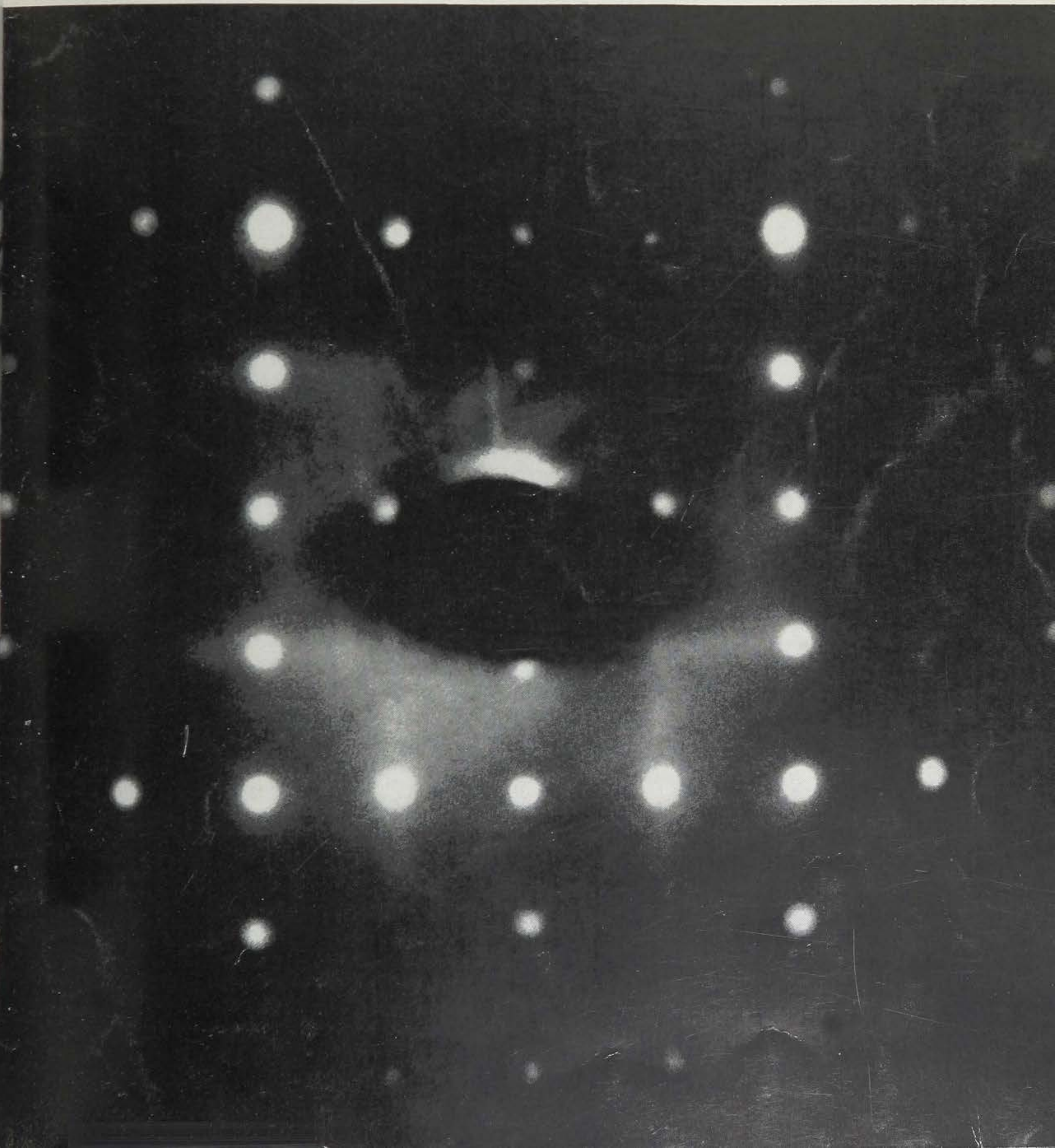
September 1962

Bell Laboratories

RECORD



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Bell Laboratories **RECORD**

