside builds up.

The combination of high-temperature and high-pressure conditions present in this process is believed to be one of the most severe encountered in any present industrial process. This gave rise to a number of problems in the selection of materials and the design of equipment.

R. A. Laudise of Bell Laboratories, right, and R. A. Sullivan of Western Electric kneel at the top of the pilot plant autoclave. Mr. Laudise holds small crystal and "bomb" used in the early research.

Complex military systems require analysis of their performance. This is true of tracking radars used to determine target aircraft position. To evaluate a particular radar system, Bell Laboratories recently developed an analog computer, the Tracking Data Evaluator (TDE), that gives statistical information which helps to define radar tracking performance.

C. C. Willhite and J. W. McIntyre

An Analog Computer for Evaluating Radar Performance

As electronic systems grow more and more complex, so does the analysis of their performance. This is a challenge, because large quantities of information must be obtained and processed; unless such work can be done efficiently, the cost and time may lead to an impossible situation.

This is the case for performance measurements of the tracking radars used in modern military systems. Radars of this type serve to indicate continuously the position and range of target aircraft. These radars must be evaluated for different types of airplanes, with variations not only in airplane range and altitude, but also with the radars themselves in different modes of operation. Since various methods of obtaining and processing radar-tracking data are difficult and time consuming, it is very desirable that automatic equipment be developed. This article discusses a particular computer, but others are possible to aid materially signal evaluation and processing.

Tracking radars do not always point directly at the target. In fact, if one would look through a telescope mounted on the radar antenna, he would see that the target does not appear exactly on the cross-hairs of the telescope, and that it appears to move around. The average indicated position of the aircraft, and the amount that the aircraft appears to move around, are the tracking errors that need to be evaluated. These two quantities are among the most important characteristics of the radar being evaluated.

The combined, instant-by-instant radar-pointing errors can be considered complex waveforms, and these can be measured to obtain "biases" and the amounts of "random motion." Bias may be defined simply as the average value of the waveform over a suitable time interval. The random motions are somewhat more difficult, however, and must be treated statistically, because both the magnitude of the random motions and the time interval for which they exist are important. Statisticians have several ways of evaluating these waveforms, and in this case, would compute what they call a "standard deviation."

This is a common measure that considers both the size and time duration of the random pointing disturbances. Standard deviation is difficult to discuss without using complicated mathematical terms, but briefly, it yields a measure of the percentage of time one may expect any given magnitude of error to exist.

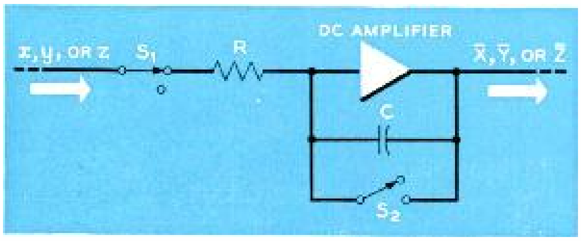
In many radar systems, signals (or voltages) are available that are proportional to the amount the radar is pointing off of the target. So, if a computer can be built that will automatically process these voltages to obtain bias and standard deviation, it will yield the desired performance information on the radar. Such a computer has been built at Bell Telephone Laboratories. It is called a "Tracking Data Evaluator" (TDE). The upper portion of the entire unit is shown in the photograph (*right*).

For the specific system the TDE was built to evaluate, the electrical waveforms give the instantaneous amount of the pointing errors in the east-west, the north-south, and the up-down directions. Thus the unit must determine the bias and standard deviation in each of these three coordinates.

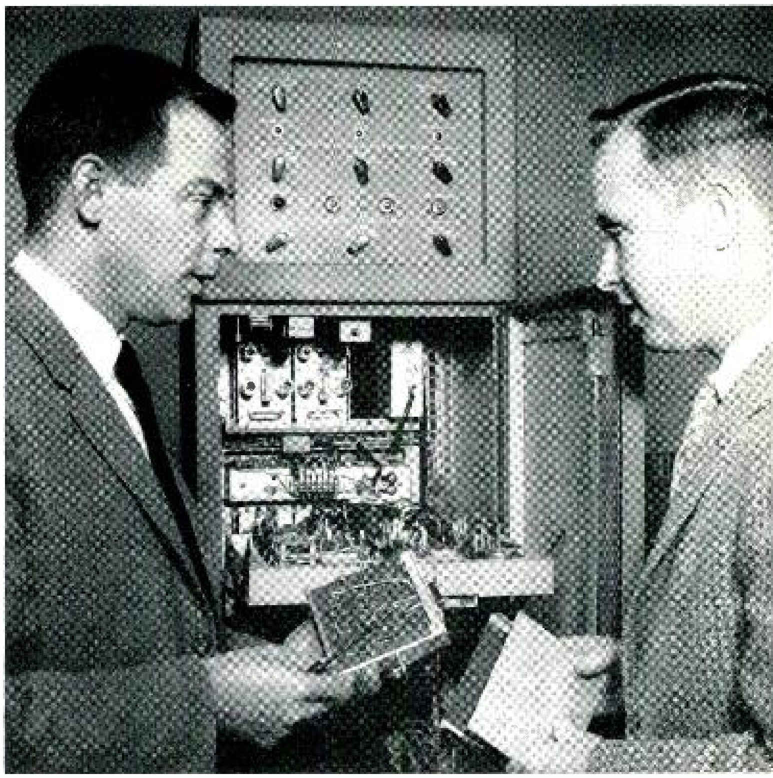
The bias outputs of the TDE are obtained by using three dc amplifier-integrator circuits.

Until the beginning of the evaluation time interval, S_1 and S_2 shown in the schematic below are closed, and the high-gain dc amplifier has zero output. At the start of the evaluation time period, S_2 is opened and a current waveform — inversely proportional to the value of R — flows into the input of the amplifier. The high impedance input and negative feedback of the dc amplifier circuit cause the input current to flow into the feedback capacitor C.

The voltage on the capacitor thus rises and falls at a rate proportional to the instantaneous input current. At the end of the evaluation period, S_1 is opened, and the value of the capacitor voltage, and amplifier output voltage, will "hold." Amplifier output voltage is now proportional to the average value (or integral) of the input taken over the evaluation interval, and thus the computed bias



The basic circuit for the bias outputs of the TDE. These outputs are obtained by using three dc amplifier-integrator circuits. The computed value is read out at the end of the evaluation interval.

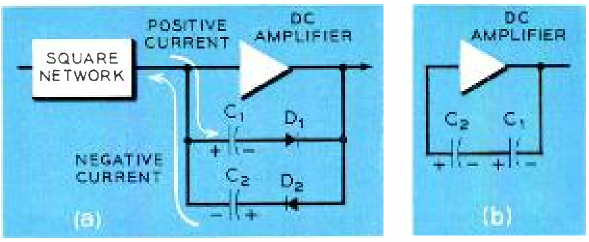


C. C. Willhite (left) and J. W. McIntyre are examining the "square" input network of the Tracking Data Evaluator. TDE standard deviation circuits require instantaneous input voltages to be squared.

may be "read-out." Closing both switches will serve to remove the charge from the capacitor and "reset" the circuit.

The next mathematical operation is finding values of standard deviation, but before discussing the circuits, it is necessary to understand how such a calculation is made. The instantaneous input must be (1) squared, (2) then averaged (or integrated) over an evaluation interval, and finally (3) the square root of this average obtained. So, computing standard deviation requires the mathematical operations of squaring, averaging and extracting the square root.

The electrical form of the input information is sometimes such that it is necessary to remove the dc component. Its nature is also such that little information appears at high frequencies. In fact, the bulk of the information is contained in a frequency band from 0.05 to 2.0 cycles per second. We thus have another "mathematical" operation to perform — that is, sometimes to eliminate information below 0.05 cps and always to eliminate information above 2.0 cps.



(a) Amplifier circuit to compute average square of its input voltage. Capacitors are connected in series with oppositely poled diodes D_1 and D_2. (b) Circuit rearranged to "hold" the squared value.

Three circuits as shown in the diagram at the top of page 19 perform the standard-deviation calculations. The first dc amplifier is a gain-filter circuit that provides the most desirable signal level in the subsequent circuits; it also filters the incoming waveforms to pass energy in the required bandpass region. The second dc amplifier (middle block in diagram) is used in a combination square and average circuit. The third dc amplifier circuit (right-hand block) calculates the square root of the voltage developed at the output of the square and average circuit. The result of these operations is the standard deviation about a mean value of 0.

As indicated, the gain-filter circuit sets a bandpass of 0.05 to 2.0 cycles. This is achieved by R-C filters in the input and feedback circuits of the first amplifier.

The input network of the second amplifier is constructed to give an output current (the input current to the second amplifier grid) proportional to the square of the input voltage. To achieve this, biased diode resistance branches are used to increase the conduction as the input signal increases. Several branches are used to obtain the desired match to a true square function.

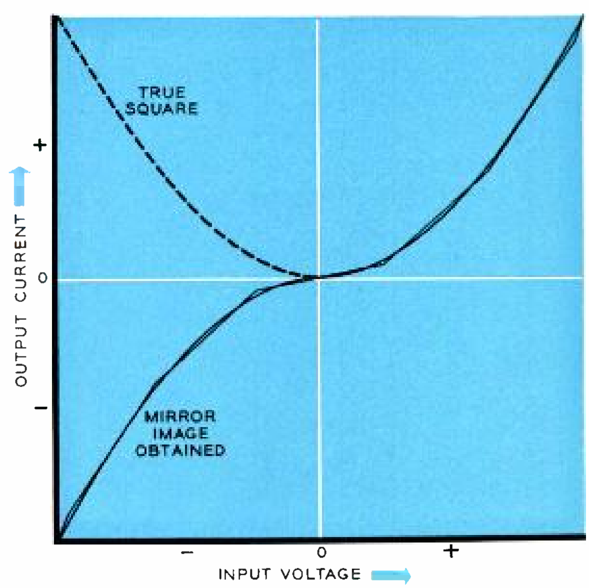
The network contains no active elements, and with the circuit arrangement used, does not provide positive output current for a negative input voltage. The assembly has an input-output characteristic as shown in the accompanying graph, and the type of straight-line approximations is indicated, it essentially makes up a square curve.

If it were not for retaining the minus sign when "squaring" the negative input, the averaging process could be accomplished as in the bias circuit. But in this instance, the modified arrangement shown in the above diagram is used. In the (a) portion of the diagram, two equal-valued capacitors are connected in series with diodes D_1 and D_2. Since the diodes are poled oppositely, only positive current will flow onto C_1 (through D_1) and negative current onto C_2 (through D_2). The high-gain dc amplifier has no difficulty recognizing this type of feedback circuit, so positive input currents will be added on C_1 and negative input currents on C_2, charging the capacitors in the directions indicated. The sum of the absolute voltages of the capacitances will be the total average regardless of the sign of the input voltage.

