

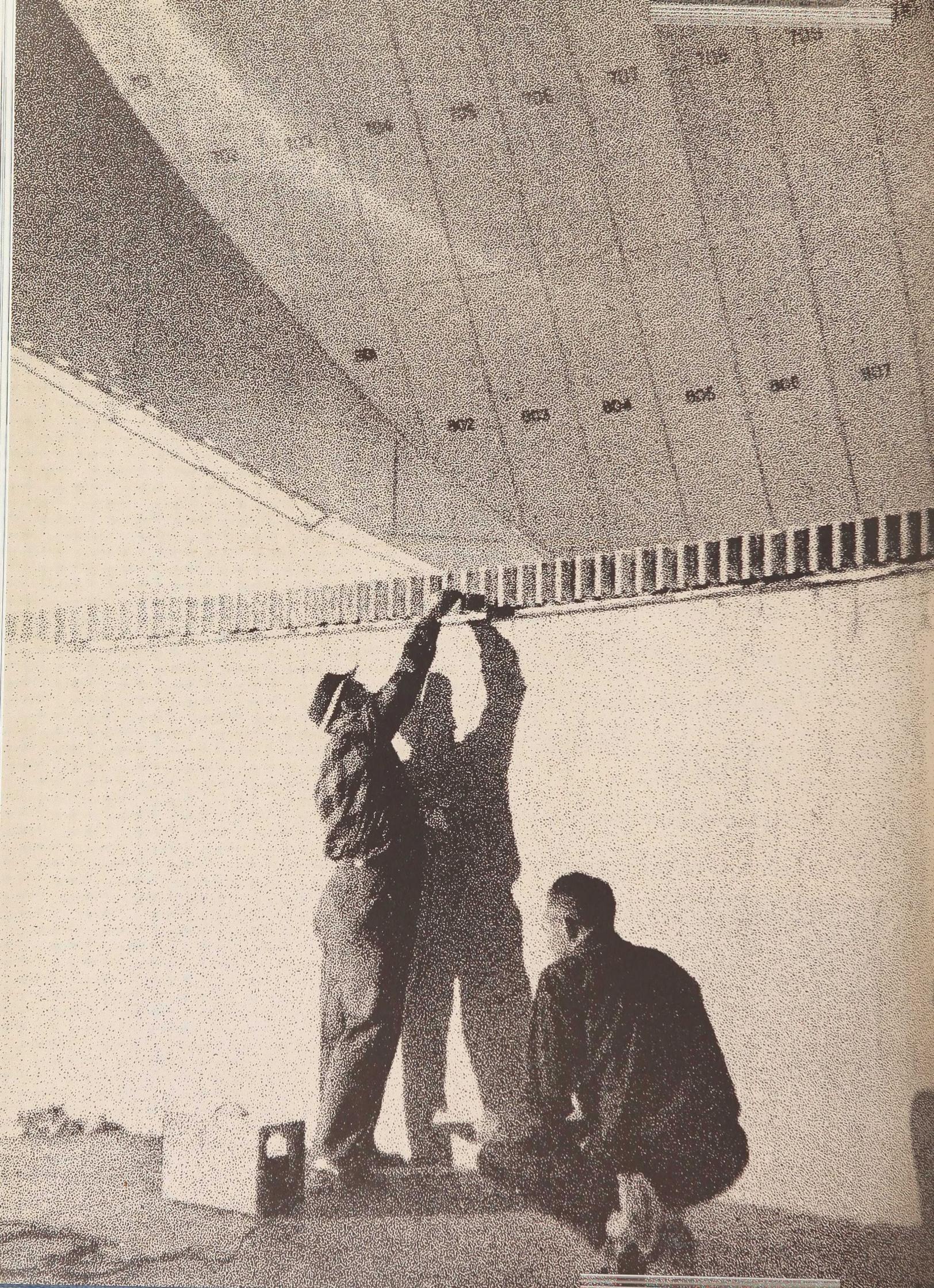
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Cover

CS Long Lines enters Baltimore harbor after its maiden voyage from Hamburg. She will start her first cable-laying project in mid-Summer (See page 204).



Present Laboratories projects require routine measurements more accurate than those of laboratory standards of the past. Without precise measuring instruments, many of these projects would never leave the drawing board.

C. L. Sappet and E. D. Knab

Mechanical Measurements — Basic Tool of Precision Engineering

UP UNTIL a relatively few years ago, the science of measurement—metrology—was hardly more than an art. Its basic tools were those of the old-time toolmaker: micrometers, dial indicators, gage blocks and feeler gages. The advent of microminiaturization, electronic computers and missilery, however, has changed all this, demanding routine accuracy undreamed of even in laboratory standards until recently.

The machine tool industry today, for instance, produces gears of a quality that would only be found in the most precise laboratory master gears a few years ago. The ball elements of high precision bearings used in gyroscopes and data computers are now selected to be uniform in diameter within five millionths of an inch. Micro-miniature circuits are produced with printed

metallic elements whose thickness is measured in Angstrom units. The angular displacement of gears and components in data transmitting apparatus is measured within seconds of arc.

To appreciate these units of measurement better, let us compare them with a strand of human hair. A millionth of an inch is approximately one three thousandth the diameter of a human hair; to get an Angstrom unit, we divide this dimension approximately two hundred and fifty times more. A second of arc is the angle subtended by a human hair from a point approximately fifty feet away!

In making measurements of this magnitude (or “minitude”!) it is easily recognized that extreme care must be exercised in establishing their true value. The traditional craftsman’s tools are no longer alone adequate to serve the demanding needs for precise dimensional control.

New metrological instruments are continually appearing in the mechanical industry today. In

Members of Mechanical Laboratory check surface roughness on “Bull Ring” gear for Telstar horn antenna at Andover.

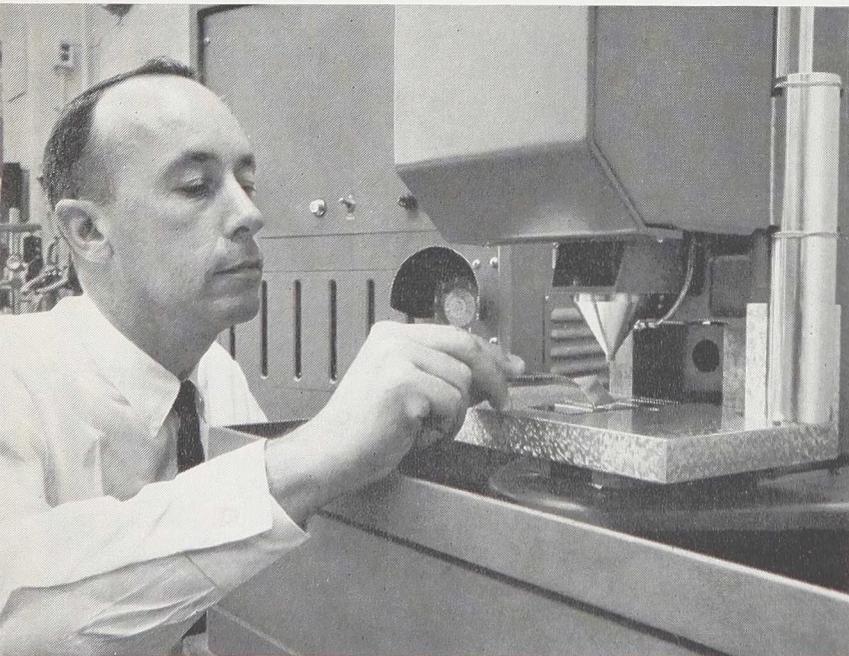
some cases, these instruments even compensate for changes in environment such as temperature, humidity, and barometric pressure in the final determination. Instruments in this category may include electromechanical, optical, pneumatic, or purely mechanical devices. They are usually situated in a temperature controlled room in which even the air is filtered to remove harmful dust particles which could otherwise affect the measurement being made.

The principles employed in many of the ultra-precise measuring devices today were actually well known many years ago. However, early devices based on these principles were likely to be found only in metrological standards laboratories and in far-simpler form than those available on the commercial market at present. Today, in fact, a metrological laboratory or "mechanical lab" under one name or another is a necessary and important part of practically every modern research and manufacturing organization.

Mechanical Lab Established in 1945

In the early part of 1945, Bell Laboratories, recognizing the then potential need for greater dimensional accuracies, established such a "mechanical lab" at the Whippany, N. J., location. The Mechanical Testing Laboratory is staffed today with two engineers, an associate engineer and six technicians, who conduct many phases of mechanical testing, control the design standards

J. W. Buckelew prepares small piece of aluminum foil for measurement. Foil was to be manufactured to thickness tolerance of only 25 millionths of inch.



for gearing and bearings, handle the design of specialized mechanical test equipment, analyze life and wear data, and design and fabricate devices and tooling to prove-in new processes. To insure accuracy of test apparatus and metrological instruments, the laboratory is maintained at constant temperature and humidity.

Various laboratory personnel are especially skilled in certain phases of metrology and mechanical testing. Besides their continuous association with their related arts, their skills are developed, in part, through enrollment at special schools, and by attendance at seminars and symposia of various technical societies.

The laboratory is equipped with precision instruments which are used to test the physical properties of materials, measure the accuracy of gears and bearings, dynamically balance gyroscope rotors and other rotating parts, and establish very accurate linear and angular dimensions through optical, pneumatic, electronic or mechanical instrumentation. They also test the dynamic or static strains and stresses in structures or apparatus, large or small, encapsulate micro-miniature specimens and intricate shapes and measure them by optical methods, and test the effect of thermal radiation on various materials.

Optical instruments are gaining wide popularity in precision measurement of linear and angular dimensions. One of the distinct advantages in the use of optical equipment is that direct contact between the instrument and the part being measured is not necessary. This eliminates errors that might otherwise be contributed by variations in contact measuring force and expansion of measuring apparatus caused by thermal instability. Among some of the better known instruments are devices such as the leveling telescope, surveyors transit, theodolite, autocollimator, optical rotary table, and contour projector. These instruments are often supplemented with other devices such as optical squares, pentaprisms, optical polygons, optical flats, and various types of targets and optical mirrors.

A typical application of an optical measuring system is shown at the right where an optical filter is being inspected. In this inspection technique, two photoelectric autocollimators are first preset facing each other along a common optical axis. The filter to be measured is then placed between the collimators on this axis. Any deviation in flatness or parallelism between the two faces of the optical filter registers on electronic monitors associated with the collimators. Deviations as small as one tenth of an arc second within a range of 10 minutes of arc have been detected and

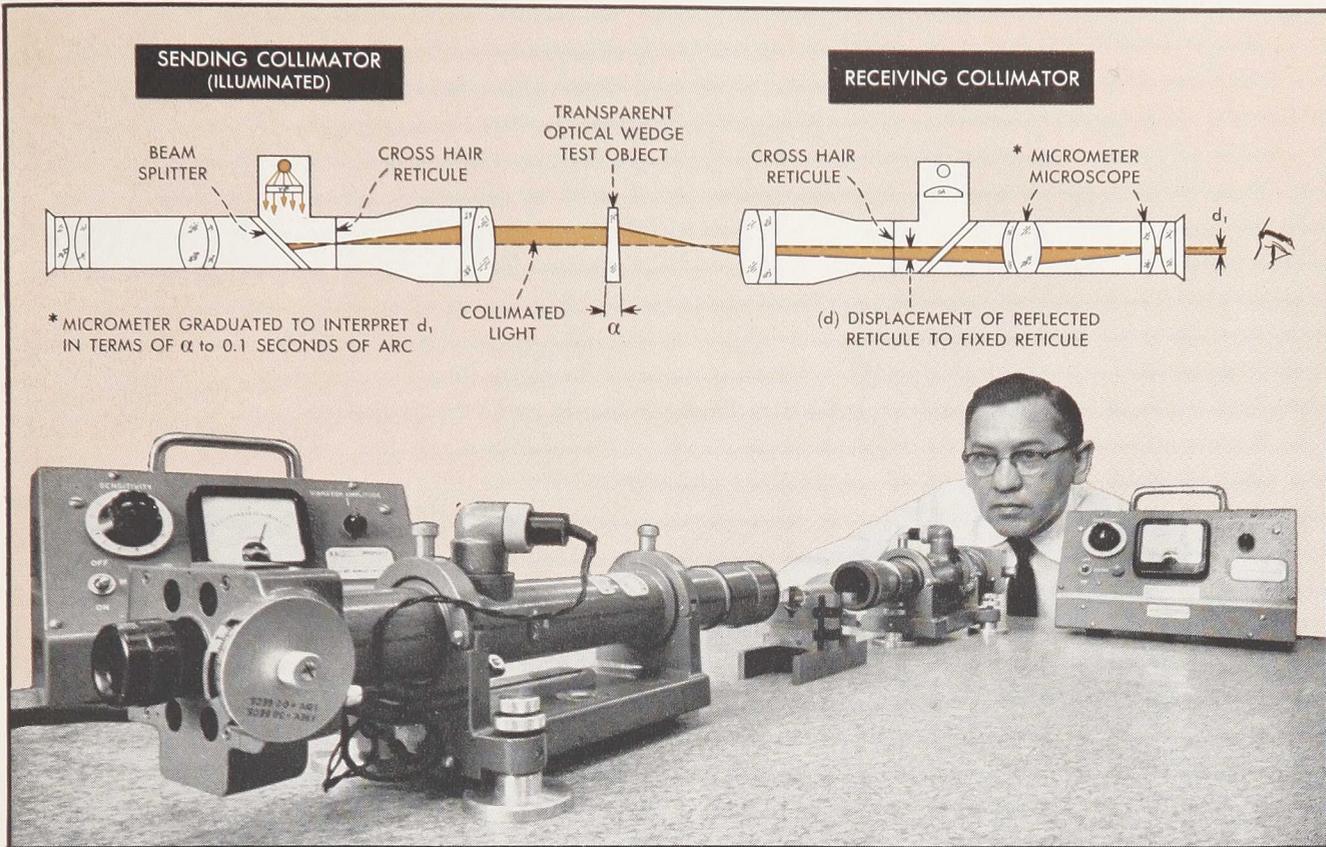


Diagram and photo shows set-up of equipment to test flatness of optical filter, using autocollimator.

measured by this method.