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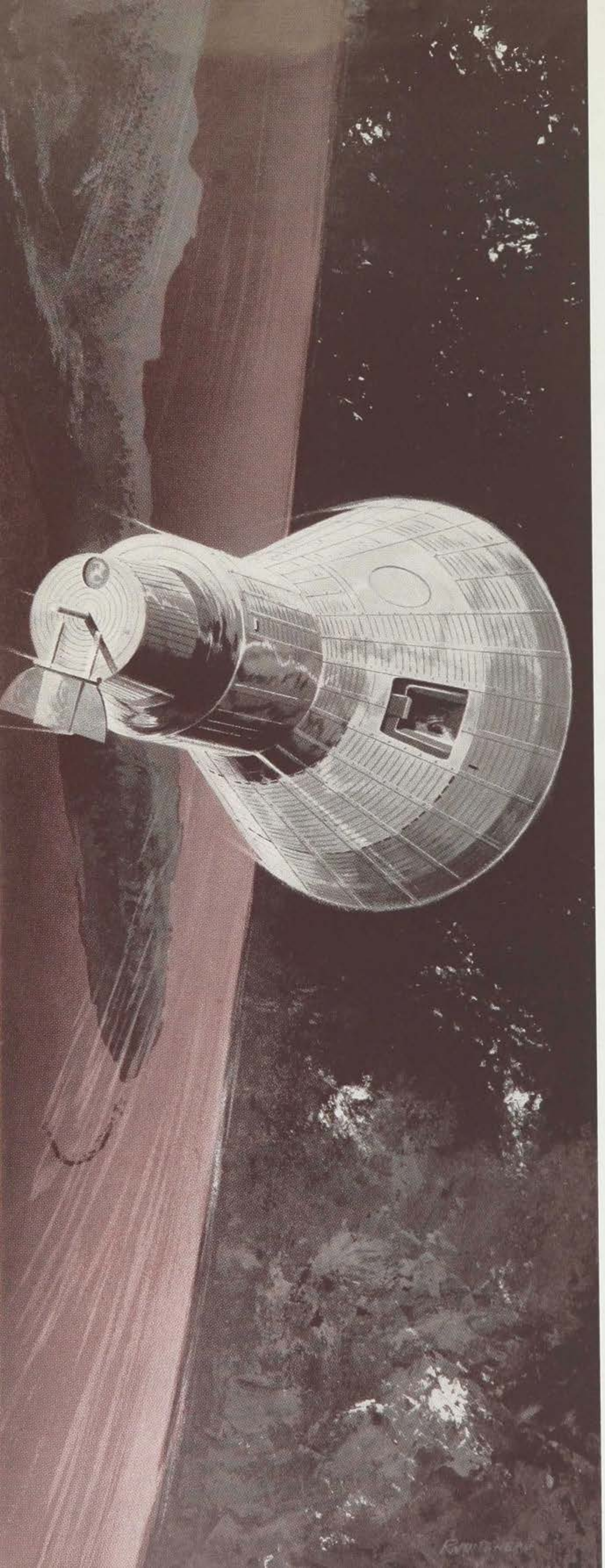
Contents

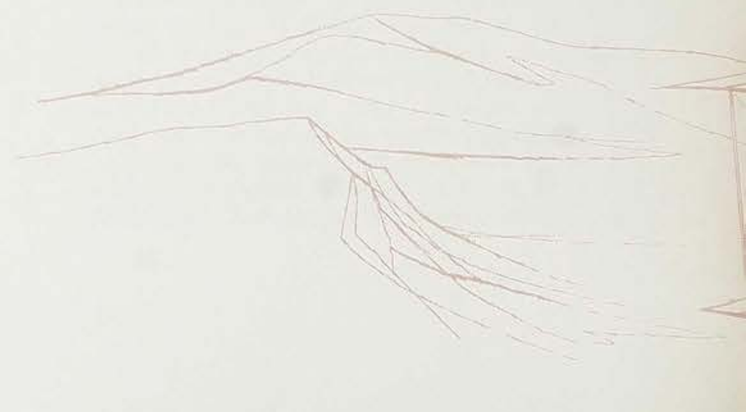
Cover *Slow electron diffraction pattern of a germanium surface is typical of the evidence used in studies of surface properties of solids at the Laboratories.* *(See story on page 282.)*