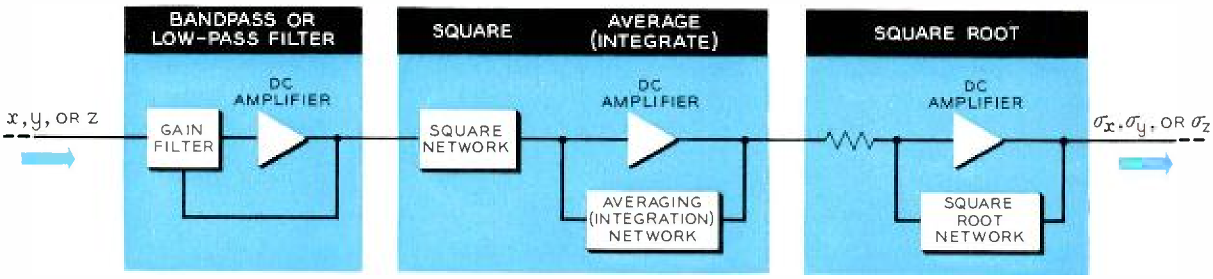
The circuit is connected as shown in (a) during the integration period; however, it must be rearranged for readout, as indicated in (b). During read-out the input is disconnected, the diodes removed, and the capacitors rearranged; this is done with relays.

When rearranged as shown, the amplifier circuit will "hold" at a value of voltage equal to the negative absolute sum of the voltages on the capacitances, and this will be the analog of the average square of the input signals over the evaluation interval. To reset, the capacitances must be discharged and reconnected as in the (a) portion of the diagram.

The square root may be obtained using the third amplifier shown on the next page, once the average of the square of the input information is computed. In this case, a network similar to the squaring network is used, this time in the feedback circuit of a dc amplifier, and it is so arranged as to provide more and more current feedback (and thus less amplifier voltage gain) as the input



The square circuit input-output characteristics, showing the actual graph of straight-line approximations. Output current is approximately the square of input voltage, but minus is retained.



Simplified schematic showing the three dc amplifiers that (left to right): filter incoming waveforms, square and average this information, and derive square root; this yields standard deviation.

signal increases. With this arrangement, the output voltage is proportional to the square root of the input voltage.

This chain of operations thus yields the desired quantity, the standard deviation.

Over-all control of the computing system is maintained by circuits containing two timers and a group of relays. The computing interval is started by a push button, and an accurate timer runs for a preselected 20-, 40-, or 60-second evaluation interval. At "run-out" of the timer, the circuits are rearranged to hold for read-out, and the answers are sent to a recording system. Also, at run-out of the timer, a second timer is started. This second timer runs for a 5-second "read" time and then restores the circuits to a reset condition. The TDE will now either await a new start signal, or start over again, depending on whether or not a "continuous" mode of operation was selected initially.

It is desirable that the data obtained from the equipment be complete, so the records are arranged to indicate other pertinent radar quantities such as radar range and radar signal strength.

The photograph on page 17 shows the actual computational equipment. The twelve dc amplifiers and associated networks are mounted in the rear. Located on the equipment assembly in the middle of the cabinet are the "zero-set" switch and zero-set amplifier that drift-compensate the dc amplifiers. The cabinet holds the accurate timer, and a detector that indicates any abnormally large disturbance that would render the computation void. The control panel is used to set circuit gains and to select the type of operation desired, as well as to introduce test signals.

Circuit arrangements used in the computations are somewhat unusual, although generally not complicated. An example is the frequency and impedance range of the bandpass filter. With a low-pass frequency of 0.05 cps, practical values of components required impedances equivalent to several thousand megohms. (The presence of an unwanted and elusive distributed capacitance of 20 micromicrofarads was causing a 1.0 db loss in transmission at 1 cps).

The Tracking Data Evaluator has been designed to allow automatic evaluation of radar-tracking performance. Using 12 dc amplifiers and other standard electronic components it evaluates the mean and standard deviation of tracking data. It digests information over a 20-, 40-, or 60-second interval, and gives answers in voltage form that are placed on a permanent record. The equipment was designed to aid in a specific radar-evaluation program, and is now being used at White Sands Missile Range. The Tracking Data Evaluator is operating essentially as anticipated, and is a significant aid in the evaluation program.

This type of computer could aid with other radar system evaluations, or where other continuous data needs to be processed. It is not limited to obtaining biases and standard deviations, since straightforward circuits are available or could be developed to yield many other quantities. These might include frequency spectra data on a continuous signal, or percentage of time a signal magnitude is above or below specific reference levels. The output of the device could be fed back, and used to control the features of the signals being examined.

The study of extremely fast electrical pulses requires specialized measuring equipment. For this reason, the Laboratories has developed an experimental system which employs television techniques and a new traveling-wave oscilloscope tube. Here, signals of low amplitude and short duration are displayed in an easily examined form.

A. F. Dietrich

Broad-Band Oscilloscope—An Application

The increasing demand for long-distance transmission circuits in the Bell System has engendered the development of broad-band transmission features such as those employed in the L3 Coaxial and TH Radio systems (RECORD, *January*, 1953; *July* 1957). In the future, new types of radio and waveguide systems may furnish additional broad-band facilities.

Among the interesting possibilities, for instance, are pulse-code modulation systems employing microwave frequencies. These systems would use very short pulses that occur at a high repetition rate and last about 1/1000th as long as pulses employed in World War II radar systems. A modulation system employing a pulse code of eight digits and capable of handling an L3 band would require pulse repetition rates of about 160 million pulses per second. In such a system, timing the regenerative repeaters might require pulses of about one milli-microsecond in length.

Successful studies of pulse systems using very short pulses depend on oscilloscopes having very wide bands. As a consequence, two special tubes — a micro-oscilloscope tube and a later design called the broad-band oscilloscope tube — have been developed at Bell Laboratories (RECORD, *December*, 1958). Both use a traveling-wave deflection system and have bandwidths of approximately 1000 megacycles. Basically, this wide band is due to the helical deflection system which, in effect, equates the velocity of the RF field and the electron beam. The deflection system is essentially a helical tape through the center of which the electron beam passes. Design of the tape is such that each *electron* "sees" the same phase of the *wave* throughout the length of the deflection system. An oscilloscope designed around a tube of this type is a useful tool with sufficient resolving power to make studies on systems employing milli-microsecond pulses.

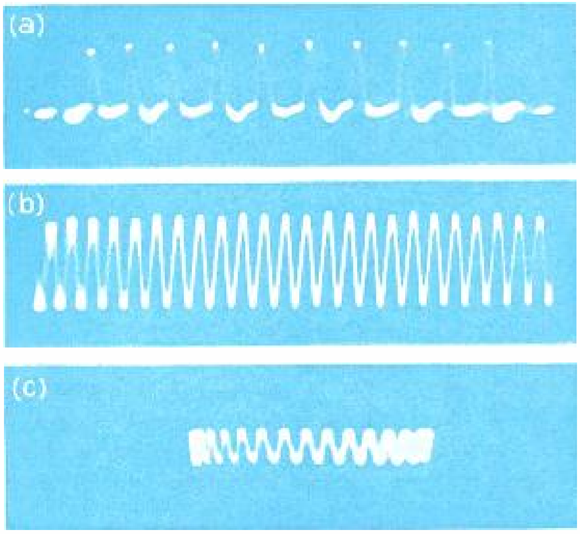
The micro-oscilloscope tube produces a very small image, and a low-power microscope magnifies the trace sufficiently to make it useful. This confines the user directly to the microscope and makes it very difficult for him to adjust the equipment under test while observing the results.

Although the broad-band oscilloscope tube uses the same principles as the micro-oscilloscope tube, the former has a considerably longer drift space between the deflection plates and the fluorescent screen on the face of the tube. Thus, it produces images large enough to be satisfactory for close viewing without the aid of optical enlargement. This presentation, however, also confines the operator closely to the face of the tube. In other words, these new tubes are extremely valuable as research instruments but heretofore they had not been convenient to use.

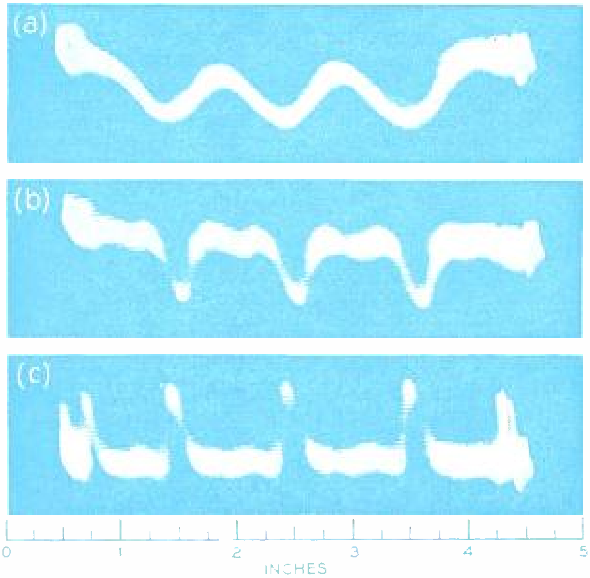
By using television techniques, however, and by televising the image on the face of the broad-band oscilloscope tube, a much larger image can be displayed on the television monitor. Successful operation of a system of this type requires the image on the broad-band oscilloscope to be a steadily recurring display. In this application, the broad-band oscilloscope tube might be regarded as a storage device where information is written in at a very high rate and read out, by television scanning, at a rate of 60 fields (or 30 pictures) per second.

In microwave propagation studies conducted at the Laboratories in 1950, the micro-oscilloscope was invaluable as an indicator in multipath-transmission phenomena. The baseband pulses used in these studies were approximately six milli-microseconds wide at the base and recurred at a rate of 10 million pulses per second. At present, studies are being made on microwave regenerative repeaters with pulse repetition rates of 160 million pulses per second. Timing pulses needed for this system are only two milli-microseconds wide at the base. Bandwidths of 500 megacycles or more are required to reproduce these short pulses satisfactorily.

Part (a) of the illustration below is an enlarged photograph of timing pulses — which occur at the rate of 160 million pulses per second — as seen on the face of the broad-band oscilloscope tube. Even the slight imperfections, caused by a "leakage" of pulses that occur at half this rate, can be clearly seen. Part (b) shows the same group of pulses when applied to a conventional oscilloscope tube where the vertical amplifier in the oscilloscope has a bandwidth of 160 megacycles at the six db down point. Without the use of the broad-band oscilloscope, these studies would be extremely difficult, if not impossible, as shown by the complete loss of pulse detail in part (b). Here, only the fundamental frequency is present.