In projects such as NIKE-ZEUS, Titan, and Telstar, structures weighing hundreds of tons and taller in height than twelve story buildings have been erected to watchmaker's precision. In some cases these structures take the form of antennas which rotate about an axis above ground, in others they are underground silos containing very precise elevators for raising a missile or antenna from underground protection to effect the launching of an ICBM. In all cases, the pointing accuracy of the antenna or missiles is measured in arc seconds. This means that investigations as to positional repetition may require measurements with accuracies in tenths of seconds—a task which would be literally impossible on structures of this size without the aid of modern optical equipment.

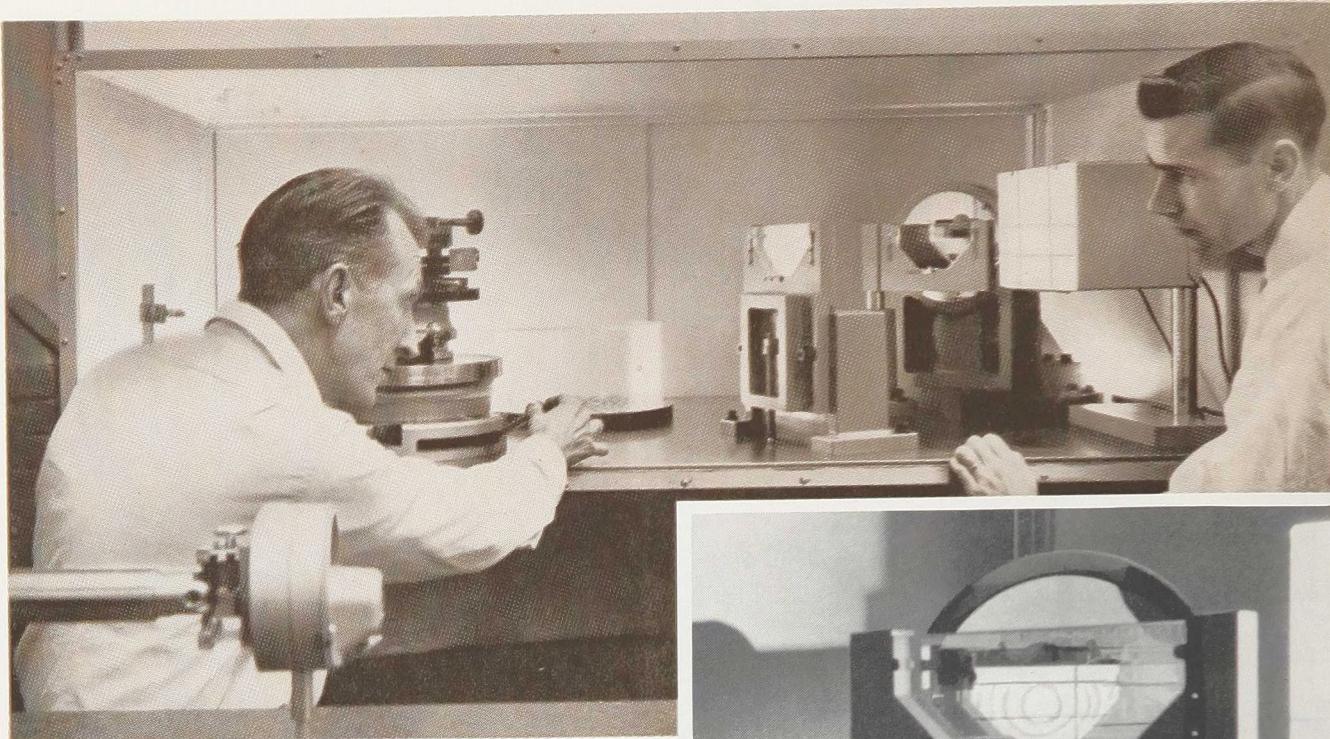
Optical measurements are also essential in the laboratory. For example, very precise linear measurements (within a range of four inches) can be made with a "Link Fringecount Micrometer." The principle of interferometry, in which "interference fringes" appear when two supposedly flat surfaces are placed face-to-face, is employed in this instrument; the measurements are "read-out" in digital form with electronic equipment. This equipment is used to inspect and

calibrate gage blocks or to determine the accuracy of optically flat surfaces to within one millionth of an inch.

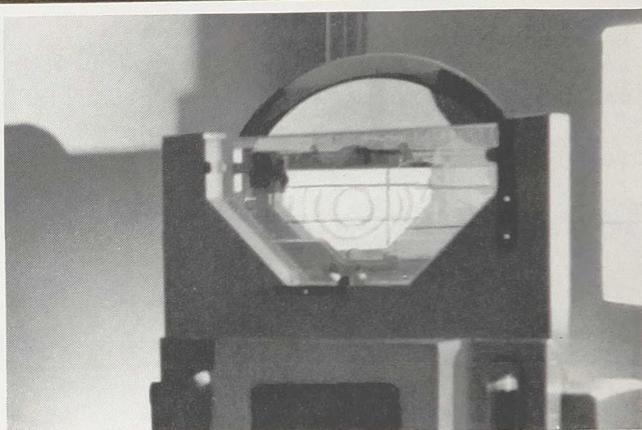
Other applications also appear regularly for this precision instrument. As an example, J. W. Buckelew is shown at the left preparing a small piece of aluminum foil for measurement in the "Link" machine in the Mechanical Laboratory. The requirements on the foil called for 0.000675 inch thickness, with a tolerance of only plus-or-minus 25 millionths of an inch! The manufacturer of the foil was guided by laboratory measurements in adjusting his equipment to produce material of accurate dimensions. The foil is subsequently fabricated, by an explosive-forming technique, into precision diaphragms which are ultimately used in new and unique flight instruments for the NIKE-ZEUS project.

Another type of parts requiring precise measurement techniques are small gyroscope rotors and other lightweight rotating parts. When these are balanced at speeds of from 2,000 to 10,000 rpm in a microbalancing machine, any unbalance present must be measured. An unbalance which causes a vibration of less than a millionth of an inch in amplitude is detectable with presently available equipment.

Compression and tensile tests are also made on



Donald Cable (right), Bell Laboratories, consults with Urban Cox of Michigan Tool Co. regarding tests to measure accuracy of precision Millichex indexing table before accepting delivery. Inset shows interference fringes visible in test.



various types of materials, components, or assemblies, under load conditions ranging from 10 grams to 10,000 pounds full scale. For this work an Instron testing machine is used, which detects and records the load applied to the specimen under test. Test data are accurately reproduced on a recording chart while tests such as spring rate, compressive load, elongation or force-deflection are in progress.

The starting torque of low-friction ball bearings, such as those used in gyroscope gimbals, are measured with a special torque tester. The testing is performed in an ultraclean chamber to meet the exacting test requirements which, in some cases, permit a maximum deviation of only 200 milligram-millimeters.

The ability of structures to withstand the concussion of atomic blasts, or that of missile vehicles to withstand the tremendous forces encountered in suborbital flight, can be determined through the use of strain gages applied to these structures during simulated tests. Special recording apparatus is used in these tests along with various types of strain gages (RECORD, *December, 1962*).

An Arc-Image furnace is used in the laboratory to study radiant energy effects such as melt-

ing time, thermal stress, and emission-reflection relationship of various materials. One common application is the simulation of thermal levels of nuclear explosions. The temperatures attained are dependent upon characteristics of the specimen. Under complete energy absorption conditions, a temperature of 6700 degrees F. can be reached. The spectral energy distribution of the image is very nearly that of unattenuated sunlight, peaking in the wavelength region of 0.5 microns.

Surface roughness measurements are made with a Profilometer to ascertain the quality of finish on machined parts, especially where smoothness of the finish is critical to the behavior of the part in service. In one such investigation, laboratory personnel measured the surface roughness of gear teeth on the 70-foot diameter "bull gear" of the Telstar horn antenna in Andover, Me. Periodic measurements of surface roughness, along with analysis of wear particles obtained from samples of gear lubricant, provided the information necessary to formulate maintenance lubrication procedures. Measurements of surface roughness over different areas of gear teeth also yielded information as to alignment of the mating pinions.

Another activity in which laboratory technicians are often involved is the determination of

the accuracy of a manufacturer's product in the field, before acceptance by the Laboratories. For example, a test was recently run at the Michigan Tool Company in Detroit, with Laboratory and manufacturer's technicians cooperating to measure the accuracy of a precision "Millichex" indexing table, as shown opposite. The accuracy of the table is being verified in Michigan Tool's Light-Wave Angle-Step Interferometer. According to specifications, the indexing table must be accurate to within $\frac{1}{4}$ second of arc at any position of rotation.

In another instance of this activity, the accuracy of tooth spacing of the 11-foot precision "data" gear used on the Telstar horn antenna was checked at the Westinghouse Electric Company plant in Lester, Pa., using a photo-electric autocollimator, a precision optical polygon, and a sensitive electronic probe. The angular position of gear teeth has a manufacturing tolerance of 12 seconds of arc. This was checked by comparing the actual position of the gear teeth to the precise angular increments of the polygon which was placed on the axis of rotation. The polygon used is accurate to one second of arc.

Future Requirements Even More Demanding

Even the precise metrological instruments and equipment presently available to the electromechanical industry are scarcely adequate to cope with the scientific procedures involved in the almost miraculous events surrounding the launching of a military ICBM vehicle or a manned orbital flight. Tomorrow, with the advent of scheduled supersonic flight, interplanetary excursions, and vast systems of satellite communications, the reliability demanded of these equipments will dictate a need for accuracies unheard of even in laboratories today.

Scientists already have devised a laboratory method, for example, of measuring angles to within a hundredth of an arc second—the needs tomorrow may be ten times smaller.

Investigations are now required as to the accuracy and life expectancy of mechanical apparatus in space environment. What happens to lubricants in space? To wear particles? What are the effects of solar radiation on mechanical parts? Of cosmic bombardment?

Further mechanical designs will require even greater resistance to environmental effects, greater dimensional accuracies, and greater reliability. More precise industrial standards and manufacturing methods will also be required and produced, in response to this never-ending cycle of improvement.

Telstar II in Excellent Condition After 200 Orbits

Telstar II, the Bell System's second experimental communications satellite, is in excellent condition after more than one month in space. The satellite, which completed its 200th orbit on June 7, is performing its communications and other experiments perfectly.

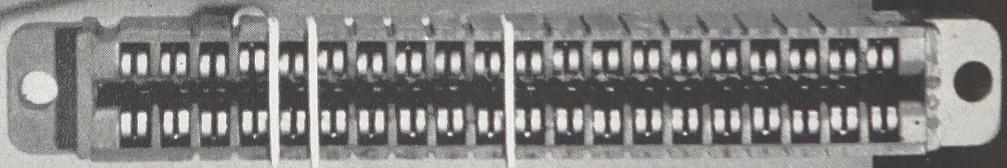
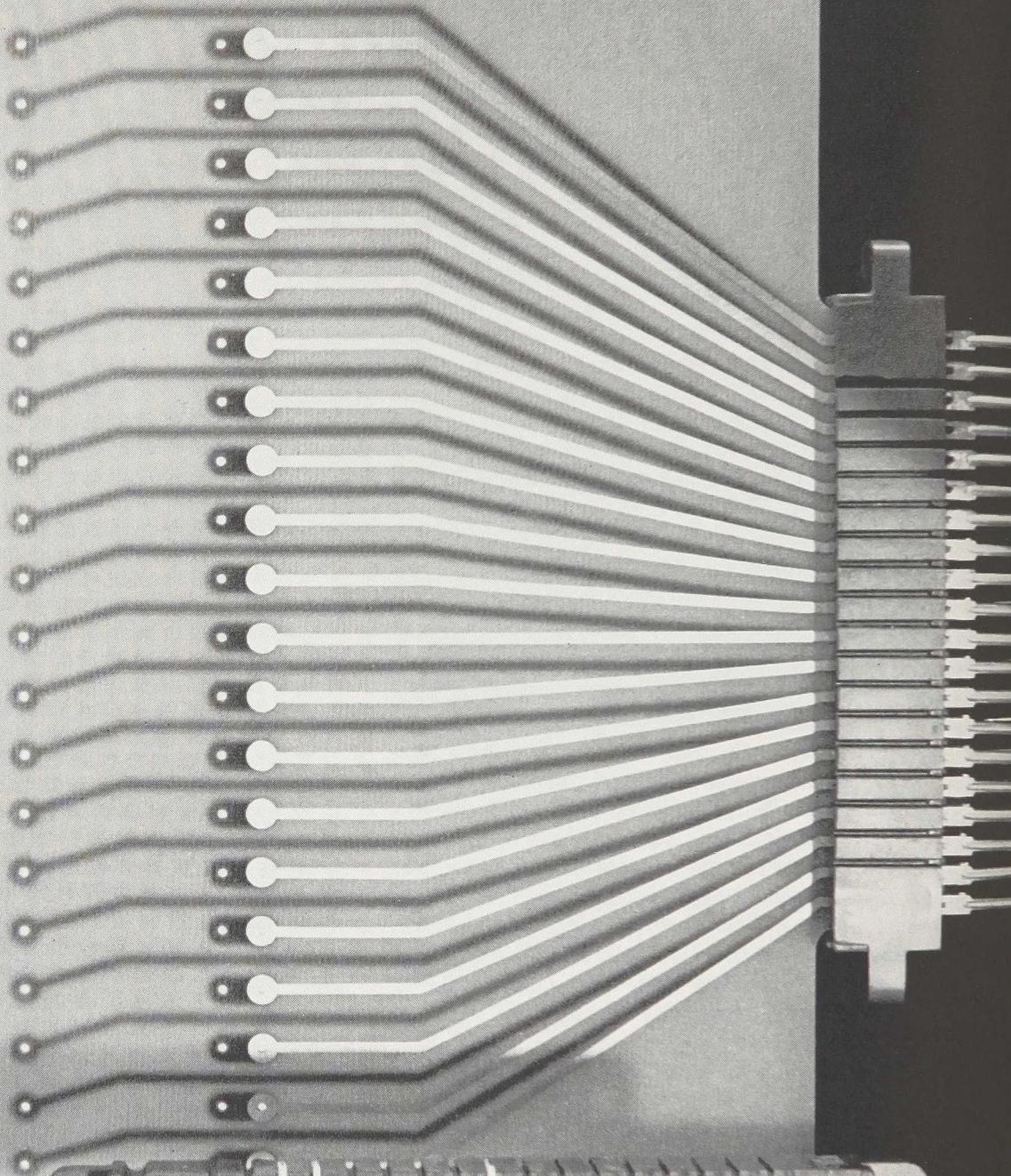
Developed by Bell Telephone Laboratories and launched at Bell System expense by the National Aeronautics and Space Administration, the Telstar II satellite is providing valuable information on the feasibility of a medium-altitude communications system. Tests conducted by engineers and technicians at the Bell System's ground station in Andover, Maine, show that satellites can be tracked and used for broadband communications (television, telephone, data, and facsimile) at ranges which a commercial system might use.