Bell Laboratori

In 1903, on the bleak dunes at Kitty Hawk, North Carolina, the world's first airplane rose 15 feet off the ground; that year the telephone industry was just beginning to revolutionize communication facilities. Any relationship between a long-distance voice communication system and Orville Wright's flying machine seemed tenuous or nonexistent. But in the course of less than 60 years, communication facilities pioneered by the Bell System have become indispensable to man's flight.

This relationship is exemplified by the close cooperation between the Bell System and the National Aeronautics and Space Administration (NASA). More than two years before Colonel John H. Glenn's Friendship 7 spacecraft soared around the earth, a team of Bell Laboratories scientists and engineers began work on the design, construction and installation of a worldwide Tracking and Ground Instrumentation System (TAGIS). Such a communication network is essential to placing an astronaut into orbit around the earth and recovering him safely. The industrial team responsible for the entire TAGIS project was led by the Western Electric Company. Other members of this team were the Bendix Corporation, International Business Machines, Burns & Roe and Bell Telephone Laboratories.



The invention of the telephone and its impact on communications is no less vital to space flight than the advance of rocketry itself. This interdependence is exemplified by Project Mercury.

nd Project Mercury

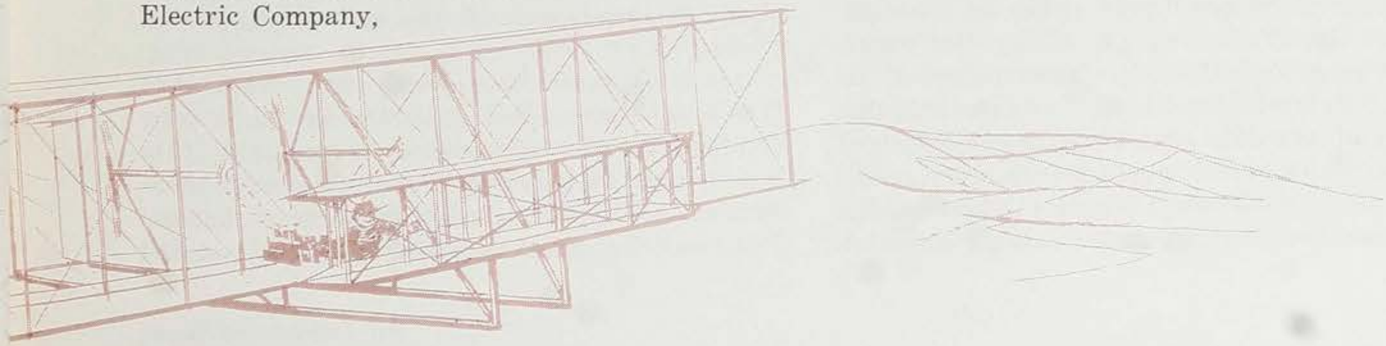
J. J. Hibbert

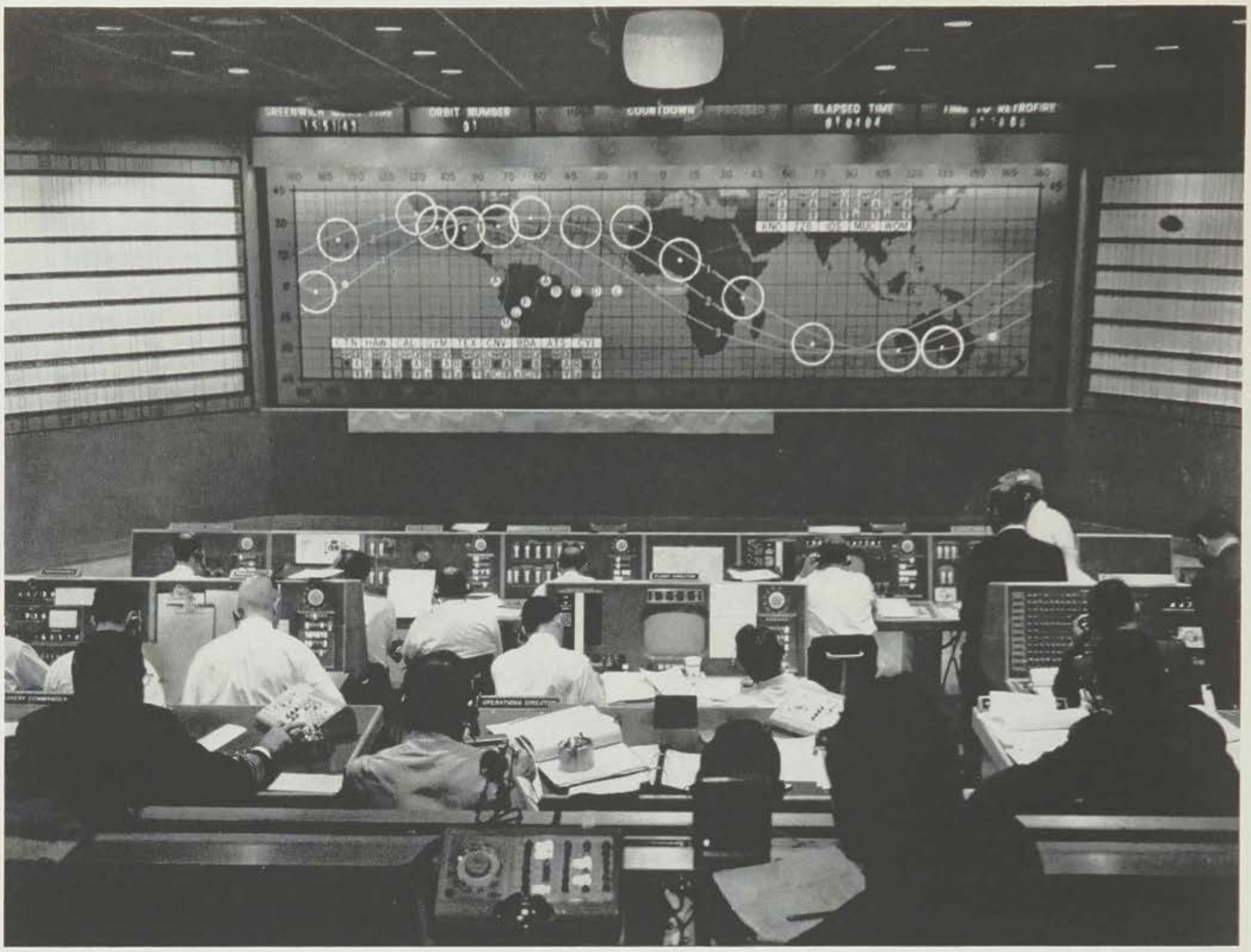
The Mercury Range, as TAGIS is more frequently called, consists of 18 sites at points around the world which (1) track the spacecraft, (2) monitor the status of the spacecraft and its occupant by telemetered signals, (3) provide voice communication with the astronaut and (4) transmit commands to the spacecraft (e.g., to fire retro-rockets). Mercury Control Center at Cape Canaveral monitors the spacecraft during its launch, orbit and re-entry. This primary control center bases its decisions on data obtained from the world-wide network of Mercury tracking sites. These data are transmitted from the Range sites to the Goddard Space Flight Center in Greenbelt, Md., where they are processed by computers and sent to Cape Canaveral.