160 million pps timing pulses as seen on (a) broad-band tube, and (b) conventional tube. Part (c) represents a display of an 800 megacycle sine wave seen on the face of the broad-band tube.



Photograph of the television monitor which shows the effects of the milli-microsecond timing pulses.

Sine-wave frequencies considerably higher than 160 megacycles also have been observed on the broad-band oscilloscope tube. Part (c) is an enlarged photograph of an 800 megacycle sine wave as seen on the tube face. Here the system displays individual cycles of a wave which actually occurs at a rate of 800 million cps.

An experimental setup at the Laboratories, using an industrial television system in conjunction with the broad-band oscilloscope, produces satisfactory pictures when adjusted for an enlargement of eight to ten times. This picture size compares favorably with the size of trace one normally views on a five-inch cathode-ray tube. A person gets a good view of the trace ten feet or more away from the picture monitor, permitting the operator greater freedom in adjusting.

In experimental and industrial applications, television systems have been used as monitors at remote points. With a little additional circuitry, the television signal furnished by the camera chain in the Laboratories system can be used in this same manner. Such a system permits several parallel monitors to be located at different points.

The second illustration is a typical photographic reproduction of the face of the television-monitor picture tube. Part (a) is the detected envelope of an 11-kmc pulse group at the output of the microwave modulator. Part (b) is the detected envelope of the same pulse group after it has been re-timed in an 11-kmc microwave gate by two milli-microsecond baseband timing pulses — shown as part (c). The scale below the reproduction shows the actual size of the pictures on the television monitor.

A self-contained unit has been built to include the broad-band oscilloscope tube, associated sweep circuits, power supplies and the television equipment. The broad-band oscilloscope tube, because of its 20-inch length, is mounted vertically in the cabinet. A mechanical arrangement for an optical switching device uses a mirror inclined at an angle of 45 degrees. This mirror may be rotated about a vertical axis to any one of three positions so that the image on the face of the tube may be either viewed directly, televised or photographed. A magnifying lens is included in the direct-viewing branch to give a two-to-one magnification of the image.

The ten-inch television monitor and the control knob for the optical switch are placed on top of the cabinet. An operator can view the face of the oscilloscope tube through a small opening located in the upper left-hand corner. Sweep-circuit panels, directly below this opening, include sine-wave sweeps from one to fifty megacycles as well as linear sweeps. The sine-wave sweeps can be satisfactorily synchronized to observe an 800 megacycle sine wave. Power supplies are located at the bottom of the cabinet and the television synchronizing unit is mounted at the rear.

The waveform displayed on the television monitor below is a sixteen-times enlargement of a two-milli-microsecond timing wave as it appears on the face of the broad-band oscilloscope tube. Between pulses is a space of four inches; the vertical deflection of each pulse is three inches. The vertical-deflection sensitivity of the over-all system is one volt per inch — a considerable improvement over ordinary cathode-ray tubes.

The broad-band oscilloscope tube, with its inherent 1000-megacycle bandwidth, has thus made possible the pursuit of studies on systems using milli-microsecond pulses. It is now practical for small images produced on the face of the tube to be considerably enlarged with closed-circuit television techniques. A combined unit, employing both the oscilloscope tube and the television system, results in a broad-band oscilloscope capable of resolving a one milli-microsecond pulse. These reproduced, enlarged images compare favorably in size with presentations on a conventional five-inch oscilloscope tube. Now that this system is available, much progress can be made toward building short-pulse microwave regenerative repeaters capable of transmitting information at the rate of over 100 million pulses per second.

C. A. Davison, left, and A. F. Dietrich discuss the more important advantages gained in using television techniques.

Some of the busiest and most versatile switching machines in the Bell System are PBX's. The 756A, newest of the dial PBX's developed at Bell Laboratories, uses modern crossbar circuitry as a basis for its small size, simple operation and diverse communication services.

R. D. Williams

CROSSBAR CIRCUITRY FOR A SMALL PBX

A private branch exchange (PBX), often called simply "a switchboard," functions essentially as a small central office. But because of its location — the customer's premises — the PBX presents a unique challenge in design. The development engineer must make the utility of a central office compatible with the appearance, ease of operation, and small size characteristic of the customer's other office equipment.

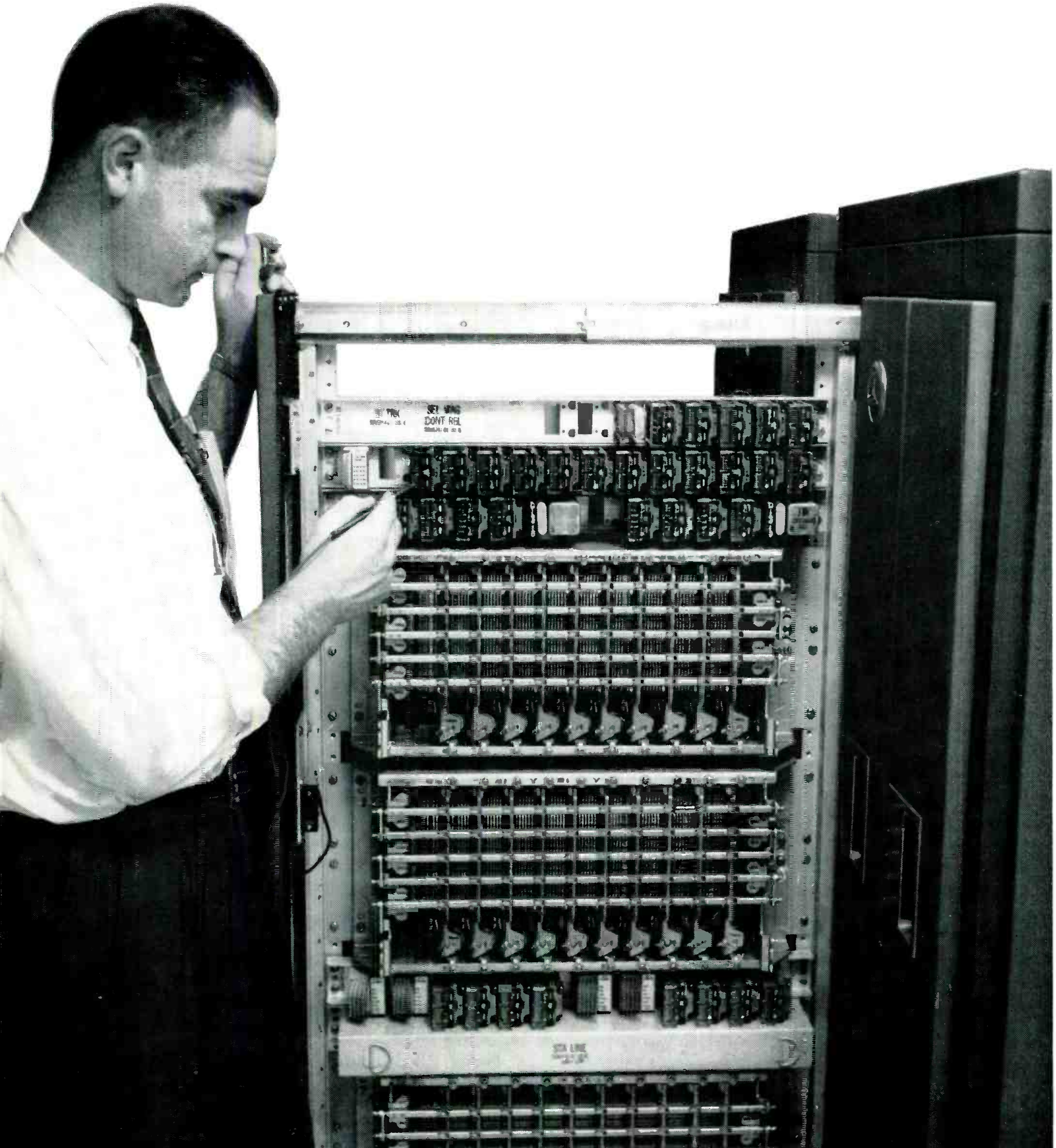
Because it is designed to occupy standard office space, the size and appearance aspects of PBX design assumed more than usual importance in the development of the 756A PBX (RECORD, *December*, 1957). This new dial PBX was designed to serve customers requiring between twenty and sixty extensions and up to ten central-office trunks. It is the smallest "packaged" dial PBX offered to Bell System customers having more than twenty lines. Bracketing the 756A in size are the smaller 755A PBX (RECORD, *June*, 1933) and the next-larger 740E PBX (RECORD, *October*, 1951). Along with the need for compactness and appearance, the system plans called for two other important requisites in the final design of the 756A: (1) reduced operating effort on the part of the attendant, and (2) more versatile communication services.

Engineers at Bell Laboratories studied several different switching arrangements to find a system that would satisfy the size and service requirements of the equipment, and yet be economical. Step-by-step and electronic switching schemes were surveyed, as were several types of crossbar switching. The electronic arrangements that were studied were eliminated for the present because many of the required components would not be available in time for reasonably early production.

The plan that evolved from these studies, and the one that is used in the new PBX, is a crossbar switching arrangement with sixteen links that have full, direct access to all lines, trunks and tie trunks. The 756A uses crossbar switches to form connecting paths through the system, and uses common-control circuits to process the dialed information and to operate the switches that establish the talking path.

The most important of these common-control circuits is the "marker." Like its namesake in the No. 1 and No. 5 crossbar systems, the marker locates the lines of calling stations, tests lines to see if they are "idle" or "busy," locates available links, junctors and trunks, and controls the interconnecting of these elements with the lines. Another important circuit in the common-control group is the "dial-pulse register." Registers are used to count and store dial pulses and to supply dial tone to lines requesting service.

The arrangement of the control and trunk circuits and the crossbar switches is shown in the diagram on page 25, along with the marker



The author checks a control-circuit relay at top of "slide," which contains four crossbar switches. Slides were designed to simplify local maintenance.