The Telstar II satellite was launched on May 7 into an orbit with an apogee of 6713 statute miles and a perigee of 604 miles. The slant ranges (actual distances) from the Andover ground station to the satellite, however, are sometimes as much as 9400 miles. The Telstar I satellite, with an apogee and perigee of 3531 and 592 miles respectively, has slant ranges of up to 6500 miles.

In addition to the broadband communications experiments, telemetered data from the Telstar II satellite is providing important information on the condition of both the satellite itself and its environment in space.

Some early data from the radiation damage experiments show that two lightly-shielded, damage-measuring transistors on the surface of the satellite took about four times as long to reach the same level of radiation damage as a similar transistor mounted on Telstar I. Telstar II is expected to undergo less radiation exposure because its higher apogee causes it to spend less time in regions of high-intensity radiation in the Van Allen belts. It will spend more time in the so-called "slot" between the belts. The exposure of devices in the satellite circuitry is also expected to be reduced because of the partial decay of the higher-energy electrons put into space by the high-altitude nuclear tests of the summer and fall of 1962.

During the first 200 orbits of the Telstar II satellite, 15 public demonstrations and 273 technical tests were conducted. The transmission characteristics of the satellite are identical to what they were in measurements before launching.



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The concept of packaging finds wide application in modern communications design. Now that circuits themselves are replaceable units, Bell Laboratories' engineers have developed . . .

A New Connector for Printed Wiring Boards

R. A. Hecht

DURING WORLD WAR II the concept of using replaceable subassemblies in equipment packaging brought about the development of rack and panel type connectors. Small plug-in packages can be economically assembled by production line methods and are easily tested before addition to larger circuit complexes. After installation, ease of maintenance is afforded by tests which can locate trouble within a particular unit. The availability of spare units facilitates quick replacement, greatly reducing the time during which equipment is inoperative. Finally, a faulty unit can be returned to central locations where special service apparatus is available. These advantages strongly recommended such packaging to the tele-

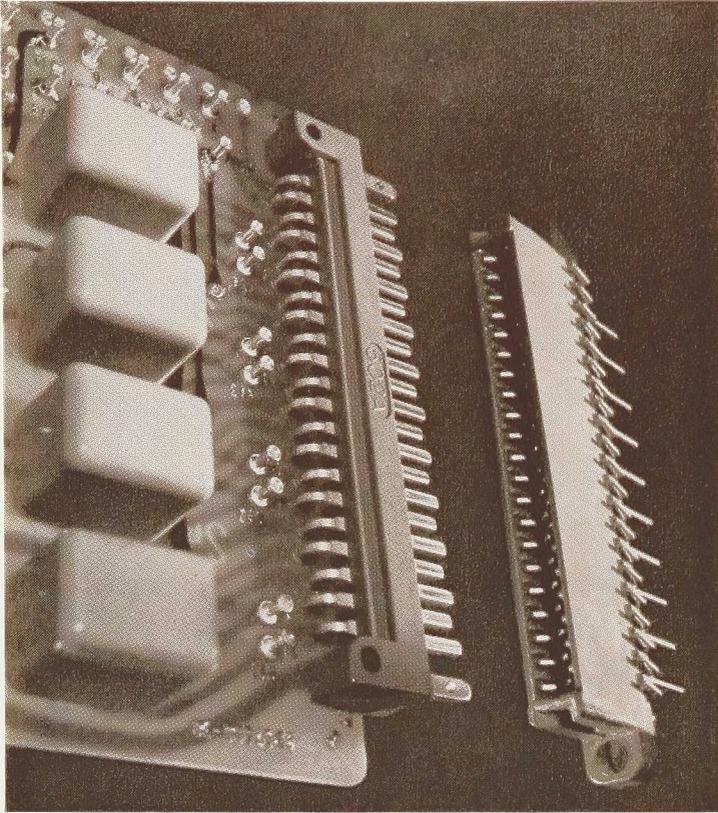
phone industry, which has made extensive use of the concept.

With the advent of printed circuitry, the circuit boards themselves became plug-in, replaceable units. Early designs which provided that the board be inserted directly into a connector had one important weakness. The connectors often damaged the foil on the board after repeated insertions. This arrangement was not adopted by the Bell System, which turned instead to the use of an "applique unit." This was mounted on the printed circuit board and the assembly was inserted into the connector.

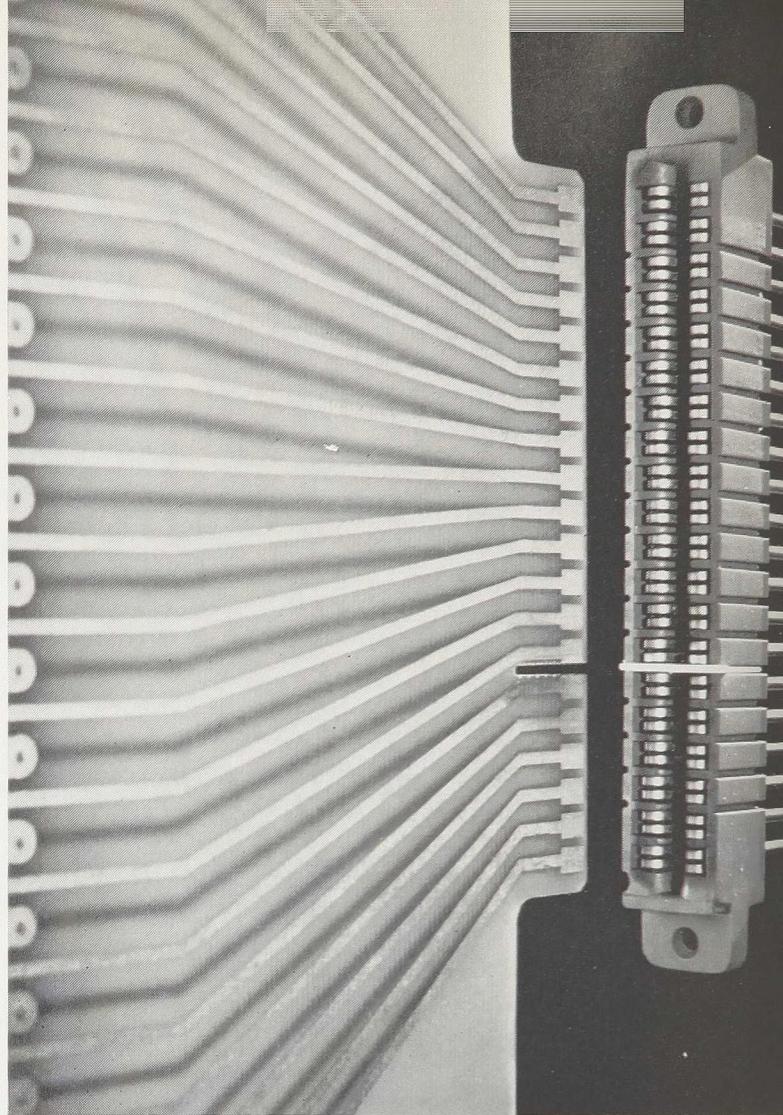
Design Objectives

Although the applique unit was highly reliable, it was also bulky and relatively expensive. Thus Bell Laboratories engineers continued to search for a connector that would accept boards directly. In 1961, development of 1A2 Miniaturized Key

A variety of circuit boards will be accepted by the new connector, which is shown here in models for both one- and two-sided wiring. Clips on the lower connector fit slots in the board, providing a convenient and foolproof means of coding.



An earlier circuit board connector required fitting the board with an "applique unit" (above). The new connector (at right) accepts the board directly.



Telephone Equipment resulted in the formulation of definite design objectives for such a connector. These were:

- (1) High reliability—a change in contact resistance comparable to that of connectors already in service.
- (2) Extended life—at least 200 operations.
- (3) Low cost—less than that of currently available connectors.
- (4) Sturdy terminals—suitable for solderless wrap.
- (5) Wide adaptability—functional with a variety of circuit board types.

To meet these objectives, the new connector features a plastic housing that contains bifurcated (double armed) springs onto which precious metal contacts have been welded. The contacts offer a wide area of contact surface and have "sled type" leading edges which offer minimum interference to the board as it is inserted. Because of their position in the housing, the contacts slide on the foil of the board only $3/32$ of an inch, again helping to reduce wear. They are made of solid precious metal alloy in current models. In future

production, however, the contacts will be made of bimetallic (two layer) tape. This offers substantial cost saving for each terminal assembly, yet assures many more operations for the connector than would be possible using conventional gold plating techniques.

Alloy Contacts

The advantages of alloy over the more conventional gold plating include its harder, thicker and hence more durable surface. Because the alloy is of a different hardness from the pure gold on the circuit board, it also tends to burnish the contact surfaces on the board, thereby reducing wear. Finally, alloy contacts reduce the cold welding which occurs when two surfaces of soft gold are pressed together. Often the asperities on the surfaces are compressed until the yield strength of the material is reached, resulting in a cold weld that is sometimes of greater strength than the strength of the underlying metal (in this case copper). When the contact is opened, a piece of copper can adhere to the connector contact, serving as a spur to score the land of the board during repeated operations.

The springs in the plastic housing of the new connector provide a contact force which is held approximately between 100 and 200 grams per tyne. These springs incorporate an inherent pretension feature through action like that of a closed safety pin, as shown below. This permits use of a relatively compliant spring and thus close control of contact forces in spite of commercial variations in springs and circuit boards. The pretension can be checked easily before it is assembled into the block.

Another feature of the new connector is the unique means provided for coding. For many commercial connectors, coding is accomplished by omitting a contact and inserting a dummy spring. This reduces the number of usable contacts by one, limiting circuit design possibilities. In contrast, the new connector is coded by insulated metal clips which fit into grooves in the plastic housing between terminals. The clips can be arranged for numerous codes and the appropriate circuit boards slotted accordingly. Thus the full complement of terminals remains available to the circuit designer.

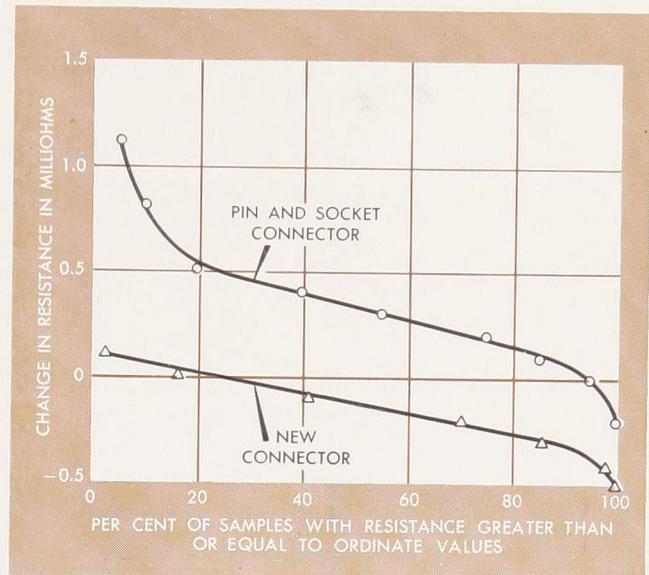
Objectives Achieved

When tested in the laboratory, the new connector demonstrated that its technical design objectives had been fulfilled. After repeated operations and accelerated corrosion tests, the change in contact resistance was less than that for other Bell System connectors which have already proved their reliability in long service. Boards which had been inserted into the new connector 400 times showed excellent wear results and the connectors were found to function well with epoxy coated metal, phenolic and epoxy-glass circuit boards.

Certain design features of the connector also assured that it would meet production objectives. The pretension of the springs, as mentioned above, can be checked before assembly. Springs can also be arranged on a rack, each held by a blade between its tyne. One operation then inserts a full set of contacts into the plastic housing. Preliminary cost studies indicate that initial economic objectives can be successfully met.