The TAGIS sites are connected by an extensive communication network. Almost all types of transmission media are used to provide teletypewriter communication between Cape Canaveral and every site and voice communication between Canaveral and all but five sites. In addition to the communication equipment provided by the Bell System, facilities are leased from 20 domestic and foreign common carriers with the cooperation of eight national governments.

While the over-all project management was the responsibility of the Western Electric Company, Bell Laboratories was responsible for system analysis and evaluation, control centers, a training simulator, and consultation on various technical problems. The tasks performed by the Laboratories for Project Mercury can be divided into four categories: equipment design and procurement, equipment engineering, development of operational procedures, and Range evaluation.

The equipment provided for the Project Mercury Range by the Laboratories includes the Operations Rooms at Cape Canaveral and at Bermuda, and the simulator used at Cape Canaveral to train flight controllers (RECORD, *October, 1961*). The Operations Room at Mercury Control Center, Cape Canaveral, is the focal point of the Mercury Range. Here, all information pertinent to the mission is received from all the other Mercury Range sites. The photograph on page 278 shows the Operations Room where 11 flight controllers control the activities of the Range under the direction of the Flight Director. Three of the flight controllers — the Capsule Communicator, the Capsule Systems Monitor and the Flight Surgeon—have their counterparts at 13 other Mercury sites. Whenever the spacecraft is in range of Cape Canaveral, telemetry data transmitted from the capsule actuates the displays on the flight controller consoles in the Control Center.





Mercury Control Center, Cape Canaveral. The position of the spacecraft, the status of its equipment, and the physical condition of the astronaut are continuously monitored and recorded. Such data, obtained from tracking stations around the world, are funneled into this control center.

At other times, while the capsule is orbiting the earth, the information obtained by flight controllers at various TAGIS sites is sent back to the flight controllers at the Mercury Control Center over teletypewriter circuits. Operators at the control center also insert these data on meters on the consoles and plot important quantities (such as temperatures and heart rate) from the capsule and astronaut on the status boards that flank the large map. The position of the capsule is computed at Goddard and transmitted to Mercury Control for automatic display on the map.

The four plot boards on the right side of the Operations Room are driven either by the computer at Cape Canaveral or, during the launch and during orbital flight, by the computers at the Goddard Space Flight Center. These boards display significant data regarding the trajectory of the Atlas launch vehicle and the Mercury spacecraft and aid the Flight Dynamics Officer and the Retrofire Controller in determining the condition of the flight. As the astronaut orbits the earth, flight information is transmitted from outlying sites to Mercury Control Center. Orders from the Flight Director to modify the duration of the mission are sent directly to sites that have command facilities.

A secondary control center in Bermuda determines the validity of the space capsule's orbit. If it is not apparent from data available at the Mercury Control Center whether the orbit is definitely good or definitely bad, the authority to stop or continue the mission is delegated to the Bermuda Control Center which is geographically closer to the capsule at the end of the launch phase.

After several discussions with NASA and Western Electric, Bell Laboratories prepared a specification of requirements for equipment in the Operations Rooms at Cape Canaveral and at Bermuda. The Electronics division of General Dynamics Corporation constructed and installed this equipment. By July, 1960, the Operations Rooms at both Canaveral and Bermuda were equipped and undergoing tests.

Although the major features of the Mercury system had been established by NASA, a systems-analysis group was set up in November, 1959, to review equipment performance and procedures. The group, which consisted of members of NASA, Lincoln Laboratory, and all team members, convened at the Laboratories during November and December, 1959. A formal report of the group's work was issued early in 1960, and it served as a guide for the remainder of the project.