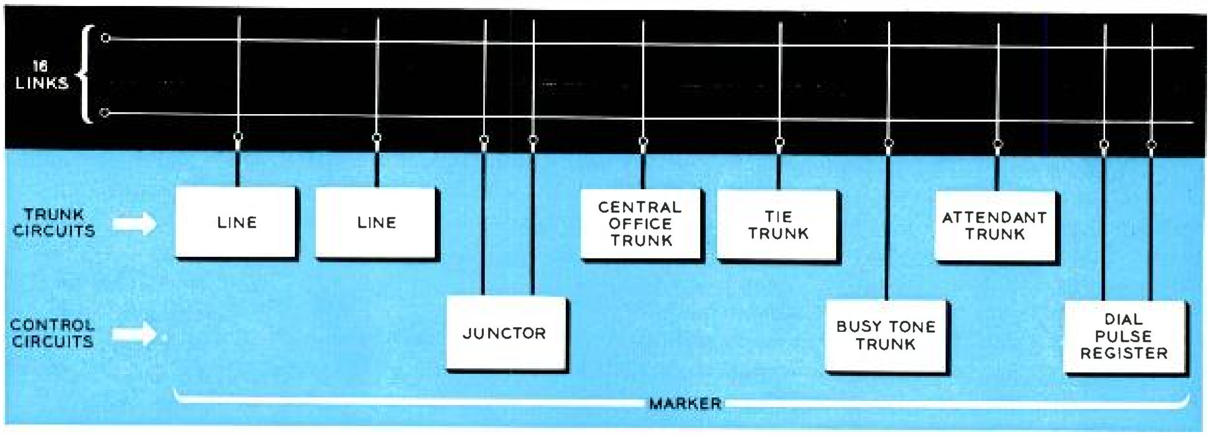


Diagram of linked crossbar switches showing approximate relationship of connecting and control circuits. As diagram shows, all common-control circuits are under the control of one marker.

circuit. Included among the connecting elements are "junctors" which supply ringing and talking power to the connected lines; central-office trunks which connect extension lines or the tie trunks of the PBX to the central office; and attendant trunks that connect tie trunks or extensions to the attendant's console.

The crossbar switches used in the 756A are the conventional ten-by-ten (ten "horizontals" and ten "verticals") switches used in both the No. 1 and the No. 5 crossbar systems. Physically, the crossbar equipment is arranged on sliding racks as shown in the photograph at the left. Electrically, the crossbar switches are wired together as though the entire group of connecting links were one, long crossbar switch with ten horizontals and numerous verticals.

All of the communication circuits that can be connected through the PBX are wired to the verticals. This arrangement permits any of the lines or circuits appearing on the verticals to be connected to any of the other circuits by any of the horizontals. The ten horizontals are wired in a special way that makes available sixteen links.

This method of wiring the crossbar switches, illustrated in the second of the diagrams with this article, is also used in the No. 1 and No. 5 crossbar systems. As the diagram shows, a pair of horizontal paths are wired on each of eight of the ten horizontals. The two remaining horizontals are used to control which one of the pair of paths is used. This wiring arrangement increases the number of available crosspoints per crossbar switch from 100 (10 x 10) to 160 (16 x 10). These 16 horizontal paths carry all the calls through a 756A PBX.

Despite the compactness of the equipment, all of the circuits for the new PBX were designed to work as simply and independently as possible. At the same time, the circuits provide adequate assurance of reliable operation in spite of such troubles as dirty relay contacts and false connections between adjacent terminals. Maintenance on the customer's premises was the important consideration in stressing simplicity and reliability in the circuit design.

The 756A PBX, like the smaller 755A, has only a single marker to set up all calls. Where so many lines and trunks are controlled by a single circuit, however, safeguards must be provided to insure continuous service. One safety feature in the circuits is the provision of enough access channels to prevent a single trouble from affecting service to more than ten station-lines.

In the marker, the vital portions of the circuit are furnished in duplicate and function in parallel. A failure in any of the vital parts of the marker will cause an alarm, but the duplicate part of the circuit will complete the call. Specifically, if any of several relays important in the operation of the marker fail to operate, another relay will operate to perform that function. Any relay failure will cause an alarm.

A "second trial" feature is also included in the PBX. This means that if the marker finds improper continuity in a connection being set up, the connection is released and another attempt made to establish it by using a different link and a different trunk or junctor. If the call cannot be completed on the second attempt, the marker will connect the calling line or trunk to busy tone.

After the second trial, the marker releases and serves other waiting calls, even if the call cannot be completed to busy tone. Troubles, such as the failure of a marker relay to operate, must occur on two successive uses of the marker before the trouble alarm is operated. This arrangement prevents momentary troubles from causing unnecessary alarms.

Although it is one of the smallest PBX's, the 756A offers customers all of the usual PBX services. With a dial PBX, customers connected to the system can avail themselves of a number of services by dialing a predetermined one- or two-digit code. These services include station-to-station calls, calls to other PBX's connected by tie trunks, calls to and from the telephone central office, dial conferences, paging, code calling, telephone dictation, recorded announcements and "class-of-service" treatment of the lines.

In addition to these many station features, the 756A PBX is outstanding in its small, modern, easily operated facilities for the attendant. The PBX attendant's principal job is to handle calls incoming from the central office. Each call appears at the attendant's console (*see photograph on opposite page*) as a lamp signal with an auxiliary ringing signal. She answers the call by pressing the "pick-up" button near the lighted lamp.

To complete an incoming call to an extension, the PBX "operator" merely presses the "hold" button, and then dials the two-digit number of the called telephone. She disconnects by pressing the pick-up button of another trunk, or if no call is waiting, she disconnects by pressing the common "release" button. The connection is automatically released when the parties hang up.

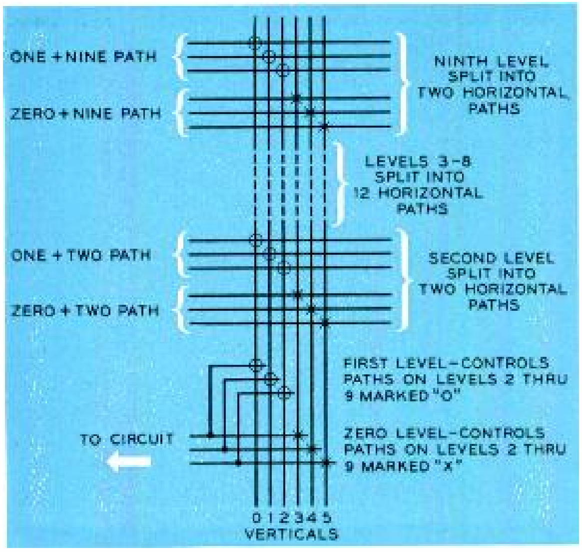


Diagram showing how 10 horizontals are arranged to form (and control) sixteen links. Crosspoints on Level 0 or Level 1, as well as those on Levels 2 through 9, must be energized to complete a connection through the switch.

The central-office trunks of the 756A are arranged for "delayed-through supervision." This means that on a call which has been completed by the attendant, the PBX customer can recall her to the connection by "flashing" the switchhook. This flashing will not cause a disconnect signal to be transmitted to the central office. A single operation of the switchhook will cause the trunk to flash a lamp at the attendant's position at 120 interruptions per minute, and will also sound an audible "recall" signal at the console.

On toll calls made from a PBX, toll operators sometimes have occasion to "ring back." The 756A is arranged so that a ring back on calls originated without assistance from the attendant will signal the calling station. If the attendant was involved in originating the call, the ring back will call in the attendant. The attendant can then re-supervise the call or write a "ticket" for it.

The attendant's console of the 756A PBX has a minimum of controls. The hold button, operated to call in dial tone to complete a call into the PBX, is also arranged to release the inward connection in case a dialing error was made or a different station is desired by the trunk.

In a sense, this operation is similar to the floor switch that changes the headlights from high to low in an automobile. The first operation connects the attendant inward to the PBX; the next time the button is pressed the inward connection is released; the next operation again connects the attendant inward, and so on. The state of the call (and the button) at any given time is easily determined by the lamp signals and the audible tones at the console.

Another arrangement that simplifies the attendant's console is the automatic establishment of a "split" connection when the attendant connects a trunk to one of the lines of the PBX. With a split connection, she can announce the call to the station without the outside party "listening in." If the attendant does not want a split connection, she momentarily disconnects, and on returning to the call she is bridged on the connection between the trunk and the station. This feature avoids extra control buttons on the console for arranging split or bridged connections.

A new service of particular interest to customers is "camp-on." If the attendant, in extending an incoming call to a PBX line, finds the line busy, the circuits will automatically camp-on the busy line. The held call will then automatically "cut-through" to the busy line as soon as it becomes idle.

Aside from assuring the calling customer a

Mrs. H. Kuhl demonstrates how an attendant releases an incoming call by pressing the "RELEASE" key. Additional six-key modules may be added to this new PBX console unit.

priority on the busy line and reducing his holding time to a minimum, the camp-on feature frees the attendant to handle other calls and automatically does the job of monitoring incoming calls that are held. A lamp flashes once every second to advise the attendant that the call has not yet been completed, and she in turn can make reports to the calling party.

If the attendant finds a line busy, and another call camped-on as well, she receives an indication of this situation by a two-per-second lamp flash. She then informs the customer that someone is already waiting. If the customer so requests, she completes the call to another station or she holds the call with the regular hold button and puts it through later.

The circuits that make possible the camp-on arrangement use three different potentials on the "sleeve" leads of the crossbar links. The link-test connector circuit places —48 volts on the sleeve leads of all links. All idle links have the same potential, —48 volts, on them, but the busy links will have only about —5 volts. When the marker is attempting to establish a camp-on call, it places a direct ground on the sleeve lead of the called line. This ground also appears on the sleeve lead of the connected link.

In this way, the link-test circuit locates the one link which is grounded from among those which have either —5 volts or —48 volts connected to them. The marker then connects the calling trunk to the proper link and establishes a "camp-on" condition in the trunk. A diode sensing-circuit in the trunk monitors the link and completes the camped-on call as soon as the established call is terminated.

The 756A PBX provides three classes of service. These are (1) "restricted," (2) "toll denied" and (3) "toll allowed." Restricted stations are prevented from placing calls to central-office trunks except with the assistance of the attendant. These stations may also be restricted from tie trunks to other PBX's if desired.

A toll-denied station, on the other hand, may dial central-office calls direct by first dialing "9" to get "outside" dial-tone. As the name implies, toll-denied telephones may not dial long-distance calls. This calling privilege is reserved for toll-allowed stations, which have complete freedom to dial all types of calls. Classes of service are easy to install or change, since they appear as simple, bare-wire "straps" on terminal strips.

A prototype model of the 756A PBX has performed very well in a trial installation in Cleveland, Ohio. Production is now well under way, and a number of 756A PBX's are being installed.

J. B. Fisk Elected President of Laboratories

M. J. Kelly, Chairman of the Board

E. I. Green, Executive Vice President

Dr. James B. Fisk, Executive Vice President of Bell Telephone Laboratories, was elected President of the company at a December meeting of the Board of Directors. Dr. Fisk assumed his new post on January 1.

Dr. Fisk succeeds Dr. Mervin J. Kelly, who was elected Chairman of the Board. Dr. Kelly served as President of the Laboratories since 1951.

The Board also named Estill I. Green to become Executive Vice President, effective January 1. Mr. Green now has responsibility for all Laboratories development and design work for the Bell System, and continues to be in charge of systems engineering. Vice Presidents M. H. Cook, W. A. MacNair and J. A. Morton report to Mr. Green.