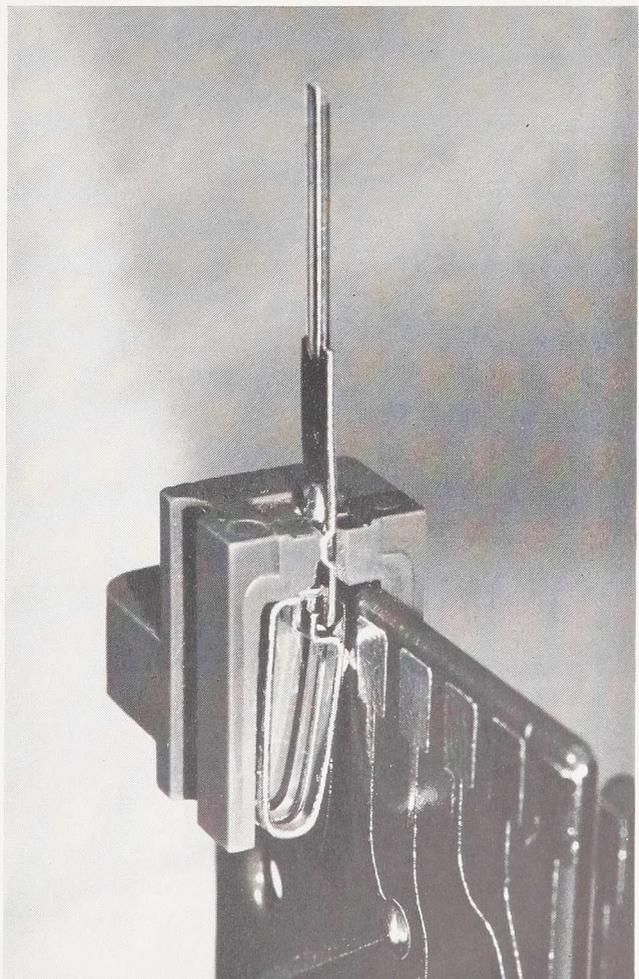
How well a connector performs in service is often determined by conditions peculiar to its installation. Corrosion and foreign particles are among the greatest obstacles to continued low contact resistance. The problem of corrosion in porous

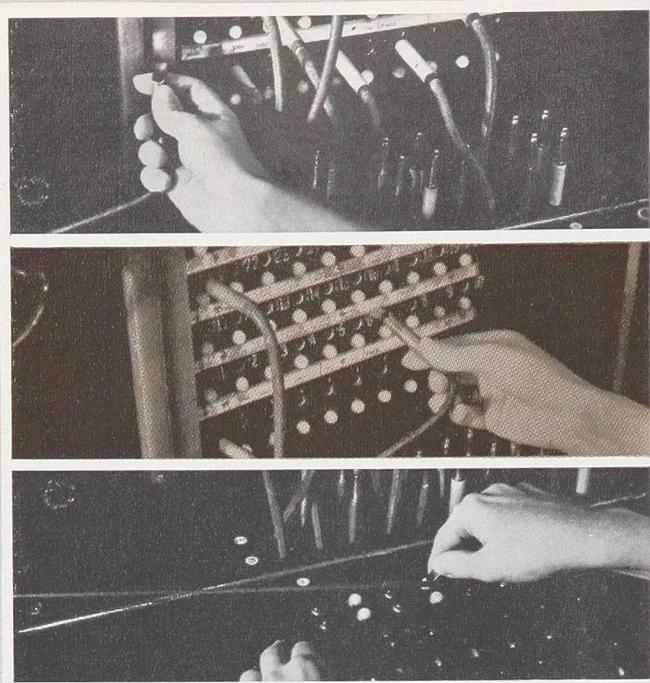
A cut-away view of the new connector with an epoxy coated board shows sled-shaped contacts, bifurcated spring, and safety-pin action.



This chart compares the performances of the new connector and a conventional pin-and-socket connector after 200 insertions and withdrawals.

electroplatings is eliminated by the use of welded precious metal contacts while that of foreign particles is reduced by providing two points of contact. Certain precautions, such as protecting the lands of circuit boards during manufacture, and using lubricant, help to achieve reliable service. With a combination of precious metal contacts and lubricant on the board, tests indicate that the new connector-board combination will meet the exacting requirements of Bell System service.





New Eyes for Blind PBX Attendants

THERE IS AN INCREASING DEMAND for equipment that can help blind persons operate telephone PBX switchboards. The first "auxiliary signal cabinet" with "pop-up" signal pins for touch operation by blind attendants was designed in 1935, and this model is still being used in some businesses. This is a large wooden box fastened to the side of the switchboard with the top surface flush with the keyshelf. The attendant operated this device by feeling the raised pins with her fingers.

In 1956, Laboratories engineers designed an exploratory model of a system which represented a new departure in aids for blind attendants (*RECORD, January, 1957*). Instead of modifying the switchboard so that it could be operated by a blind person, equipment was developed which a blind person could use to operate almost any type of standard PBX switchboard.

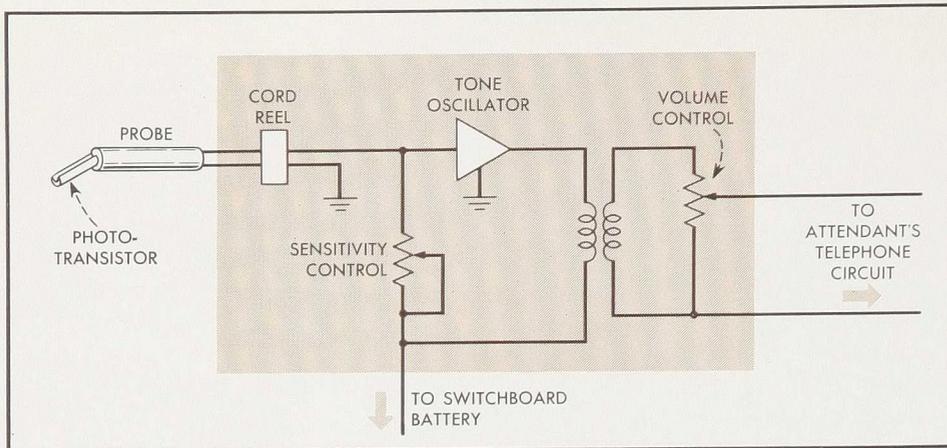
The exploratory model of the Seeing-Aid equipment consists of a phototransistor mounted on a ring which an operator can slip on her finger. The phototransistor is connected to a two-transistor oscillator circuit housed in a small box. A four-foot length of flexible cable connects the phototransistor to the oscillator circuit; a headset also plugs into the oscillator. The circuit operates

on power from a small mercury cell battery in the housing. A buzzer indicates an incoming call, and the operator then scans the lamps on the switchboard with the phototransistor. A lighted lamp actuates the phototransistor, which picks up the message indicating that a call has come in on a particular line. The oscillator transmits a tone to the attendant through her headset. To answer the call, the attendant plugs a cord into the jack associated with the lighted lamp.

The new Seeing-Aid system is similar both in design and operation to the exploratory model described above; it consists of a three-transistor circuit actuated by a phototransistor probe. A zener diode makes it possible to operate the circuit on power from the PBX. The circuit operates over a

Miss Rosmarie Jankowicz operates a single panel switchboard at the Industrial Home for the Blind in Jamaica, L. I. She uses a phototransistor device to determine which cords require action. Photos inset above show hands searching sectionalizer with probe to determine location of an incoming call, scanning lamp strips to complete a call, and probing cord supervisory lamps.





Simplified circuit of the Lamp Signal Detector unit. The phototransistor in the probe actuates the tone oscillator which notifies an attendant of presence and location of incoming calls.

PBX voltage range of 16 to 52 volts.

To reduce the scanning time, a lamp strip assembly is used as a "sectionalizer" to divide the PBX in half. There are two vertical rows of lamps in this sectionalizer, two lamps for each level of standard lamp strip for subscriber's lines and trunks. A lighted lamp in this lamp strip assembly directs the attendant to an incoming call in either the left or right half of the PBX. On single panel switchboards such as shown in photograph on page 197, the sectionalizer is mounted on one side and only one vertical row of lamps is utilized. The new sectionalizer has a flat smooth surface instead of projecting translucent knobs formerly used. In addition, a single lamp in each vertical row at the bottom of the sectionalizer indicates a cord supervisory signal. This directs the attendant to probe the standard cord supervisory lamps, one for each cord, located in the keyshelf in front of the switchboard cords. A steady light here tells the attendant that the parties have hung up and the cords should be disconnected whereas a flashing signal indicates that a party desires more service.

To locate an incoming call from a line or trunk, the attendant holds the phototransistor probe in one hand and scans the PBX lamp strips. When the probe detects a lighted lamp, it actuates the oscillator which transmits a tone to the attendant's headset. With the calling party thus identified, the attendant uses the other hand to insert a plug into the associated jack.

The lamp signal detector equipment is contained in a metal box that can be mounted in any convenient place on the switchboard. The photosensitive probe which protrudes from the box is attached to a cord connected to a retractile cord reel. This probe consists of a modified switchboard plug having a hollow rectangular section projecting out

from the plug body at an angle and the phototransistor is fastened therein near the open end. A small, sturdy receptacle is thus provided to protect the solid-state device and to withstand constant handling. An external knob is furnished on the box to adjust an audio potentiometer to the desired tone level. A photosensitive potentiometer inside the box can be used to raise or lower the sensitivity of the phototransistor.

Braille Designation Strips

Braille designation strips are used to help the attendant locate the jacks for completing a call. Characters are embossed on plastic strips coated with a pressure-sensitive adhesive, and they are mounted over the standard designation strips. The Braille strips are transparent so that the printed designations can be read if needed for standard operation of the board. The embossed characters themselves are durable enough to withstand constant handling for many years.

To make these strips, thin plastic strips of polyvinyl chloride acetate may be embossed by using either a Braille typewriter or a hand-embossing tool. This material is extremely tough and has high-gloss clarity, chemical inertness, and excellent tensile, tear-strength, and elongation properties.

It is planned that the new Seeing-Aid equipment will be made available for all PBX switchboards that are considered suitable for operation by blind attendants. This equipment facilitates operation of the switchboards and provides substantial economies in manufacture and cost to the telephone companies relative to the early versions. This approach minimizes the cost and time involved in adapting a PBX for blind attendant operation; moreover, it is an effective way of utilizing the abilities of blind persons.

Proposed New Short-Haul Microwave Systems

The TL Microwave System, operating in the 11,000-mc (11-gc) band, was introduced to the operating telephone companies somewhat over one year ago (RECORD, *February* 1962). It has now been enthusiastically accepted by the majority of the telephone companies as an economical and highly dependable facility for providing circuits between central offices.

The TL System was designed to carry up to 240 voice channels over distances of about 150 miles. A later version, known as TL-2, will be introduced in July. It will have improved noise characteristics and will be capable of transmitting 600 telephone channels over distances in the order of 150 miles. Alternately, it could be used to transmit a 4.2-mc color television signal for distances approaching 100 miles.

The effects of heavy rainfall in some areas of the country reduce the reliability of 11-gc transmission below a point considered acceptable in the Bell System. One solution to this problem has been the design of the 6-gc TM-1 Microwave System, which is not troubled with interruptions due to rain. However, in some areas this band is occupied by the TH long haul system as well as by many short haul 6-gc microwave systems, and optimum use of the spectrum becomes an important matter. For example, short-haul microwave systems which depend on frequency diversity to maintain high reliability in the presence of heavy fading, equipment outages, and maintenance interruptions require twice as many radio channels as nondiversity system. This conflicts with the desire to use the 6-gc common carrier frequency assignments prudently.

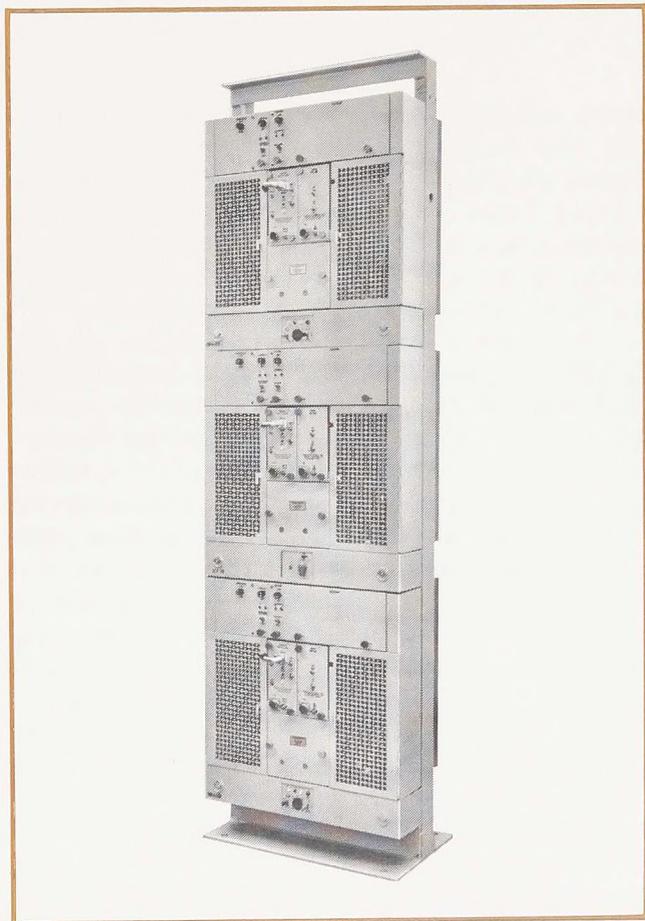
In a proposed new approach to diversity channel operation, these objections and difficulties would be substantially reduced by operating the diversity system with one channel at 6-gc and the other at 11-gc. From the standpoint of outages due to selective fading, this arrangement would be almost ideal, because of the wide frequency separation of the two channels. Under conditions of heavy rainfall, service would be maintained via the 6-gc channel. Experience has also shown that when rainstorms are present, selective fading on the 6-gc channel is relatively low.

The 6-gc/11-gc TM-1/TL-2 system is proposed for a maximum of 600 channels of L multi-

plex for distances up to 10 hops and a maximum system length of 250 miles. Both the 6-gc and 11-gc equipment designs use all solid-state devices, except for the two receiving and transmitting klystrons which provide the required power at microwave frequencies. Battery standby operation adds to the over-all system reliability. Flexible packaging arrangements allow for many system combinations and for orderly growth of the radio route.

The TM-1 System could also be used for operation on a diversity basis with TJ and TL-1 (11-gc) systems to reduce outages due to heavy rainfall.

U. S. BERGER
Director, Radio Transmission
Laboratory



Three TM-1 transmitter-receiver units in bay.

Trying to achieve greater relay design flexibility, Bell Laboratories' engineers have developed several dry-reed sealed contacts which perform transfer functions. This article describes one possible design.