There were continuing problems of making certain that the Range equipment was compatible with capsule equipment. An example of such a problem concerns the Acquisition Aid equipment. (This is automatic telemetry tracking gear which, because of its broad (20°) antenna beam, is usually the first to acquire the spacecraft over a site.) The Acquisition Aid was originally designed to track only the carrier frequency of the telemetry transmitter in the capsule. It was believed that the degree of modulation used in the telemetry system would provide an adequate margin of signal power at the carrier frequency. Unfortunately, it was discovered during tests that the degree of modulation was such that, for certain magnitudes of telemetered data, only a small amount of carrier signal strength was present. In these cases, the Acquisition Aid lost the signal. The problem was quickly resolved by increasing the bandwidth of the Acquisition Aid to accept the sidebands as well as the carrier frequency of the telemetry transmitter.

Another type of equipment engineering undertaken by the Laboratories was the development of diagrams to show all of the equipment used at each site to delineate their interfaces. This task, initiated by the Laboratories, was continued by a systems-engineering group composed of representatives of all members of the Mercury team. In this way, over-all site equipment diagrams obtained early in the program permitted expeditious installation.

The Laboratories also participated in the preparation of test specifications for the equipment used at the range sites. These specifications were used in testing site equipment and verifying its performance. After discussions with NASA, it was decided that three levels of testing should be provided: (1) unit tests (e.g., a radar receiver), (2) subsystem tests (e.g., the radar subsystem), and (3) integrated subsystem tests (e.g., the acquisition system comprising the radars and the Acquisition Aid). Although most of the unit tests were prepared by the team members who supplied the equipment, the Laboratories was primarily responsible for the two higher levels of tests. The 25 specifications for these tests were first tried out with actual equipment at the Mercury Demonstration Site at Wallops Island, Virginia. Several members of the Laboratories, stationed at Wallops Island during this period, checked and verified the test specifications. Subsequently, revised specifications were approved by NASA, issued by Western Electric, and distributed to all range sites. The tests were used to determine whether the equipment would satisfy the requirements of the Mercury Range and served as a basis for NASA's acceptance of the Range equipment.

Laboratories Was Technical Consultant

As the technical consultant to the Mercury Project, the Laboratories contributed to the solution of a number of special problems involving Range equipment and operation. These studies included the investigation of interference between various units at each site, the selection of the intercom system to be used for intrasite communications, the choice of an appropriate boresight camera for the tracking antennas, the removal of interference from power supplies, and the redesigning of shipboard equipment to avoid the effects of vibration. Other special problems concerned the testing of the high-speed data lines between Cape Canaveral and the computers at Goddard Space Flight Center.

Throughout the project, the Laboratories monitored the computing and programming developments and served as advisor to Western Electric on such tasks. This work included studies of data processing, computer programming, geophysical effects upon the orbits, and the effects of radar errors on the computation.

One of the major requirements for large systems such as the Mercury Range is the definition of appropriate operational procedures. The generation of such procedures is a challenging and frustrating task. The frustration is the result of the changing character of the problem. The operational procedures were first prepared by the Laboratories, revised by Western Electric's training division, and completed by NASA under operational trials. The Laboratories prepared detailed operational plans in which the activities of the maintenance and operational personnel were prescribed for the sites at Cape Canaveral, Bermuda, Grand Canary Island, and Muchea, Australia. The NASA Space Task Group established the procedures for Flight Controllers at all sites.

One significant characteristic of the Mercury

Symbols

- ■ *Goddard Space Flight Center*
- *Land Lines*
- *Submarine Cable*
- *Radio*
- *Alternate Route*

Project Mercury Ground Communications

1. *Cape Canaveral, Florida*
2. *Grand Bahama Island*
3. *Grand Turk Island*
4. *Bermuda*
5. *Atlantic Ship*
6. *Grand Canary Island*
7. *West Central Africa*
8. *East Africa*
9. *Indian Ocean Ship*
10. *Muchea, Australia*
11. *Woomera, Australia*
12. *Canton Island*
13. *Kauai Island, Hawaii*
14. *Point Arguello, Califo*
15. *Guaymas, Mexico*
16. *White Sands, New Me*
17. *Corpus Christi, Texas*
18. *Eglin, Florida*

Range is that it was the first range designed to be operated, if necessary, by teletypewriter messages alone. Previous range operations depended primarily on voice communication. This was not available to five Mercury sites. Thus, a major task was establishing the format and character of the teletypewriter messages that would be used during an operational mission. These formats, with some modifications by Western Electric and by NASA after several trials, were used in the subsequent Mercury missions.