J. B. Fisk

Dr. Fisk, who has been associated with Bell Laboratories for nearly twenty years, has combined a distinguished career in industrial research with outstanding service to the government in the field of science.

In the summer of 1958 he served as chairman of the Western delegation at the Geneva Conference to study the possibility of detecting violations of a possible agreement on the suspension of nuclear tests. He was director of the Division of Research of the Atomic Energy Commission in 1947-48, and Gordon McKay Professor of Applied Physics at Harvard University in 1948-49. He also served for six years on the General Advisory Committee of the Atomic Energy Commission. He is vice-chairman of President Eisenhower's Science Advisory Committee and he has also served on other government committees.

Dr. Fisk joined the technical staff of Bell Laboratories in 1939. During World War II he headed the Bell Laboratories group engaged in developing microwave magnetrons for high-frequency radar. After the war he was in charge of electronics and solid-state research. In 1949, when he returned to the Laboratories from the Atomic Energy Commission and Harvard, he was placed in charge of research in the physical sciences. He became Vice President in charge of research in 1954, and assumed the post of Executive Vice President in 1955.

Dr. Fisk received the bachelor's and doctoral degrees from Massachusetts Institute of Technology in 1931 and 1935, respectively. From 1932

J. B. Fisk

to 1934 he was a Proctor travelling fellow at Cambridge University (England), and from 1936 to 1938 was a junior fellow in the Society of Fellows at Harvard. He also served as Associate Professor of Physics at the University of North Carolina.

Dr. Fisk has been awarded honorary Doctor of Science degrees by Carnegie Institute of Technology (1956) and by Williams College (1958). He is a fellow of the American Physical Society, the American Academy of Arts and Sciences and the Institute of Radio Engineers, and was formerly a senior fellow of the Society of Fellows at Harvard. He is a member of the National Academy of Sciences and of a number of other scientific and professional societies.

M. J. Kelly

Dr. Kelly is one of the nation's leaders in the field of industrial research. He began his Bell System career in 1918 as a research physicist with the research division of the Western Electric Company's engineering department. This department was later incorporated as Bell Telephone Laboratories.

After serving as director of vacuum tube development and as development director of transmission instruments and electronics, he was named Director of Research in 1936. He became Executive Vice President in 1944 and President of the Laboratories in 1951.

Dr. Kelly has had wide experience not only in research and development programs relating to communications, but also in projects for the Armed Forces. In the course of World War II, Bell Laboratories converted almost completely to military research and development programs, all of which were under Dr. Kelly's guidance. In recognition of his World War II contributions, he was awarded the Presidential Certificate of Merit.

Since the war he has held many public service assignments in Washington, particularly with the Atomic Energy Commission, the Department of Commerce and the Department of Defense. He is a member-at-large of the Defense Science Board. Among his many honors are the Air Force Exceptional Service Award and the 1953 Trophy of the Air Force Association, awarded "for distinguished service to air power in the field of science." He has been named to receive the 1959 John Fritz Medal for "his achievements in electronics, leadership of a great industrial research laboratory, and contributions to the defense of the country through science and technology." He has also received the Medal of the Industrial

M. J. Kelly

E. I. Green

Research Institute and the Christopher Columbus International Communication Prize.

Dr. Kelly is also active in the field of education. He is a Life Member of the Massachusetts Institute of Technology Corporation, and is a member of its Executive Committee; a trustee of Stevens Institute of Technology; and serves on advisory committees at M.I.T., New York University, Case Institute of Technology, Columbia University, and the New York City Board of Education. He is also a member of the New York City Health Research Council. He is a trustee and member of the corporation of Atoms for Peace Awards and is a trustee of the Alfred P. Sloan Foundation.

Dr. Kelly received the B.S. degree in 1914 from the Missouri School of Mines and Metallurgy, the M.S. degree in 1915 from the University of Kentucky, and the Ph.D. from the University of Chicago in 1918. He has been awarded eight honorary doctorates by American and European universities in recognition of his distinguished contributions in the fields of science and defense.

Dr. Kelly is a member of the National Academy of Sciences and is a fellow of the American Physical Society, the Acoustical Society of America, the Institute of Radio Engineers, and the American Institute of Electrical Engineers. He is also a member of the American Philosophical Society and a Foreign Member of the Swedish Royal Academy of Sciences, and is associated with many other scientific and professional societies.

Dr. Kelly has served on the Board of Directors of Bell Laboratories since 1944. In addition, he is a Director of the Sandia Corporation, The Prudential Insurance Company of America, and the Bausch and Lomb Optical Company. He is also a Director of the Economic Club of New York.

E. I. Green

Mr. Green has a long record of distinguished engineering experience and achievement, including more than 70 patents granted for his inventions. He is also the author of many articles on scientific and personnel subjects.

He began his telephone career in 1921 with the American Telephone and Telegraph Company's development and research department, and with that department transferred to Bell Laboratories in 1934. For many years he specialized in planning the development of new transmission systems, and services and facilities for special customers. During World War II he was engaged in development work on radar testing apparatus and other electronic equipment.

He was appointed director of transmission apparatus development in 1948 and headed the development of systems components, including electronic components for transistorized systems. In 1953 he was named director of military communications systems, in charge of planning and development in that area. He became Vice President in charge of systems engineering in June 1955. In that post he has been responsible for all Bell Laboratories work related to the systematic analysis and planning of future communications developments and systems.

Mr. Green received the B.A. degree from Westminster College, Fulton, Mo., in 1915 and the B.S. degree in electrical engineering from Harvard in 1921. Westminster awarded him the honorary Doctor of Science degree in 1956. He is a fellow of the American Institute of Electrical Engineers and of the Institute of Radio Engineers, and is a member of the Acoustical Society of America, the American Physical Society, the Operations Research Society of America, and the American Association for the Advancement of Science.

news notes

Wayne State University Honors J. A. Morton

J. A. Morton, Vice President — Device Development, was recently honored by Wayne State University's College of Engineering with a "Distinguished Alumnus" citation. The citation recognized Mr. Morton's "outstanding achievements and . . . his contribution to the advancement of the field of engineering."

Mr. Morton is a 1935 graduate of Wayne State, which previously awarded him an honorary doctorate degree.

Six Members of Bell Laboratories Named Fellows of the I.R.E.

Six staff members of Bell Laboratories, two retired engineers and one now with the Western Electric Company have been named Fellows of the Institute of Radio Engineers. The grade of Fellow is the highest membership rank in the I.R.E. It is bestowed only by invitation on those who have made outstanding contributions to radio engineering or allied fields. The new Fellows were named by the I.R.E. Board of Directors at a meeting in Atlanta, November 18.

I.R.E. Sections will present the awards in areas where the recipients reside. Recognition of the awards will be made at the I.R.E.'s Annual Banquet March 25 in New York City during the 1959 National Convention.

Members of the Laboratories and their citations are:

• J. M. Barstow: "For contributions to the transmission of monochrome and color television." He is Television Systems Engineer in the Transmission Engineering I Department.

• J. M. Early: "For contributions in the development of high-frequency transistors." He is Semiconductor Device Development Engineer in the Transistor Development Department.

• D. K. Gannett: "For contributions to the transmission of television and sound broadcasting signals." He is in the Transmission Studies Department.

• R. E. Graham: "For contributions in the field of radar tracking systems and television research." He is Visual Research Engineer in the Visual and Acoustics Research Department.

• A. W. Horton Jr.: "For contributions to long-distance telephony, electronic switching and military electronics." He is Technical Relations Manager.

• Sidney Millman: "For contributions in the fields of magnetrons, traveling-wave amplifiers and backward-wave oscillators." He is Director of Physical Research at the Laboratories.

A. E. Anderson, former Director of Development at the Allentown Laboratory and now with the Western Electric Co. at Allentown, and retired Laboratories engineers R. D. Parker, who retired in 1947, and Eugene Peterson, who retired in 1954 were also named Fellows.

F. H. Blecher Receives Prize

The I.R.E. Board of Directors also named F. H. Blecher, of the Transmission Systems Development Department, as winner of the 1959 Browder J. Thompson memorial prize. This award, which will be presented to Mr. Blecher at the March 25 banquet, is given annually to an author under 30 who has written an I.R.E. paper combining the best technical contribution and presentation. Mr. Blecher's paper, "Design Principles for Single Loop Transistor Feedback Amplifiers," appeared in the September, 1957, issue of the *I.R.E. Transactions on Circuit Theory.*

This is the second consecutive year that a member of the Laboratories has won the prize. A. Karp, now on educational leave to study at the Cambridge University Engineering Laboratory in England, won the 1958 award for his paper on "Backward-Wave Oscillator Experiments at 100 to 200 Kilomegacycles" which appeared in the April, 1957, *Proceedings of the I.R.E.*

U. S. Berger Is Chairman of New I.R.E. Subsection

U. S. Berger, Assistant Director of Development at the Merrimack Valley location of Bell Laboratories, was recently elected Chairman of the Merrimack Valley Subsection, Institute of Radio Engineers.

The newly-formed subsection serves the areas of northeastern Massachusetts and southeastern New Hampshire.

E. B. Ferrell Named Honorary Professor

E. B. Ferrell, Director of Communications Techniques Research at Bell Laboratories, was recently made an Honorary Professor of Applied and Mathematical Statistics at Rutgers University. In this position, Mr. Ferrell will advise faculty members on curriculum development in the field of applied and mathematical statistics, and will serve as a consultant on statistical methods and their application in industry.

Members of Bell Laboratories who have previously been similarly honored by the University are W. A. Shewhart, P. S. Olmstead and H. F. Dodge.

F. R. Kappel Speaks on "Private Enterprise and Public Affairs"

Any business with a good competitive product to sell must have the freedom to make itself financially strong, A. T. & T. President Frederick R. Kappel told members of the Bond Club of New York recently.

This statement headed a list of four factors Mr. Kappel said he felt were important to the nation's economic health and the welfare of its people.

"We must not and we cannot let up in our efforts to bring about *real* gains in productivity," he gave as the second factor. This means industry has a very real need to increase its research and development work, including basic research, he added.

"The continuous hiking of wages beyond real gains in productivity," his third factor, "is sure to intensify inflation. As industry makes such gains, everyone ought to share the benefits. However, if wage increases absorb them all — and more besides — not only is sharing impossible, we are living beyond our means and in the long run no one will benefit."

"Fourth on my list," Mr. Kappel said, "we have this tremendous pressure for government spending; and at the same time, a disposition on the part of many people in government to put more and more restrictions on business."