K. F. Bradford

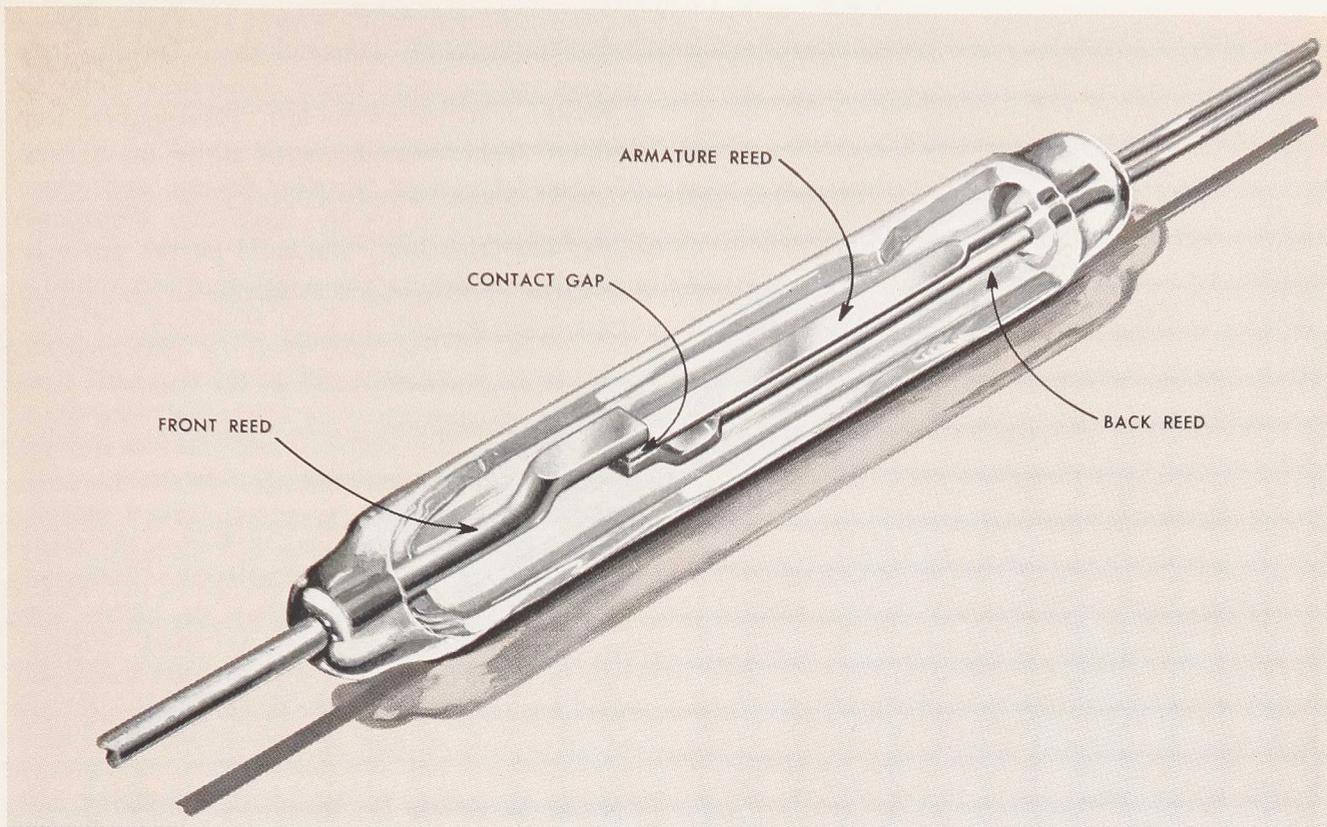
An Experimental Dry-Reed Sealed Transfer Contact

DRY-REED SEALED CONTACTS have been used in the Bell System for many years to provide greater switching reliability by freeing the contacts from environmental effects such as airborne contaminants and corrosion. These have normally been simple "make" contacts; using them with suitable permanent magnets, they can also provide a simple break contact. The appropriate combination of such make and break contacts can, of course, also provide a transfer function. However, using these simple individual sealed contacts to achieve the desired combinations of make, break and transfer functions has involved several technical and economic problems.

In an effort to gain greater relay design flexibility, a self-contained, dry-reed sealed transfer contact, comparable in size with other small size sealed contacts, has been under exploratory development for some time. Several specific designs are being investigated; this article describes one

design, shown at right, and discusses some features and probable operating characteristics.

The sealed contact consists of three reeds of magnetic material sealed into a glass envelope, which serves both as a mechanical support for the reeds and as an environmental control chamber. Both the front and back reeds are relatively large, rigid members, while the armature reed, on the other hand, is smaller, and flexible enough to bend under forces of only a few grams. During the assembly of the transfer, the armature reed is pretensioned against the stiffer back reed, thus forming a normally closed contact pair. To operate the transfer, a magnetic field is introduced in a direction parallel to the reeds by placing the unit in the center of a suitable coil. The magnetic field forces the armature reed to bend away from the back reed and holds it against the front reed. When the magnetic field is removed, spring tension produced in the armature reed will return it



Artist's rendering of experimental dry-reed sealed contact transfer switch.

to its unoperated position, a typical break-before-make transfer. (This design does not lend itself to a make-before-break operation; other designs are under consideration for this purpose.)

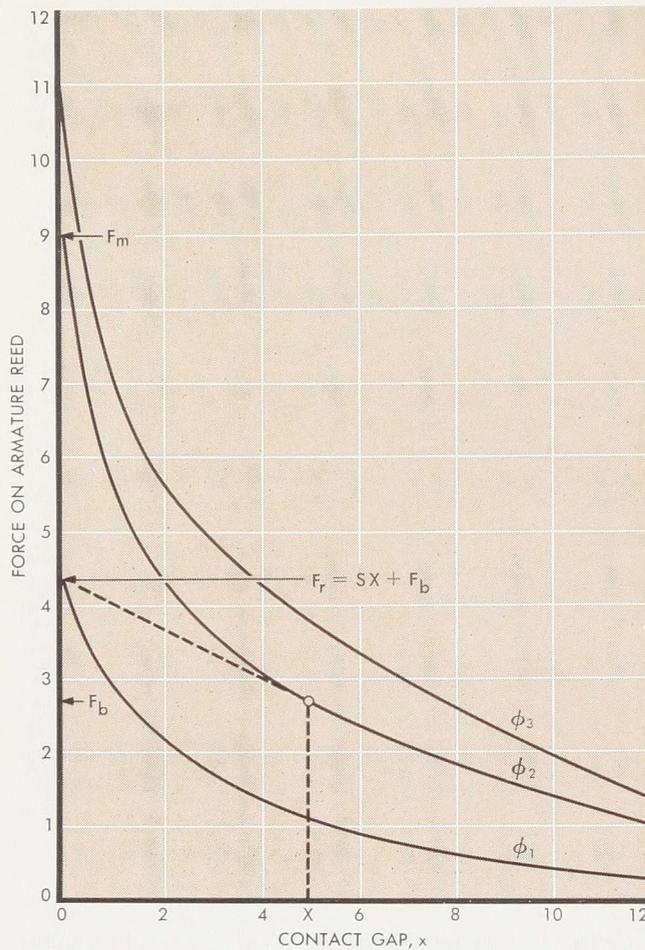
Beyond the minimum responsibility of providing an electrical connection that can be transferred between two alternate paths upon command, a useful dry reed sealed transfer must bring with it a number of other desirable attributes. One of the foremost of these is a uniformly low and stable contact resistance between the contacting members. The contact resistance depends on the type of contact material, the surface condition of this material and the force existing between the two contacting reeds. Several satisfactory contact materials have been used in sealed contacts in the past and new materials and techniques are constantly being investigated and developed for these specialized applications.

Usual Construction Methods Not Suitable

The usual methods of providing a precious metal contact by attaching the material in the form of a button or inlay to the base metal are not suitable here. These techniques adversely affect the magnetic structure of the sealed contact by introducing a relatively large magnetic separation and hence a high magnetic reluctance be-

tween the closed reeds. For this reason, special plating and diffusion techniques have been used most generally to provide the necessary balance between the need for precious metal and low magnetic reluctance at the contacting interface. The glass envelope, of course, serves to control the environment of the reeds and thus contributes to the stability of the contact resistance. Oxidation, corrosion and other contaminants are a chief cause of failure in unsealed contacts; in low power devices, where contact forces are small, control of these factors is especially important.

In addition to a suitable contact material and environment, adequate and uniform contact forces are required to establish and maintain a really good electrical contact. The two contact forces in this design arise from different causes—the *back* contact force is produced mechanically by pre-tensioning the armature reed against the back reed, while the *front* contact force is produced upon operation by the magnetic field in the contact gap. The magnitude of this front contact force for a given magnetic flux density, however, is also dependent upon the back contact force and the retractile force of the armature reed, since part of the magnetic force must be used to overcome the pretensioned back contact force and move the armature reed across the gap against its stiffness



Graph shows the relationship between the forces on the armature reed and the gap x . The solid curves are magnetic pull forces representing three values of flux ϕ . The dashed curve is retractile force due to the armature stiffness S . In the unoperated state the armature reed is pretensioned against the back reed ($x = X$) with a back contact force F_b . To operate the transfer the magnetic flux is increased until ϕ is equal to or greater than ϕ_2 , at which time the magnetic force is greater than the retractile force for all gaps x and the armature reed moves into position against the front reed ($x = 0$). In this position the front contact force F_f is the difference between the pull force and the retractile force ($F_f = F_m - SX - F_b$). To release the transfer the flux must be reduced to the point where the retractile force is greater than the magnetic force which is true for ϕ equal to or less than ϕ_1 . In actual use, an operate flux $\phi_3 > \phi_2$ is always used to provide an operate margin and adequate speed. Since for a given coil and contact geometry ϕ is proportional to NI (ampere turns), these curves completely describe the relation between front and back contact force, operate and release NI sensitivity, gap X , and armature reed stiffness.

before the front contact force is established.

The relationship between these various parameters can be more easily understood from the pull curves shown at the left. These curves were derived from measurements made on a large scale model of this transfer design, and appropriately modified for the particular dimensions under investigation. The solid curves are magnetic pull vs. gap for three different flux values ϕ , and the dashed curve is the armature reed stiffness. It can be seen that when the operating flux is equal to or greater than ϕ_2 the magnetic force is always greater than the retractile force due to the armature reed stiffness and the transfer will operate. A subsequent reduction of the flux to ϕ_1 or less will reduce the magnetic force below the retractile force for zero gap and allow the transfer to return to its unoperated state. Under normal operating conditions, a flux, ϕ_3 , higher than the "just operate" value is always used. This provides a positive operate margin and materially increases the speed of operation. For the same reason, a release flux of zero is normally used.

Precise Assembly Techniques Essential

Because of the complete interdependence of these factors and their importance to contact resistance, assembly techniques that will adequately control all of these parameters are absolutely essential. In addition, these assembly techniques must be compatible with completely automatic manufacturing methods, otherwise highest quality and uniformity cannot be obtained at a reasonable cost.

Another important characteristic of a sealed contact is its operating sensitivity. As seen above, for any given dimensions the operate sensitivity can be varied within certain limits depending upon the contact and retractile forces desired. It can also be seen, however, that in general the operate sensitivity of a transfer contact is less than that of a comparable-sized make contact. In a simple make contact the energy required to bring the two reeds together works only against their combined stiffness. In a transfer, additional energy is required to overcome the pretensioned back contact force. This consideration indicates why this basic difference in sensitivity exists. Experience with actual models has generally confirmed predictions based upon measurements such as those shown in the graph.

We should point out that a sealed transfer contact of this general design is not limited to any one size. Depending upon the application and operating characteristics required, a transfer of considerably different size might be required.

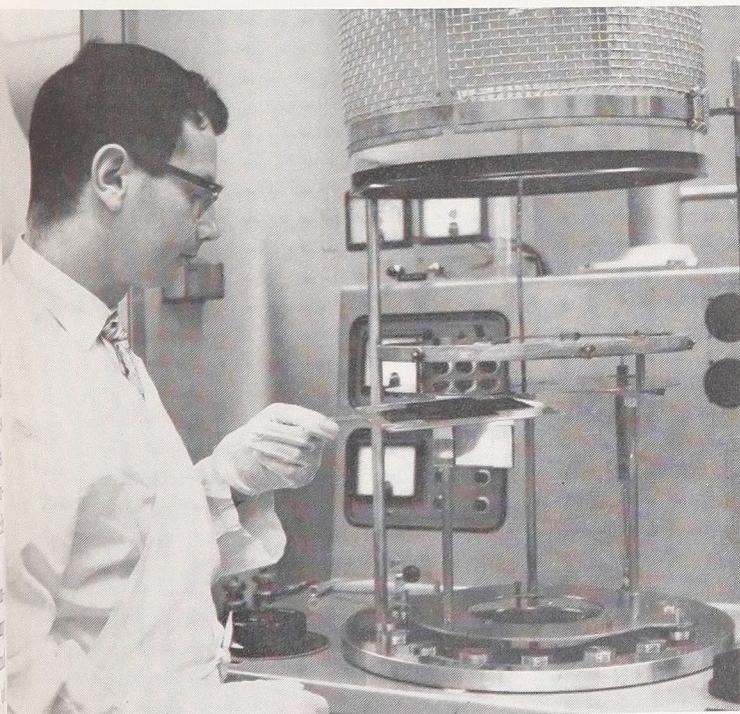
Tantalum High Resistance Films Produced

Thin films with sheet resistivities as high as 10,000 ohms/square have been produced at Bell Laboratories by sputtering tantalum in a partial oxygen atmosphere. This high sheet resistivity means that a 100 megohm resistor, for example, can now be made on approximately 0.02 square inches of substrate.

W. J. Pendergast of the Components Laboratory described the process at a recent meeting of the Electrochemical Society held in Pittsburgh, Pa. He said that by controlling the pressure of oxygen during sputtering in argon, stable, high precision tantalum resistors can be obtained with relatively low temperature coefficients. Mr. Pendergast described a tantalum resistor that had been sputtered in an argon-oxygen mixture. The resistor had a sheet resistivity of 1000 ohms/square and a temperature coefficient of resistance of -500 parts per million per degree C.

Ohms/square characterizes the sheet resistivity of a film and is proportional to the specific resistance of the material and inversely propor-

D. Gerstenberg removes tray of substrates on which tantalum has been sputtered.



tional to the film thickness. The term square is a dimensionless quantity that represents a square area of film. For a given film thickness, any square area of the film has the same resistance value.

Sputtered thin films are produced by bombarding a metal cathode with ionized inert gas molecules. The metal atoms dislodged from the cathode redeposit on a nearby surface to form a thin film. Earlier, D. Gerstenberg, also of the Components Laboratory, and E. H. Mayer of the Electron Device Laboratory demonstrated that sputtering tantalum thin film resistors in a partial nitrogen atmosphere increased the stability and reliability.

These oxygen-sputtered thin films offer a range of electrical properties that complement those of nitrogen-sputtered films, which are limited to applications of less than 200 ohms/square. Up to 10,000 ohms/square, Mr. Pendergast reports, oxygen sputtered films can be trimmed to precise tolerances. (To trim a film, the surface is electrolytically oxidized, producing a resistor within two hundredths of one per cent of a desired resistance value. The oxide layer also serves as a protective coat and humidity barrier over the film.)

Such oxygen-sputtered resistors have been produced with temperature coefficients ranging from plus 100 ppm to minus 500 ppm depending on the sheet resistivity. Since precise temperature coefficients can be obtained, oxygen-sputtered resistors could be used in integrated networks where a constant frequency response is desired over a wide temperature range. For example, a high resistance film with a temperature coefficient of -250 ppm/degree C could be used in conjunction with a capacitor having a temperature coefficient of +250 ppm/degree C.

The oxygen-sputtered resistors can be substituted for the carbon composition type devices used in high-resistance circuits, and generally yield resistors with lower temperature coefficients.

Mr. Pendergast described tests made on these films in which the films showed resistance changes of less than 0.3 per cent after aging for 500 hours at 150 degree C. The stability of the films held up under 20 watt/square inch load at 25 degree C.

CS Long Lines Prepares for World-Wide Cable Project

CS Long Lines, the world's most modern telephone cable ship, arrived at Western Electric's Baltimore plant on her maiden voyage from Hamburg, West Germany, on Easter weekend.

In Mid-Summer, she will start her first project—work on the first trans-Atlantic telephone cable to link the U. S. directly with England. The ship's schedule over the next three years calls for placing nearly 16,000 miles of deep-sea cable in the Atlantic, Caribbean and Pacific oceans. The ship will also be used to help maintain 20,000 miles of ocean cable now in service.

The cable ship is named for AT&T's Long Lines Department, the Bell System's long distance operating arm, which provides nation-wide communications and overseas telephone service to more than 170 countries and areas.

New Ship for New Cable Repeaters

The \$19,000,000 vessel was designed to place the new armorless cable and two-way repeaters developed by Bell Telephone Laboratories. The new cable gets its strength from a core of 41 steel wires. The rigid repeaters, also of an entirely new design, provide two-way transmission over a single cable (*RECORD*, September 1962). Previous Bell System transoceanic systems used flexible repeaters and two cables—one for each direction of speech.

CS Long Lines features a unique cable repeater

handling system developed by the Laboratories that permits uninterrupted cable laying to provide precise control of slack, to minimize potential hazards to the cable system and to provide a facility capable of laying future systems without major modification.

A major feature of the system is a linear cable engine of novel design used to pay out cable and the bulky, rigid repeaters in a straight line at a steady speed of 800 ft./min. The cable engine somewhat resembles two tractors placed bottom to bottom so that their caterpillar tracks touch. It was designed and developed at Bell Laboratories, and built by the Western Gear Corporation.

Until now, a cable ship had to be either slowed or completely stopped to lay a bulky two-way repeater. However, stopping or changing the speed of a ship makes it difficult to control the descent of the cable into the ocean and increases the possibility of damage to the cable.

The new cable engine can grip both cable and repeaters between its flexible caterpillar tracks. Each track consists of 175 V-shaped blocks of forged aluminum attached to a continuous chain. The tracks are squeezed together by hydraulic forces applied through a compliant stationary belt in contact with rollers on the gripping blocks. The blocks grip the cable so that equal forces are applied 90 degrees apart.

Hydraulic motors at each end of the engine

drive the tracks. A control system regulates the hydraulic flow to brake or drive the cable. Since the cable is gripped by the blocks, pay-out control does not depend on friction induced by tension as is the case in other cable engines. The engine is 40-foot long, 15-foot high and 10-foot wide and weighs 85 tons.

To match the capabilities of the cable engine, new stowage arrangements for cable and repeaters had to be developed. Rigid repeaters had to be stored on deck rather than in the tank with the cable, so a scheme had to be devised to permit transfer of payout from the cable tank to the repeater location without slowing down. A full-scale mockup at Chester (the *CS Fantastic*) was the vehicle for new developments of slotted decks, crinolines and other cable handling devices that would meet all the requirements of continuous payout.

Facilities for Repair Operations

Twin drum-type cable engines are located in the bow section for repair operations. The bow sheaves are designed to pass rigid repeaters at slow speed where necessary. The drum engines and their auxiliary gear were also designed by the Laboratories and manufactured by Western Gear Corporation. They incorporate new arrangements for passing rigid repeaters at slow speed and versatile control systems for any operations required.

CS Long Lines was designed by Gibbs and Cox, Inc., New York naval architects, and built by Schlieker Werft in Hamburg. When the ship was about 90% complete, Schlieker Werft declared bankruptcy and Deutsche Werft, also in Hamburg, completed the ship.

The ship is 511 feet long and has a beam of 69 feet. The cruising speed is 15 knots. When carrying 2,000 nautical miles of armorless cable in her three cable tanks the displacement is 17,000 tons.

Built for efficiency and good control, *CS Long Lines* is powered by a steam-turbo electric propulsion system with twin screws and rudders. Her two propulsion plants total 8500 shaft horsepower. A third reversible propeller in a tunnel at the bow, called a bow jet, can force a jet of water out of either side, making exceptional maneuverability possible at low speeds. The ship can be controlled from the bow or stern as well as from the bridge for more precise maneuvering, and it can travel 10,000 miles without refueling.

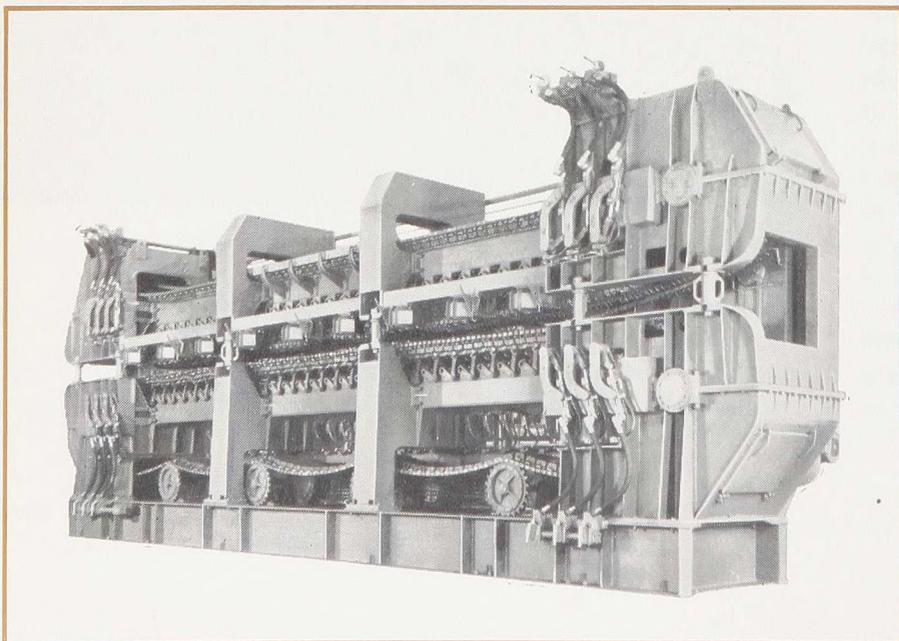
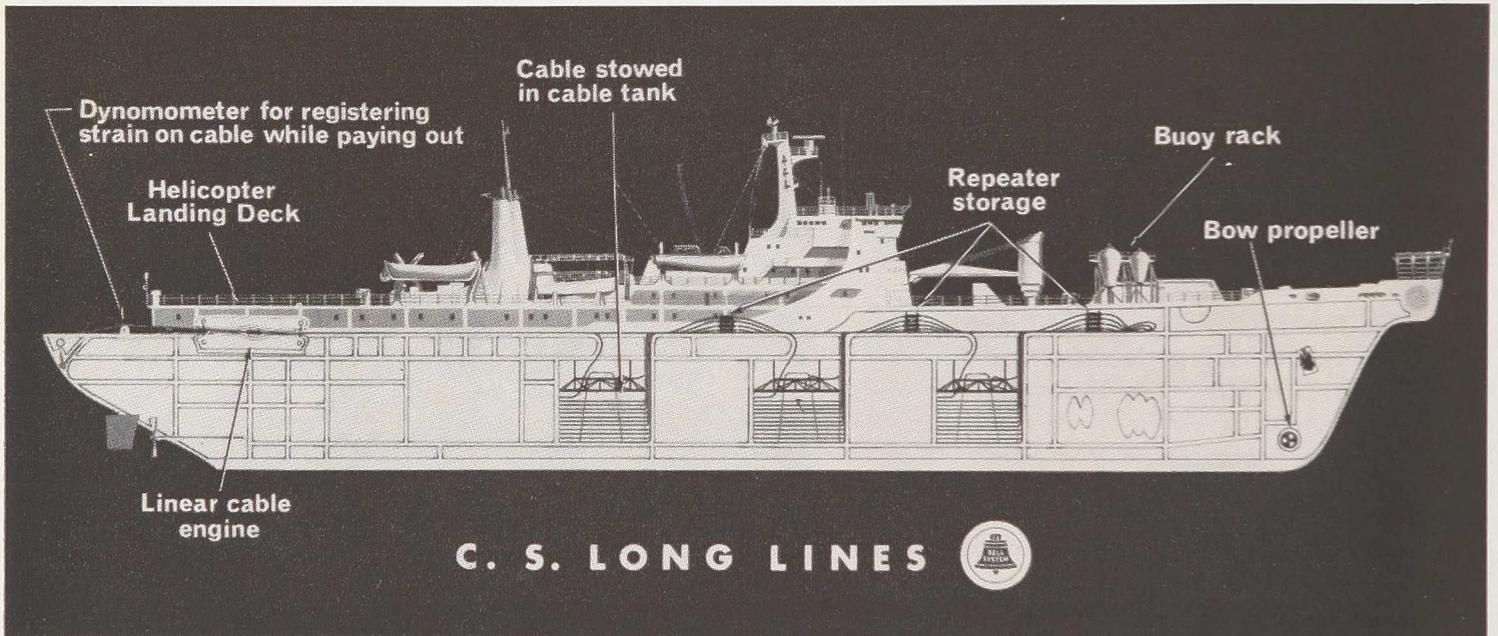
The ship is equipped with a modern testroom and facilities for maintenance of the large amount of electronic gear. A room is provided for central-



Completing its maiden voyage from Hamburg, West Germany, the CS Long Lines is nudged by a tug into its Baltimore berth. The Bell System's new cable ship has been designed to lay the armorless submarine cable and two-way telephone repeaters, both designed at Bell Laboratories.



Side view of the CS Long Lines (above) shows relative locations of major features and construction.



Linear cable engine (left) will pay out cable repeaters continuously. Above, 2nd Engineer Toher checks the electrical system's alarm con

ized control of the cable-laying operation. Facilities are provided for cable jointing and splicing and oceanographic work. The vessel is air-conditioned throughout and her cable-handling deck is enclosed so that work can be done under cover. The hull is strengthened to resist ice-damage.

Isthmian Lines, Inc. will operate the *CS Long Lines* under an American flag with an American crew of about 90 officers and seamen. Master of the *CS Long Lines*, Captain James H. Connelly was skipper of the U. S. Army Cable Ship, *Albert J. Myer*, which laid the Seattle-Alaska telephone cable and several military cables. The ship is owned by Transoceanic Cable Ship Company, Inc., a subsidiary of AT&T.

A Bell System PBX provides communications between all work locations. Radio facilities are provided for ship-to-ship and ship-to-shore communications. The ship can also communicate with the shore over the cable being laid.

A special facility to manufacture ocean cable has been built at the Baltimore Works of Western Electric to meet the growing demand for transoceanic submarine cable. The 160,000 square-foot, steel-walled building, with its specially designed manufacturing equipment, was in operation within thirteen months after the approval of the project.

Unlike conventional cable factories, where cables are made in a wide variety of designs and types, the new facility was expressly built to make one product—armorless telephone cable in continuous 23-mile lengths.

The manufacturing operation involves several operations in tandem as the product advances in a continuous pass from one step to the next (RECORD, *March* 1962). High strength steel wires are first stranded together to form a central strength member. The inner conducting member is then formed around this, rolled and drawn down until its inner surface is forced into the steel strand. Polyethylene is extruded over the copper inner conductor, and after cooling and shaving, the outer conductor is applied. Over this a high density, black polyethylene jacket is extruded to a finished diameter of 1 1/4 inches. The finished cable is coiled into pans and immersed in tanks of water for several days for electrical testing. Both ends of the cable are then terminated with 11-inch diameter gimbal-jointed beryllium copper couplings, which later allow the cable lengths to be quick-connected to the repeaters.

At loading time, the pans are towed on specially designed trailers to the dockside, where the cable is payed out of the pans and “walked” into circular tanks aboard the ship.

“CS Fantastic”

The *CS Long Lines* had a strange predecessor, a ship that wasn't a ship, called the “*CS Fantastic*”. A mock-up of the cable tanks and working decks of the *CS Long Lines*, known as the “*CS Fantastic*” for many months “floated” on a hilltop in Chester, N.J.

There, Bell Laboratories engineers carried out the most extensive modernization of cable ship equipment and techniques since the first telegraph cables were laid a century ago. They simulated deck layouts and cable handling operations of present and future cable ships. During cable laying experiments, for example, a winch pulled the cable out of tanks, down hill and around a sheave, simulating the cable being pulled into the sea by gravity.

Some of the design innovations that emerged from the “*CS Fantastic*” experiments were: slotted decks and crinolines to allow stored cable and repeaters to pay out continuously; recesses in the walls of the cable tanks from bottom to deck to store leads to repeaters; and arrangements for efficient storage of repeaters and associated leads in the cable working area.

When Bell Laboratories men stepped “ashore” from the “*CS Fantastic*,” they were 900 feet above sea level, on the slopes of windy Telegraph Hill in the Laboratories 120-acre outdoor test center. Above them the “*CS Fantastic*” stood 50 feet high, extending nearly 200 feet from stem to stern.