"Nowadays everybody talks about inflation, but few of the efforts to do something about it have had conspicuous success," Mr. Kappel continued. "Ideally, if inequities in taxation were eliminated or minimized, the overall tax burden on business reduced, and individual incentives restored, I think gains in productivity would accelerate, we would have much less inflation of prices, real wages would increase, business would do more business, and government revenues would be greater."

"Government is just full of able, hard-working and reasonable men who have much the same fundamental thoughts," Mr. Kappel continued. "As a practical matter, however . . . it is difficult for them to act always as they would most deeply and personally desire. And I think we in business have added to their difficulties by failing to expose ourselves, our ideas and the facts at our command in ways that win widespread belief."

"What then should we in business be doing about these things?"

"Number one in our business — and I assume in any business — is that we simply must do the best possible job for the people we serve. But doing our best is not enough. We must also tell our story convincingly in every community." Also, Mr. Kappel said, "Let us once and for all get over the habit of going to people in government when we need something, and ignoring them when we have nothing to ask for. Let's never ignore them — and I mean never.

"While I am dead against corporations engaging in partisan support of candidates," Mr. Kappel concluded, "I certainly think we should do the most we can to discuss policies and issues and call attention to their impact."

Members of Laboratories Active in A.I.E.E. For the 1958-1959 Year

A number of Laboratories people are serving the American Institute of Electrical Engineers in official capacities for the year 1958-1959.

Board of Directors, J. D. Tebo. General committees: Professional Development and Recognition, R. A. Heising (retired) Chairman, H. A. Affel (retired); Board of Examiners, R. A. Heising (retired), E. C. Molina (retired), F. J. Singer, J. D. Tebo, H. M. Trueblood (retired); Edison Medal and Finance, J. D. Tebo; Prize Awards, W. Keister, J. Meszar; Safety, L. S. Inskip, and A. B. Haines, Division Liaison Representative; Standards, R. D. deKay; Publications, E. I. Green, J. D. Tebo; Periodicals and Transactions, W. H. MacWilliams, Jr.; Special Publications, P. B. Findley (retired); Planning and Coordination, R. A. Heising (retired); Professional Conduct, H. A. Affel (retired), Chairman; Research, J. Meszar, J. D. Tebo; Education, R. M. Bozorth; Recognition Awards, J. Meszar; Technical Operations, J. Meszar, J. D. Tebo, D. E. Trucksess, W. H. MacWilliams, Jr.

Technical Committees: Communication Division Committee, J. Meszar, Chairman, L. G. Abraham, H. A. Affel (retired), D. T. Osgood; Communication Switching Systems, H. F. May, Vice-Chairman, A. E. Joel, W. Keister, R. S. Neikirk; Automation and Data Processing, W. T. Rea, W. Keister; Man-Machine Integration, W. H. MacWilliams, Jr., Chairman; Communication Theory, L. G. Abraham, W. R. Bennett, W. A. Depp; Data Communication, R. M. Gryb, L. A. Weber, A. L. Whitman; Radio Communication Systems, P. T. Sproul, Vice-Chairman (and Liaison Representative on Standards Committee), W. W. Sturdy; Military Radio Systems Subcommittee, W. W. Sturdy, Chairman; Telegraph Systems, W. Y. Lang, R. B. Shanck (retired); Printing Telegraph Subcommittee, W. Y. Lang, Chairman, R. B. Shanck; Television and Aural Broadcasting Systems, H. J. Fisher; Wire Communication Systems, D. T. Osgood, Chairman, L. R. Montfort; Special Instruments and Auxiliary Apparatus, S. J. Zammataro; Ground Resistance Subcommittee, W. C. Ball; Fundamental Standards Subcommittee, S. J. Zammataro; Protective Devices, J. B. Hays, Jr.; Fault Limiting Devices Subcommittee, J. B. Hays, Jr.; Lightning Protective Devices Subcommittee, D. W. Bodle; Insulation Life Subcommittee, E. E. Aldrich (alternate), and L. W. Kirkwood, Working Group on Insulation Requirements for Specialty Transformers; Science and Electronics Division Committee, D. E. Trucksess, Chairman, R. M. Bozorth, A. B. Haines; Basic Sciences, R. M. Bozorth, V. E. Legg; Electric Circuit Theory Subcommittee, J. T. Bangert; New Concepts Subcommittee, V. E. Legg; Computing Devices, B. D. Holbrook, W. H. MacWilliams, Jr., W. W. Sturdy; Digital Computer Comparisons Subcommittee, W. H. MacWilliams, Jr., Chairman, E. G. Andrews, R. W. Hamming, B. D. Holbrook; Gaseous Insulation Subcommittee, T. B. Jones, K. B. McAfee, Jr.; Electrical Insulation Liaison Representative to Standards Committee, D. R. Brobst; Electronics, S. B. Ingram, W. J. King, L. W. Kirkwood, D. E. Trucksess; Hot Cathode Converters Subcommittee, D. H. Smith, D. E. Trucksess; Electronics Transformers Subcommittee, L. W. Kirkwood, Secretary.

Magnetic Amplifiers, A. B. Haines, Chairman, P. L. Schmidt, Secretary, D. Katz; Applications Subcommittee, D. Katz, Chairman, E. J. Alexander; Definitions Subcommittee, D. Feldman, Chairman, D. H. Smith, Secretary, T. G. Blanchard, A. B. Haines; Materials Subcommittee, J. R. Conrath, P. L. Schmidt, F. F. Siebert; Planning Subcommittee, A. B. Haines, Chairman, P. L. Schmidt, Secretary, D. Katz; Theory Subcommittee, H. L. Goldstein, A. B. Haines; Combined Magnetic and Controlled Semiconductor Devices Subcommittee, E. J. Alexander, H. L. Goldstein, P. L. Schmidt; Semiconductor Metallic Rectifiers, J. Gramels, D. E. Trucksess; Administrative Subcommittee, J. Gramels, D. E. Trucksess; Components Subcommittee, J. Gramels Chairman; Service Subcommittee, P. L. Schmidt; Standards Group, J. Grammels.

Intersociety Representatives—Engineering Foundation Board, E. I. Green; Engineers Joint Council Board of Directors, J. D. Tebo, E. I. Green (alternate); Hoover Medal Board of Award, O. E. Buckley (retired) National Bureau of Standards Advisory Committee, Ralph Bown (retired).

A New Correcting Code For Bursts of Errors

A new error-correcting code, developed by D. W. Hagelbarger of the Communications Techniques Research Department, shows promise of correcting bursts of errors in digital data being transmitted over telephone lines. Bursts of errors frequently result when lightning flashes and other electrical disturbances cause static and noise on communication lines. The terminal equipment required for this new code is simple and inexpensive, and synchronization is relatively easy to maintain.

Previous error-detecting and correcting codes either could not handle adjacent (consecutive) errors, or required complicated terminal equipment and presented difficult synchronization problems. The new code is applicable to systems where the data must be accepted and delivered continuously, as well as systems where the data is organized in blocks.

Error-correcting systems are not required in the transmission of analog signals such as speech or television, because these signals have high degrees of redundancy which reduces the detrimental effect of errors. However, in data-transmission systems, such as Dataphone (RECORD, *April*, 1957; *September*, 1957; *April*, 1958), the transmitted information is in digital form, so mutilation of a single digit could throw a complete set of data in doubt. In this type of transmission, bursts of errors could be critical, and correction methods become an essential part of transmission equipment.

Terminal equipment using the new code can be designed to handle practically any length of error burst which system analysis indicates is required. In general, the shorter maximum burst-lengths require smaller and simpler terminal equipment. Also, a short burst-length will result in less "guard space," or "clean-data section," which must follow the burst before another group of errors can be corrected. For example, after any burst equivalent to six digits or less, a 19-digit errorless guard space is required to prepare the decoder for correcting another burst of errors.

In its simplest form, the coding system uses alternate binary data digits and check digits, giving a redundancy of one-half. Such a system, designed to correct error bursts of length six (three data digits and three check digits) or less, operates in the following manner. The data digits enter the "encoder" and are shifted through a seven-position register. At each shift, a check digit is computed to make the sum of the data digits in the 1st and 4th positions and the check digit even (zero or two). This check digit is transmitted soon after it is computed and just before the data digit from the seventh position; data and check digits emerge on the transmission line alternately, forming the coded message.

At the receiving end of the line there is a "decoder" in which the message is separated into check and data digits — the decoder checks the relation between digits for the "evenness" described above. After establishing that an error exists in a data digit, the equipment changes the digit as it is shifted through the register.

The redundancy of these codes can be reduced, or they can be used to correct for bursts longer than six without difficulty. But to do so, engineers must build

NEWS NOTES (CONTINUED)

more costly terminal equipment. Furthermore, the error statistics of the transmission system must be compatible with an increase in the length of the guard space. The new decoder also can be equipped to detect bursts of errors longer than those it is designed to correct. For instance, a code to correct error bursts of length six can detect all but seven of the 512 possible bursts of length nine or less.

Laboratories engineers are evaluating the new code under transmission-line conditions. Their initial results indicate substantial improvement in code redundancies of one-half and one-quarter. This program will continue to examine various combinations of burst length and redundancy to determine the best choices for more accurate data transmission.

W. McMahon Named To Insulation Group

W. McMahon of the Chemical Research Department has been appointed Vice Chairman of the Conference on Electrical Insulation. This group is a unit of the National Research Council's Division of Engineering and Industrial Research.

C. L. Luke to Serve Analytical Chemistry

C. L. Luke of the Chemical Research Department has been named to the Editorial Advisory Board of *Analytical Chemistry* magazine. The magazine, which has an international reputation in the field of chemical analysis, is a monthly journal published by the American Chemical Society.

PATENTS

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

Abbott, H. H. and Williams, R. D. — *Telephone System Involving the Dialing of Extension Stations at a Cordless PBX* — 2,855,463.

Blake, J. T. — *Frequency Indication System* — 2,857,566.

Burton, E. T. — *Delay Circuits* — 2,861,181.

Carter, H. T. — *Holding Arrangement for Universal-Type Line Circuit* — 2,862,062.

Cook, J. S., Kompfner, R. and Poole, K. M. — *Non-Reciprocal Wave Transmission* — 2,860,278.

Crowley, J. C. — *Suppression of Arcing in Wave Guides* — 2,860,244.

David, E. E., Jr. and McDonald, H. S. — *Artificial Reconstruction of Speech* — 2,860,187.

DeMotte, F. E. — *Matrix Translator* — 2,856,597.

Doherty, W. H. — *Electrical Conductor Having Transposed Conducting Elements* — 2,859,272.

Dunlap, K. S. — *Communication Switching Network* — 2,859,283.

Dunlap, K. S. and Taylor, J. P. — *Communication Switching Network* — 2,859,282.

Fagen, M. D. — *Ultrasonic Acoustic Wave Transmission Delay Lines* — 2,859,415.