Construction of a life-size mock-up turned out to be more practicable and economical than chartering a cable ship for the long experimental periods necessary. In addition, many of the experiments needed could not be readily performed nor adequately observed aboard a real ship at sea. Engineers could watch their experiments taking place on the skeletonized “*CS Fantastic*” and took motion pictures for detailed later study.

The nautically-minded engineers had a set of international maritime signals they hoisted at the yardarm—to tell any other ships in the New Jersey hills to stand clear of cable-laying operations. But they never met another such ship, for the “*CS Fantastic*” was the only structure of its kind in the world.

Why Do Materials Stick Together?

Comprehensive Theory of Adhesion May Provide Answer

Scientists now know the most important physical-chemical property a material must have to adhere strongly to another. A comprehensive theory developed at Bell Telephone Laboratories departs radically from most past ideas on adhesion to show that, in principle, *any* two materials can be made to adhere strongly. The practical secret lies in knowing which of the two materials must be fluid when brought into contact with the other.

Same Criteria for Spreading and Bonding

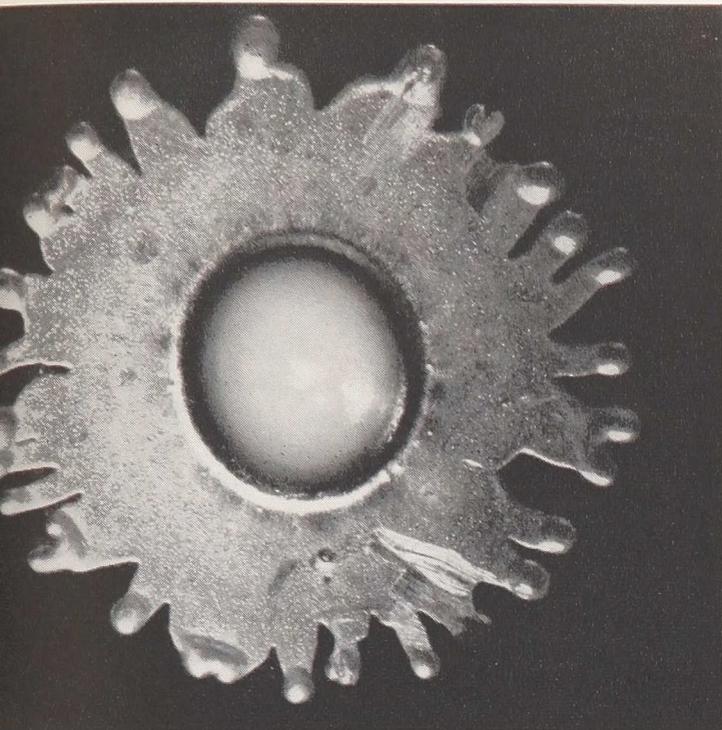
Drs. Louis Sharpe and Harold Schonhorn of the Chemical Research Laboratory explain adhesion in terms of the relative surface tensions (actually, surface free energies) of materials. They described their theory at the Kendall Award Symposium of the American Chemical Society held recently in Los Angeles.

The theory states that the criteria for thermodynamic spreading and for strong adhesion are basically the same; the only condition necessary for strong adhesion between pure A and pure B

is that either A spread on B, or B spread on A. (Thermodynamic spreading requires that the surface tension of the solid equals or exceeds the sum of the surface tension of the liquid plus that of the boundary between the liquid and solid.) Spreading is a nonreciprocal phenomenon—if pure A spreads on pure B, pure B will not spread on pure A. In a practical sense the same is true of adhesion. For example, a conventional epoxy resin adhesive cured in contact with polyethylene does not stick but polyethylene melted onto a cured epoxy resin adheres strongly.

Sharpe and Schonhorn emphasize that the theory applies to the *making* of adhesive bonds, and tells nothing about the breaking strength of an adhesive joint; the former belongs in the province of surface chemistry while the latter is primarily a matter of rheology and strength of materials.

The surface tensions of solids and of solid-liquid boundaries are, at present, not measurable in organic materials. Therefore, practical application of Sharpe and Schonhorn's theory requires



Top photo shows polyethylene spread from the molten state on a cured epoxy resin surface. Lower photo shows polyethylene spread from the molten state on a cross-linked polystyrene. Spreading is evident in both pictures, although the extent of spreading is somewhat less in lower photo.

the use of the concept of the critical surface tension of wetting first suggested by Dr. William A. Zisman of the Naval Research Laboratory in Washington, D. C. The critical surface tension of a smooth solid is the surface tension a liquid must have in order to just spread on that solid. In a practical sense, spreading of a liquid on a solid surface will occur when the liquid's surface tension equals or is less than the solid's critical surface tension. The surface tension of liquids and the critical surface tension of solids are measurable. Thus, scientists can decide whether one material will adhere strongly to another simply by knowing these physical-chemical properties of the materials under investigation.

Polar and Non-Polar Materials Bonded

Sharpe and Schonhorn's theory shows that the long-standing de Bruyne adhesion rule is incorrect. The rule states that strong joints can never be made with nonpolar adhesives and polar adherends. (A polar material consists of molecules with separated equal but opposite centers of electrical charge. Ideally, nonpolar materials have no such separation of charge.) Sharpe and Schonhorn have demonstrated that such nonpolar materials as polyethylene, polypropylene, Teflon FEP and other thermoplastics (materials with low surface tension) will adhere strongly to polar substances such as cured epoxy and metals (materials with higher surface tension). Conversely, however, the epoxy will not adhere strongly to these plastics. They emphasize that surface tension, rather than polarity, is the property of fundamental importance in adhesion.

The Laboratories scientists point out that materials such as polyethylene, polypropylene and Teflon FEP have low surface tensions and are, therefore, difficult to stick to. Because they are themselves low-surface-tension materials, however, they will stick to a wider variety of materials than most generally-used adhesives. This, say Sharpe and Schonhorn, is predicted by their theory and represents a radical departure from conventional thought. As a consequence, polymers of low surface tension have been defined as a completely new class of adhesive materials.

Sharpe and Schonhorn say that useful adhesive materials may result from appropriate substitution of fluorine or fluorinated side chains for hydrogen in hydrogen-containing polymers, since this substitution lowers the surface tension. They further suggest that a completely perfluoroalkyl-substitute polymethylene would be the "universal" adhesive.

Chromium Bromide Produces Strong Magnetic Effects on Light

Scientists at Bell Laboratories have discovered that light passing through crystals of ferromagnetic chromium tribromide is affected very strongly by the magnetic properties of the crystal. Making use of these properties in several experiments, they have obtained extremely large magnetic rotations of polarized light; and, in so doing they have modulated light at higher frequencies than ever before. In addition, they have literally seen, for the first time, ferromagnetic resonance and magnetostatic modes in the crystals.

J. F. Dillon, Jr. of the Solid-State Electronics Research Laboratory, H. Kamimura of the Semiconductor Research Laboratory, and J. P. Remeika of the Physical Research Laboratory, reporting in the April issue of the *Journal of Applied Physics*, observed that thin sections of chromium tribromide crystals (up to about a hundredth inch thick) are slightly transparent at 1.5 degrees K. If such a crystal is magnetized to saturation and plane-polarized light passed through it, the light's axis of polarization will be considerably rotated.

The amount of this magnetic rotation (which is a form of the Faraday rotation) is different for different wavelengths of light, and is proportional to the component of magnetization in the direction of the light and to the thickness of the crystal.

Extremely large magnetic rotations (over 600,000 degrees per cm) have been observed in chromium tribromide. Its transparency is so great that specimens may be used whose rotation is at least 100 times greater than that obtainable with any other known material. These optical properties of chromium tribromide make possible the modulation of light at microwave frequencies.

In the experiments, a disk of chromium tribromide was mounted in liquid helium in a transparent Dewar, as shown in the drawing. A steady magnetic field was then established in the plane of the disk, magnetizing the crystal. A microwave magnetic field was applied perpendicular to the plane of the disk, and plane-polarized light was shone through the face of the disk.

When not in resonance, the magnetization of the crystal lies in the plane of the disk, perpendicular to the direction of the light. However, at ferromagnetic resonance, the direction of magnetization precesses around the direction of the steady field. This means that a component of magnetization lies in the direction of the light, and its

strength varies at the microwave frequency.

Since the polarization of the light is rotated in proportion to this magnetization component, the axis of polarization of light emerging from the crystal at resonance is modulated at the microwave frequency.

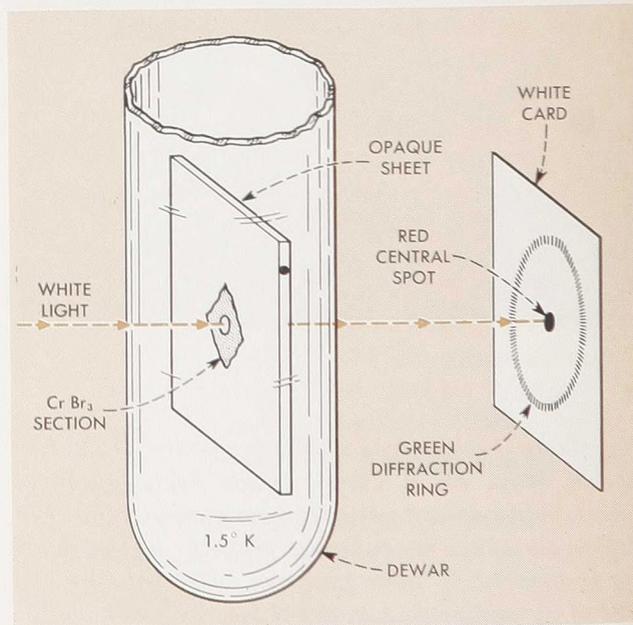
An analyzer converts this variation in the axis of polarization into an intensity modulation. If the analyzer is "crossed" relative to the polarizer, the intensity of the light is modulated at twice the microwave frequency. Plane polarized light was modulated at 23 gc and 46 gc, a higher frequency than light has ever before been modulated.

If the analyzer is crossed and the light passing through the crystal falls on a photomultiplier, ferromagnetic resonance can be observed as an increase in the photocurrent. Many resonant peaks can be easily observed in this way.

If the crystal is examined between crossed polarizers with a telescope as the magnetic field is swept across resonance, patterns of light and dark areas can easily be seen in the field of view. These patterns correspond to variations in the absorption of microwave energy; and are the so-called magnetostatic modes—ways in which the magnetization of a crystal responds to excitation by electromagnetic waves of proper resonant frequencies.

The experiments have also produced valuable spectroscopic information on the electron energy levels of chromium tribromide and have led to the formulation of a theory explaining the absorption associated with very large magnetic rotations.

Schematic drawing of experimental set-up.



SIMPLE TOOL FOR MEASURING MAGNETIC FIELDS

Easily made and rugged instruments for measuring strong magnetic fields in small spaces, such as the cores of superconducting solenoids, have been devised by Frank Hsu and J. E. Kunzler of the Metallurgical Research Laboratory. A typical instrument, which was used to measure the field distribution along the axis of a solenoid, has a diameter of 3/32 inches and a length of 1-1/4 inches. It consists of five 1/4-inch sections (or probes) of No. 36 commercial copper wire windings, each of which measures the average magnetic field passing through it.

The instrument makes use of the fact that the electrical resistance of copper wire in a high magnetic field at liquid helium temperatures increases greatly and almost linearly with an increase in the strength of the surrounding field. Field strengths from a few kilogauss to about 120 kilogauss have been measured by this instrument with a sensitivity of a few hundredths of a kilogauss. By using copper wire of greater than commercial purity, greater sensitivity is obtained.

NEW WIDE-BAND, HIGH-GAIN TRANSISTORIZED AMPLIFIER

A wide-band, high-gain microwave amplifier using common-emitter transistors has been developed by Joji Hamasaki of the Electron Device Laboratory for use in the 1150 to 1600-mc band. The amplifier consists of six stages on a printed circuit board. It has an almost flat gain characteristic of 32 db over the entire bandwidth with matched input and output impedances. The measured noise figure is 6.5 db at 1250 mc and the output level at which the gain is 1 db less than the small signal gain is 2 dbm. The amplifier requires 6 v and 30 milliamps of dc power. Its outside dimensions, including connectors, are 14.5 inches by 3.4 inches by 0.9 inches.

NEW GASEOUS LASERS

Scientists at Bell Laboratories have observed optical maser oscillation in four more gas systems: nitrogen, bromine, carbon monoxide, and sulphur hexafluoride. In addition, they have increased to more than 150 the number of different frequencies emitted by noble gas lasers.

The four new gas laser systems use a mechanism called "dissociative excitation transfer" in which a polyatomic molecule containing the required atom is broken up in such a way that the atom attains an excited state conducive to laser operation. Wavelengths in the polyatomic devices range from 0.8446 to 5.5971 microns.

Gas lasers now emit radiation ranging in wavelength from 0.6118 to 28.053 microns, more than halfway across the gap between light and microwaves.

Technical News Briefs (continued)

NEW PHENOMENON OBSERVED IN SUPERCONDUCTING TUNNEL DIODES

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

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

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

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

FLUX-GROWN RUBY FOR OPTICAL MASER

A flux-grown ruby crystal has been operated as an optical maser using a pair of natural faces as the feedback surfaces. Radiation losses through the crystal, when it is operated as a laser, are less than 1 per cent per pass, most of which are due to imperfect end mirrors. This loss is considerably smaller than that in rubies grown by the flame-fusion technique. Flux-grown rubies are grown slowly at temperatures far below the melting point. The resulting crystals have a homogeneity of the index of refraction, an absence of scattering centers, and faces whose flatness and parallelness are not obtainable by other known methods.

The feedback faces of the crystal are perpendicular to the optic axis and 5.5 mm apart. Because they naturally grow flat and parallel, there is no need for cutting and polishing the crystal. Interferometry measurements have shown the optical path length through the crystal to vary only about one tenth of a wavelength of red light over the entire reflecting face.

The process for growing ruby from a flux was developed at Bell Laboratories by Joseph P. Remeika of the Physical Research Laboratory. Donald F. Nelson of the Solid-State Electronics Research Laboratory performed the laser studies.

news in brief

Calls to Europe Now Dialed by Operators

Overseas operators in the United States and the United Kingdom began dialing direct to telephones across the Atlantic during March. According to the Long Lines Department of A.T.&T., this forward step in intercontinental telephony means faster service for trans-Atlantic callers.

The United Kingdom was the first European country to be linked to the North American dial network, followed the next day by West Germany. The dial network will be extended to France in July, and to Italy and Switzerland in the fall.

Most calls to any of the 9,000,000 telephones in the United Kingdom are dialed from the overseas gateway in White Plains, N. Y., and most calls to West Germany's 7,000,000 telephones from the gateway in New York City.

Overseas operators should have no language problem in handling calls. An arrangement has been provided to transmit a "language" digit whenever an operator dials an overseas call. If she needs help from a foreign operator, she presses a key which activates a signal carried by the "language" digit. This brings in a specially trained operator to assist on the call.

The dialing system now used between the U. S. and Europe has also been agreed upon for use between the United States and Australia, Japan and New Zealand. It will be introduced for service between the United States and Australia late in 1963, when North America and Australia are linked by a cable of the British Commonwealth countries. Operator dialing with Japan will follow in 1964 upon completion of a cable between Hawaii and Japan.

A. T. & T. Applies for Authorization to Own Stock in Communications Satellite Corporation

The American Telephone and Telegraph Company requested authorization in March from the Federal Communications Commission to own stock in the Communications Satellite Corporation.

Such authorization has been requested by some 50 communications companies. The international carriers who have applied are Hawaiian Telephone Company, International Telephone and Telegraph Corporation and Tropical Radio. The FCC has indicated that it will entertain applications from all communications common carriers furnishing interstate or foreign communications by wire or radio.

The request itself is not a commitment on the part of any applicant to purchase stock in the new corporation and the FCC's rules do not require that the applicant state the amount of stock that it is interested in acquiring.

The Commission's rules require an applicant to state why its application "will be consistent with the public interest, convenience and necessity." In answering this inquiry AT & T said, "As a United States international communications common carrier, AT&T has both a statutory and a public obligation to furnish service in an efficient manner and to provide adequate and reliable facilities for this purpose.

"AT&T's communications services between the United States and overseas points are currently provided almost exclusively through submarine cables and high frequency radio. Communications via satellites will afford another means of relaying long distance communications and will thus afford diversification of facilities and routings

needed to assure greater continuity and security of the international services which AT&T provides between the United States and overseas points.

"For this reason AT&T has an important interest in the successful establishment of the proposed communications satellite system and anticipates that it will be a substantial user of that system through the leasing of communications capacity from the newly established Communications Satellite Corporation.

"It would therefore seem clearly to be consistent with the public interest, convenience and necessity, that AT&T be among those communications common carriers who are authorized to support the establishment of the proposed communications satellite system by investment in the stock of the Communications Satellite Corporation as contemplated by the Communications Satellite Act of 1962."

Cable Linking Florida And Panama Complete

A new deep-sea telephone cable between Jamaica, W.I., and the Panama Canal Zone was placed in service last month. It is part of an undersea network planned for Central and South American points, and is linked to the Florida-Jamaica cable completed in February. Linking of the two cables provides high-quality voice paths between the U.S. and some 45,000 telephones on the Isthmus of Panama.

The \$25,000,000 system is a joint undertaking of A.T.&T., its subsidiary, Transoceanic Communications, Inc. and the International Telephone and Telegraph System. The cable, which extends 1450 miles from Florida via Kingston, Jamaica, to Fort Sherman in the Canal Zone, was laid by the cable ship *Alert*. The newly completed route consists of a single cable capable of transmitting 128 simultaneous conversations. The cable and two-way repeater are described in the article on page 204 of this issue.

P. J. Boddy Receives Award for Paper

P. J. Boddy of the Physical Research Laboratory has been selected as the winner of the 1962 Francis Mills Turner Award by the Electrochemical Society. The award, sponsored by the Reinhold Publishing Company, is presented in recognition of technical papers prepared by authors less than 31 years old.

Mr. Boddy's award was for papers co-authored with Walter H. Brattain, entitled "The Interface Between Germanium and a Purified Neutral Electrolyte," and "Effect of Cupric Ion on the Electrical Properties of the Germanium-Electrolyte Interface." The papers were published in the July and September issues of the *Journal of the Electrochemical Society* respectively.

The award consists of \$100 worth of scientific and technical publications.

Laboratories Authors Publish Six Books In 1962

Six technical books written by authors from Bell Laboratories were published during 1962. They were released by four different publishers.

Columbia University Press published two titles: *Crystal Orientation Manual* by Mrs. E. A. Wood; and *Modern Communications* by Messrs. G. G. Harris, T. H. Crowley, S. E. Miller, J. P. Runyon, and J. R. Pierce.

McGraw-Hill Publishing Company also released two: *Computing for Scientists and Engineers* by R. W. Hamming; and *Delay Tables for Finite Source Systems* by A. Descloux.

The two remaining books were: *A Methodology for Systems Engineering* by A. D. Hall, published by D. Van Nostrand and Co., and *Network Analysis and Synthesis* by F. F. Kuo, published by John Wiley and Sons.

"Talks" Listing Discontinued

Effective with this issue, the list of talks delivered by Laboratories' personnel is being discontinued. The list of papers and patents will be continued, but printing will occur quarterly, rather than monthly. This combined list will appear next in the June issue.

A list and index of talks approved for presentation are included in each issue of *Laboratories Talks and Papers*, published monthly by the Technical Information Library. Most of the functions of the previous listing in the RECORD are now being accomplished by this publication. Copies can be obtained by members of the Laboratories on request from R. A. Kennedy, Head, Library Systems Department at Murray Hill.

Vandenberg Award to Dickieson and Pierce

Alton C. Dickieson and John R. Pierce of Bell Laboratories have been named as co-recipients of the Arnold Air Society's General Hoyt S. Vandenberg Award for 1963 for their "contributions to space age research and development in the field of communications."

Mr. Dickieson, Executive Director, Transmission Division, is honored for "major contributions to the communications art in peace and war through the years, and as a major architect of the monumental Telstar satellite system."

Dr. Pierce, Executive Director, Research - Communications Principles and Communication Systems Divisions, is cited as "a pioneer contributor to communication research and a major contributor to wartime electronic development, (who) originated in 1954 . . . the first concrete American proposals for spaceborne radio relay. The Telstar satellite communication system . . . is credited as an outgrowth of his work."

Assuring Quality in Percussive Welds

A method of assuring high quality connections between wires and terminals while they are being percussively welded together has recently been developed at Bell Laboratories. The method increases the reliability of percussive welds in mass production.

According to J. C. Coyne of the Columbus Laboratory, you can expect less than one defective connection in 10,000 with proper continuous welding controls. Control of the process consists of measuring the duration of the arc and the approach speed of the wire for each weld, and setting up a rejection mechanism if the arc is too long or too short. Mr. Coyne developed a formula to determine the range of arc times for good welds between terminals and various wire types and gauges.

Some of the advantages of percussive welding are: wire and terminals covering a wide range of sizes and metals can be welded, without being cleaned or tinned beforehand; rapid heating is confined to a small area near the arc, hence there is no appreciable temperature rise beyond one wire diameter; less than one calorie of heat is liberated in about 200 microseconds, thus the welding operation is fast and efficient. Also, the process is excellent for making a number of butt connections to closely spaced terminals or to the same terminal.

Electrodes in the process are actually the wire and terminal. The wire moves toward the terminal at a regulated speed as a charged capacitor produces a 50-volt electrical field between the two materials. The wire tip and terminal arc just before they touch so that the wire begins to melt. Initially, melting exceeds the speed of the wire; as the capacitor discharges and voltage begins to decrease, melting slows up, the tip and terminal come together, and the weld is completed.

New Western Electric Engineering Research Center Opens

New laboratory and office facilities have been officially opened at Western Electric's Engineering Research Center. The Center, where some of the company's research scientists and engineers are developing new techniques for manufacture of telephone communications products, is located on a 192-acre tract in Hopewell Township near Princeton, N. J.

The work at the Center involves three areas of manufacturing operation: mechanization studies—the development of radically new concepts and techniques to permit automatic manufacture of communications apparatus; system studies—the application of mathematical techniques, automatic data processing and computer technology to plan and control production; and process studies—the application of the principles of chemistry, metallurgy and physics to manufacturing problems.

The Research Center staff works closely

with Bell Telephone Laboratories development engineers to evolve new manufacturing processes for new products designed by the Laboratories, as well as with engineers at various Western Electric plant locations to introduce new processes and improve existing ones.

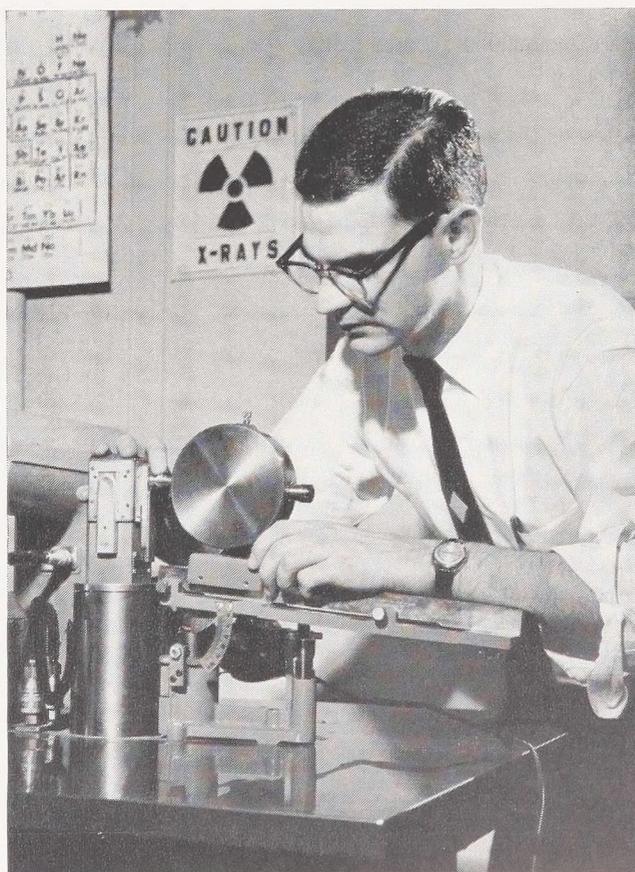
The new three-story main building, containing offices and the principal laboratories, and a one-story building, containing high ceiling laboratories and the Center's service facilities, provide a total of 138,000 square feet of floor space.

The exteriors of both buildings are of modern laboratory design with a polished glass and aluminum facade set in masonry foundation. The main building overlooks a 3½ acre manmade lake which serves as an emergency source of water for fire protection.

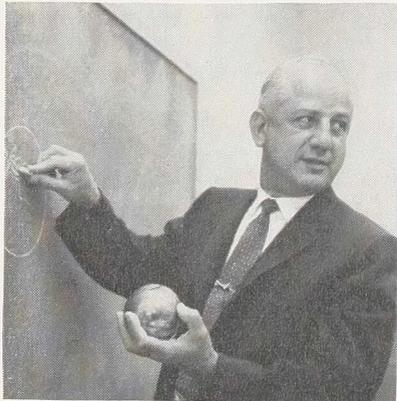
The present staff numbers nearly 300, including technical and administrative support personnel.



Western Electric's new Engineering Research Center. At right, research chemist Larry Morgenthaler operates an X-ray spectrophotometer in new laboratory.



AUTHORS



C. L. Sappet

C. L. Sappet, a native of Hudson, Mass., joined Bell Laboratories in 1943. He was assigned to Whippany where he has been associated with the mechanical design of radar equipment. His initial assignment was on military airborne equipment for the Army and Navy. He was later assigned to Army ground-based equipment, and since then has been associated with the mechanical design of all the NIKE systems. He presently has supervisory responsibility for the mechanical design of the NIKE-ZEUS Acquisition Antennas and supervisory responsibility for the Mechanical Laboratory at Whippany. Mr. Sappet attended Massachusetts Institute of Technology where he received his B.S. degree in Mechanical Engineering. He is co-author of the article on mechanical measurements in this issue.

E. D. Knab, co-author of "Mechanical Measurements — Basic Tool of Precision Engineering", is a native of Abington, Massachusetts. His Bell System service started in 1941 when he joined the Western Electric Company in Kearny, N. J. as an instrument and tool maker. A year later he transferred to the Laboratories in Whippany, N. J. where he continued until 1951, at which time he joined the Engineering Department. He was assigned to the Mechanical Laboratory in Whippany



E. D. Knab

where he engaged in problems dealing chiefly with mechanical design analysis, instrumentation, and methods of measurement. Among his particular projects has been the design and development of a high-speed rotary switch, a dynamic torque meter, a bellows coupling tester, printed circuit through-connections, and a coaxial beading tool on which he holds a patent. Mr. Knab, an Associate Member of the Technical Staff, studied at the Newark School of Fine and Industrial Arts, and graduated from there in 1934.

R. A. Hecht, author of "A New Connector for Printed Wiring Boards" in this issue, has been designing circuit components for over twenty-five years. He transferred to the Laboratories at its



R. A. Hecht

inception in 1925, after three years with Western Electric Company. During World War II he helped develop such items as connectors, plugs, jacks and sockets for military use. Before and after that time he designed similar items for application in telephone central offices. In 1958, Mr. Hecht was appointed supervisor of a Common Systems Apparatus group, and is continuing on new designs of coaxial and multicontact connectors. Mr. Hecht was born in Haledon, N. J., and was graduated from the Mechanical Engineering Evening Course at Newark Technical School. He now lives in Teaneck, N. J.



R. Morse

R. Morse, author of "New Eyes for Blind PBX Attendants," in this issue graduated from Northeastern University in 1941 with a B.S. degree in Industrial Engineering. During the second world war, as Project supervisor in the Applied Physics Laboratory at Johns Hopkins University, he was responsible for field-testing of the radio proximity fuze. In 1946, Mr. Morse joined the Laboratories and has been engaged in the design of various types of central-office switching equipment. Presently a supervisor in the Common Systems Apparatus group, Mr. Morse is responsible for the development of switchboard and frame apparatus. He is a native of Canton, Me.