Feldman, C. B. H. and Norwine, A. C. — *Derivation of Vocoder Pitch Signals* — 2,859,405.

Fuller, C. S. and Tanenbaum, M. — *Fabrication of Semiconductive Devices* — 2,861,018.

Gerkensmeier, O. F. and Spack, E. G. — *Two-Speed Pulse Generator* — 2,857,529.

Hall, A. D. — *Transistor Decade Counter* — 2,860,258.

Hall, O. C. — *Alarm Sending Circuit* — 2,859,285.

Haring, H. E. and Taylor, R. L. — *Electrolytic Capacitors* — 2,862,157.

Hefele, J. R. — *Television Transmission Channel Sharing System* — 2,860,186.

Hefele, J. R. — *Line Amplifier for a Television System* — 2,861,124.

Henning, H. A., Murphy, O. J., and Teager, H. M. — *Magnetic Drum Computer* — 2,855,146.

Hoover, C. W., Jr. — *Light Position Indicating System* — 2,855,539.

Hoover, C. W., Jr. and Ketchledge, R. W. — *Beam Positioning System* — 2,855,540.

Hopper, A. L. — *Compensated Plate Type Limiter* — 2,861,185.

Hose, R. H. — *Public Coin Telephone Station* — D-183,985.

TALKS

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

CONFERENCE ON MAGNETISM AND MAGNETIC MATERIALS, Philadelphia, Pa.

Alley, R. E., Jr., *In-Pile Measurements of Radiation Effects in Magnetic Materials.*

Baldwin, J. A., Jr., and Rogers, J. L., *Inhibited-Flux — A New Mode of Operation of the Three-Hole Memory Core.*

Bobeck, A. H., and Fisher, R. F., *A Reversible, Diodeless Twistor Shift Register.*

Fisher, R. F., see Bobeck, A. H.

Fox, A. G., *Principles of Ferrite Amplification.*

Geller, S., see Gilleo, M. A.

Gilleo, M. A., and Geller, S., *Magnetic-Ion Interaction in* $Gd_3Mn_2Ge_2GaO_{12}$ *and Related Garnets.*

Gilleo, M. A., and Mitchell, D. W., *The Magnetic Properties of Substituted Manganese-Tin Spinels.*

Gyorgy, E. M., and Hagedorn, F. B., *Uniform Rotation in Ferrite Toroids.*

Hagedorn, F. B., see Gyorgy, E. M.

Hagedorn, F. B., *Partial Switching of Thin Permalloy Films.*

LeCraw, R. C., and Spencer, E. G., *Spin Wave Damping and Intrinsic Losses in Ferromagnetic Resonance of Yttrium Iron Garnet.*

Looney, D. H., *Recent Advances in Magnetic Computer Elements.*

Martin, R. L., *High Power Effects in Ferrite Slabs at X-band.*

Mitchell, D. W., see Gilleo, M. A.

Rogers, J. L., see Baldwin, J. A.

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

Weiss, J. A., *The Ferromagnetic Amplifier.*

Weiss, M. T., *Microwave and Low Frequency Oscillations Due to Resonance Instabilities in Ferrites.*

OTHERS

Anderson, O. L., *The Adhesion of Metals in Air at Room Temperatures*, A.S.M.E., Syracuse Section, Syracuse, New York.

Anderson, P. W., Matthias, B. T., and Remeika, J. P., *Radical Motions: A Cause of Ferroelectricity*, Conference on the Physics of Dielectrics, Academy of Sciences, Moscow, U.S.S.R.

Aschner, J. F., see Bittmann, C. A.

Benes, V. E., *Type I Counters with Arbitrary Particle Arrivals*, Meeting of the American Mathematical Society, Princeton, N. J.

Bennett, W. R., *Laplace Transforms*, Waveforms and Systems Lecture Series, I.R.E., Professional Group on Circuit Theory, University of Pennsylvania, Philadelphia, Pa.

Bittmann, C. A., Aschner, J. F., Hare, W. F. J., Kleimack, J. J., and Chaplin, N. J., *A Double Diffused Silicon Switching Transistor for High-Current High-Speed Applications*, I.R.E. Professional Group on Electron Devices Meeting, Washington, D. C. (Presented by Kleimack, J. J.).

Budlong, A. H., *Logic and Memory*, Newark College of Engineering, Newark, N. J.

Chaplin, N. J., see Bittmann, C. A.

David, E. E., Jr., *Perception, Puzzles, and Computers*, Radio Station WMUB—Oxford, Ohio.

David, E. E., Jr., *Speech, Hearing, and Communications*, I.R.E. Professional Group on Audio Communication and Broadcast Transmission Systems, Philadelphia, Pa.

Dorff, L. A., *The DEW Line*, University of Michigan, Ann Arbor, Mich.

Early, J. M., *High Frequency Transistors*, Meeting of Central New York Chapter of I.R.E. Professional Group on Circuit Theory, Syracuse, N. Y.

Early, J. M., *High Frequency Transistors*, Electrical Engineering Graduate Seminar, Columbia University, N. Y. C.

Farrow, Mrs. L. A., *Dynamic Nucleation of Domain Walls*, Lehigh University, Bethlehem, Pa.

Feldman, W. L., *Powder Pattern Techniques for Delineating Ferroelectric Domain Structures*, American Physical Society Meeting, Chicago, Illinois.

Fox, A. G., *Ferrite Amplification*, NSIA - ARDC Symposium on Molecular Electronics, Washington, D. C.

Gnaedinger, R. J., Jr., *Some Aspects of the Vacuum Deposition of Metals in Transistor Fabrication*, Fifth National Vacuum Symposium, American Vacuum Society, San Francisco, California.

Goldstein, H. L., *Introduction to the Magnetic Amplifier*, North Carolina Mid-Section Meeting of the A.I.E.E., Winston-Salem, North Carolina.

Hare, W. F. J., see Bittmann, C. A.

Herrmann, G. F., *Parametric Amplifiers*, Physics Department Seminar, New York University, New York City.

Hogg, D. C. and Lowry, L., *Effect of Antenna Beamwidth and Upper-Air Wind Velocity on Fading of 4 kmc Waves Propagated Beyond the Horizon*, U.R.S.I., Meeting (Joint meeting with I.R.E. Professional Groups), University Park, Pennsylvania.

Irvin, J. C., *The Current Status of Solid-State Device Development*, A.I.E.E., Denver Section, Power and Communications Groups, Denver, Colorado.

Kelly, M. J., *Science and Technology—The Servants of Man, with an Analysis of the Basic Research Component*, Robert Kennedy Duncan Memorial Lecture, Mellon Research Institute, Pittsburgh, Pa.

Kelly, M. J., *Science and Technology — The Servants of Man*, Virginia Polytechnic Institute, Blacksburg, Va.

Kleimack, J. J., see Bittmann, C. A.

Legg, V. E., *The Origin and Properties of High Permeability Magnetic Materials*, Thomas A. Edison Laboratory, West Orange, N. J.

Levenbach, G. J., *Life Testing — A Tool for Improving Quality Engineering and Statistical Aspects*, Elmira Section, American Society for Quality Control, Corning, N. Y.

Lowry, L., see Hogg, D. C.

Maggio, J. B., *Engineering as a Career*, Summit High School, Summit, N. J.

Mason, W. P., *Energy Conversion in the Solid State*, Seminar on Advanced Energy Sources and Conversion Techniques, U. S. Department of Defense, Los Angeles, Calif.

Mason, W. P., *Use of Internal Friction Measurements in Determining Dislocation Motions, Fatigue and Fracture in Solids*, Physics Colloquium, U.C.L.A., Los Angeles, Calif.

Matthias, B. T., see Anderson, P. W.

McKay, K. G., *Future Aspects of Solid-State Electronics*, Joint I.R.E.-A.I.E.E. Lecture Series, New York City.

McSkimin, H. J., *Measurement of Ultrasonic Wave Velocities and Elastic Moduli for Small Solid Specimens at High Temperatures*, 56th Meeting, Acoustical Society of America, Chicago, Ill.

Mellor, H. L., *Thermal-Compression Bonded Contacts in Large Area Silicon Diodes*, I.R.E. Professional Group on Electron Devices Meeting, Washington, D. C.

Miller, R. C., *Sidewise 180° Domain Wall Motion in Single Crystal Barium Titanate*, Conf. on the Physics of Dielectrics, Academy of Sciences, Moscow, U.S.S.R.

Monro, S., *Tolerance Problems*, Allentown - Bethlehem Section, American Society for Quality Control, Allentown, Pa.

Moore, E. F., *Variable Length Binary Encodings*, Electrical Engineering Department Colloquium, M.I.T., Cambridge, Mass.

Olmstead, P. S., *Statistical Quality Control in Engineering Research and Development*, 13th Midwest Quality Control Conference, Kansas City, Mo.

Olmstead, P. S., *Operations Research in the American Society for Quality Control*, Scottish Rite Temple, Hamilton, Ontario.

Pearson, G. L., *The Direct Conversion of Solar Energy into Electrical Energy*, Physics Colloquium, National Research Council, Ottawa, Canada.

Pearson, G. L., *The Role of Silicon in Modern Communications; Diffusion Techniques in Semiconductor Technology; Thermistor Devices; Hall Effect as a Research Tool; Magnetoresistance Devices; Photo-processes in Elemental Semiconductors; and Solar Energy Converters*, Semiconductor Devices Seminar, Stanford University, Stanford, Calif.

Pierce, J. R., *The Problems of Communications; Some Examples of Communications Research;* and *Future Possibilities in Communications*, California Institute of Technology, Pasadena, Calif.

Remeika, J. P., see Anderson, P. W.

Ruppel, A. E., *SAGE*, Worcester Polytechnic, Worcester, Mass.

Schawlow, A. L., *Penetration of Magnetic Fields into Superconductors*, Physics Colloquium, University of Toronto, Ontario, Canada.

Sherman, R. E., *Engineering as a Career*, Haverhill High School, Haverhill, Mass.

Simkins, Q. W., *Transistor Circuits for Computer Application*, I.R.E., Professional Group on Electronic Computers Meeting, Minneapolis, Minn.

Suhl, H., *Ferromagnetic Effects*, National Security Industrial Organization, Washington, D. C.

Suhl, H., *The Ferromagnetic Amplifier and Impurity Scattering in Superconductors*, Cornell University, Ithaca, N. Y.

Talley, H. E., *The Principles of Semiconductor Electronics*, Physics Club, Lehigh University, Bethlehem, Pa.

Thorpe, G. A., *Tactical Missile Instrumentation*, North Carolina Section, A.I.E.E., Duke University, Durham, N. C.

Weiss, M. M., *Changing Role of the Scientist in Industry*, The 6th Annual Science and Engineering Career Conference, Hunter College, New York City.

Wolfe, R., *Anisotropic Hall Effect and Magnetoresistance in Semiconductors*, I.B.M. Research Center, Poughkeepsie, N. Y.

PAPERS

Following is a list of the authors, titles, and places of publication of recent papers published by members of the Laboratories.

Baker, R. G., Coatings for Contact Surfaces, *Reliable Electrical Connections 1958—Third EIA*, pp. 219-230, 1958.

Bemski, G., *Recombination Properties of Gold in Silicon*, Phys. Rev., 111, pp. 1515-1518, Sept. 15, 1958.

Bond, W. L., see Geller, S.

Corenzwit, E., see Matthias, B. T.

Darnell, P. S., *History, Present Status and Forecast of Future Needs for Electronic Components*. I.R.E. Trans. on Component Parts, CP-5, pp. 124-129, Sept., 1958.

Dillon, J. F., Jr., *Ferrimagnetic Resonance in Yttrium Iron Garnet at Liquid Helium Temperatures*. Phys. Rev., 6, pp. 1476-1478, Sept. 15, 1958.

Dillon, J. F., Jr., *Magnetostatic Modes in Ferrimagnetic Spheres*, Phys. Rev., 112, pp. 59-63, Oct. 1, 1958.

Feher, G., *Electron Nuclear Double Resonance (ENDOR) Experiments*, Physica, pp. S-80-S-87, June 23-28, 1958.

Garn, P. D., and Gilroy, H. M. (Atomics International), *Determination of Maleic Anhydride in Polyesters*, Anal. Chem., 30, pp. 1663-1665, Oct., 1958.

Garn, P. D., *Diffusion Thermal Analysis*, Supplement to the Engineering of Chem., (Book), Random Publishing Co., 1958.

Geballe, T. H., Herring C., and Kunzler, J. E., *Phonon-Drag Thermomagnetic Effects in n-Type Germanium*, Phys. Rev., 111, pp. 36-57, July 1, 1958.

Geller, S., *Revised Lattice Constants and Powder Pattern for $YFeO_3$*, Acta Crys., 11, pp. 565, Aug., 1958.

Geller, S. and Bond, W. L., *Crystal Structure of Copper Fluoride Dihydrate*, $CuF_2 \cdot 2H_2O$, J. Chem. Phys., pp. 925-930, Oct., 1958.

Herring, C., see Geballe, T. H.

Jahn, A. P., and Vacca, G. N., *Accelerated Aging Tests and Service Performance of Neoprene Jacketed Drop Wire*, Wire and Wire Products, 33, pp. 1178-1285, Oct., 1958.

King, J. C., *Effects of X-Ray Irradiation on the Anelasticity of National and Synthetic Quartz*, 12th Annual Symp., Proc. on Freq. Control, pp. 84-100, Oct., 1958.

Kunzler, J. E., see Geballe, T. H.

Leihr, A. D., *Errata and Some Additional Comments on Critical Study of Vibronic Interaction Calculations*, Canadian J. of Phys., 36, pp. 1588-1589, Nov., 1958.

Locke, W. J., *Microfilm Pushes Drawings Aside*, Product Engineering, 29, pp. 44-47, Oct. 27, 1958.

Mandell, E. R., see Slichter, W. P.

Matthias, B. T., Corenzwit, E., Zachariasen, W. H., *Superconductivity and Ferromagnetism in Isomorphous Compounds*, Phys. Rev., Letter to the Editor, 112, p. 89, Oct. 1, 1958.

Moore, E. F., *Table of Four-Relay Contact Networks*, "Logical Design of Electrical Circuits," App. III, pp. 195-216, McGraw-Hill, Nov., 1958.

Raisbeck, G., *Minimum-Loss Two-Conductor Transmission Lines*, Trans. I.R.E. Professional Group on Circuit Theory, VCT-5 #3, pp. 214- 230, Sept. 1958.

Shulman, R. G., *NMR and Hyperfine Interactions in Paramagnetic Solutions*, J. Chem. Phys., 29, pp. 945-947, Oct., 1958.

Slichter, W. P., and Mandell, E. R., *Molecular Motion in Polypropylene, Isotactic and Atactic*, J. Appl. Phys., 29, pp. 1438-1442, Oct., 1958.

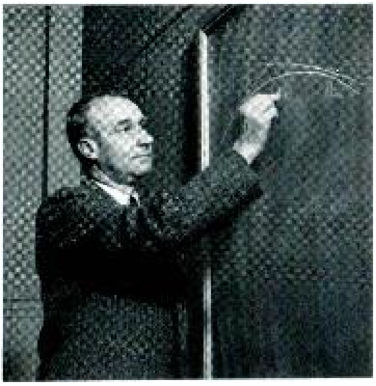
Suhl, H., *The Ferromagnetic Microwave Amplifier*, Physics Today, 11, pp. 28-30, Sept., 1958.

Vacca, G. N., see Jahn, A. P.

Wertheim, G. K., *Neutron-Bombardment Damage in Silicon*, Phys. Rev., 111, pp. 1500-1505, Sept. 15, 1958.

Wolff, P. A., *Theory of Plasma Resonance in Solids*, Phys. Rev., 112, pp. 66-69, Oct. 1, 1958.

Zachariasen, W. H., see Matthias, B. T.



G. R. Frantz

G. R. Frantz, a native of Erie, Pennsylvania, received the B.S. degree in Electrical Engineering in 1935 and the M.S. in Electrical Engineering in 1936, both from the University of Colorado. He joined the Laboratories in 1936 and worked initially on the coaxial cable system. During the war, he was engaged in the development of airborne fire control and bombing systems. This was followed by work in the development of the TE and TD-2 Radio Systems. In 1951 Mr. Frantz became the supervisor of a group responsible for studying radar problems of the Continental Air Defense System and for the radar portion of the experimental DEW Line. In 1954 he was appointed Subdepartment Head and later Project Engineer for the DEW Line. Mr. Frantz is the author of the article on the DEW Line development in this issue. He is a member of Tau Beta Pi and the I.R.E.

W. P. Mason, who was born in Colorado Springs, received the B.S. degree in Electrical Engineering from the University of Kansas in 1921. He received the M.S. degree and Ph.D. degree from Columbia University in 1924 and 1928, respectively. Mr. Mason has been principally engaged in investigating the properties of piezo- and ferro-electric materials, in the transmission of sound waves in liquids, solids and filter structures, and in studies of the static and dynamic properties of solids. He has also studied wear, fatigue in metals, and the joining of materials in solderless wrapped connections. He is in charge of the Mechanics Research group of the Mathematical Research Department. Mr. Mason is a fellow and past president of the Acoustical Society, a fellow of the American Physical Society and the Institute of Radio Engineers and a member of the Rheological Society, Sigma Xi and Tau Beta Pi scientific and engineering fraternities. Mr. Mason is the author of "Semiconductors in Strain Gauges," in this issue.

W. P. Mason

W. M. Bishop came directly to Bell Telephone Laboratories from his native state of Ohio following his schooling at Miami University from which he received an A.B. degree. His first assignment in the Laboratories was with the research group concerned with magnetic material development and processing. After five years in this work he transferred to the submarine cable group to work on the application of magnetic materials to long deep water cable systems. During the change to the application of repeaters to such a system he remained to pursue the development and design of the repeater. With the exception of a short period in central office maintenance tool design and a few side projects carried on in the submarine cable group, he has continued with problems associated with long deep sea telephone cable projects. He is a member of the A.I.E.E. and an associate of the I.R.E. Mr. Bishop is co-author of "Flexible Repeaters for the Transatlantic Telephone Cable," in this issue.

W. M. Bishop

W. A. Klute was born and raised in New York City. He joined the Laboratories in 1925 as a Technical Assistant. After completing the Technical Assistant Course offered by the Laboratories he studied at Brooklyn Poly Tech and New York University. He received a B.S. in Electrical Engineering from New

W. A. Klute

AUTHORS (CONTINUED)

York University in 1934. His earliest work was in the station apparatus area. Subsequently he transferred to the research department (1939-1953). In 1953 he transferred to the submarine cable area of the system development department. Since the Transatlantic Cable, he has worked on the system aspects of the Alaskan and Hawaiian Cable installations. Mr. Klute is co-author of "Flexible Repeaters for the Transatlantic Telephone Cable," in this issue.

C. C. Willhite was born in Kent, Connecticut, and received a B.S. degree in Electrical Engineering from the University of Missouri

C. C. Willhite

in 1944. After serving in the U.S. Army, he returned to Missouri University where he received an M.S. in Electrical Engineering in 1947. He joined the Laboratories in that year and was initially concerned with the manufacturing relations engineering in connection with commercial broadcast equipment. He transferred to the Military Development Departments where he was associated with, and later had the responsibility for, the development of computers for anti-aircraft weapons. He is currently associated with planning for Military Weapons Systems. He is a member of Eta Kappa Nu, and Tau Beta Pi. Mr. Willhite is co-author of "Analog Computer for Evaluating Radar Performance," in this issue.

J. W. McIntyre

J. W. McIntyre was born in Florence, South Carolina and lived in Rockingham, North Carolina. He attended Clemson A&M College in Clemson, South Carolina, receiving the B.E.E. degree. In 1954 he joined Bell Telephone Laboratories, participated in the C.D.T. program, and subsequently became engaged in work on military systems such as Nike Hercules in the computer area. At present he is attending evening classes at Stevens Institute of Technology for an M.S. in E.E. Mr. McIntyre is an associate member of I.R.E. and a member of Tau Beta Pi and Phi Kappa Phi. He is co-author of "Analog Computer for Evaluating Radar Performance," in this issue.

A. F. Dietrich, a native of New York City, joined the research department of the laboratories in

A. F. Dietrich

1942. During the next two years, he worked on radar projects, including the SCR 545. Since 1943 he has been engaged in experimental studies of broadband, baseband and microwave systems. This has included both frequency modulation and pulse-code modulation terminals and repeaters for microwave-radio and waveguide applications. The article on applications of the traveling-wave oscilloscope tubes is by Mr. Dietrich.

R. D. Williams, a native of Minneapolis, Minnesota, received the B.S. degree in electrical engineering from Case School of Applied Science in 1945. After graduation he served as a Radar Officer in the U. S. Navy. He joined the trial installation group of the Laboratories in 1946 where

R. D. Williams

he worked on the initial installation of the No. 5 crossbar system. Subsequently he transferred to the PBX equipment group and later the PBX circuit group where he was concerned with development of the 740E and 756A PBX's and special systems work such as recorded telephone-dictation equipment and the Civil Air Raid Warning System. He is now engaged in exploratory development work on an electronic PBX. Mr. Williams is the author of the article "Crossbar Circuitry for a Small PBX," in this issue.