To determine the operational adequacy of the instrumentation and manning of the remote sites of the Mercury range, a series of tests was conducted at Wallops Island during November and December, 1961. These tests, called the Demonstration Site Operational Test Series (DSOTS), simulated the passage of the Mercury spacecraft in real time over the Canary Islands. The preparation and conduct of the DSOTS was a team effort of the Western Electric Company, Lincoln Laboratory, and Bell Laboratories. All equipment, except the radar, was operated according to established procedures, and an observer monitored each operating position and noted the timing of specific events as well as the over-all efficiency of the operations.

In addition to tests with all equipment operating normally, tests were also made with programmed equipment malfunctions. One objective of these tests was to determine whether the equipment and established procedures provided the operators sufficient time to complete their tasks during a capsule pass. The tests showed that the site instrumentation and manning were generally satisfactory. However, some changes in procedures resulted. This was the first time that flight controllers worked as a team with the equipment operators, and the procedures were modified to integrate their operations.

During these tests, the site received simulated teletypewriter messages appropriate to the mission; magnetic tape activated the telemetry displays; one of the operating personnel simulated the voice of the astronaut. Antennas, pointed at the boresight tower, were made to appear to be moving on the operators' displays. This was done by inserting differential synchros between the azimuth and elevation antenna servo and the operators' display. These synchros were adjusted during each simulated pass to make the received signal appear as though it were coming from an object in transit from the western to the eastern horizon. The telemetry signal was in all cases actually radiated from the boresight tower. Attenuators in the voice and telemetry rf circuits were varied during the pass to simulate both the change in range to the spacecraft and the antenna lobe patterns. In this way, the simulated passage of the capsule over the Canary Islands site became quite realistic.

Subsequently, NASA and Western Electric used similar exercises at Wallops Island to refine the operational procedures. The revised procedures were used at each Mercury Range site for training the operating personnel.

In early 1961, after the site equipment was installed and the training program completed, NASA requested that the ability of the entire Range to support the first Mercury mission be established. On behalf of the Western Electric Company, the Laboratories conducted a program to determine the readiness of the Mercury range to support the Mercury Atlas (MA-3) mission, which was scheduled for the Spring of 1961. The original MA-3 mission for an instrumented spacecraft was not planned to go into a complete orbit but to impact in the vicinity of the Canary Islands. Engineers from Bell Laboratories and Western Electric evaluated the condition of each site involved in the mission and monitored the conduct of Range exercises in which these sites operated together in simulated missions in real time. During these simulated missions, three types of exercises were conducted: (1) the nominal MA-3 mission, (2) an aborted mission resulting in a landing near a ship in the Atlantic Ocean and (3) an over-speed mission in which the capsule attained sufficient velocity to continue in orbit beyond the Canary Islands.

Astronaut Walter J. Schirra indicates switch which sends signal to fire retro-rockets in spacecraft to slow it down for its re-entry and recovery.

Actual Flight Tests Needed

Despite the success of the tests that were conducted, the performance of TAGIS had to be confirmed during an actual orbital flight. This proof came on September 13, 1961, with the successful single-orbit flight of the Mercury Atlas-4, an unmanned instrumented spacecraft. The flight and recovery of this capsule definitely established the over-all adequacy of the range equipment and procedures of the Mercury Range.

Since that time, the participation of the Laboratories in Project Mercury has been in connection with the communication system for the Range. This work began in July, 1961, and is an evaluation of the performance of the world-wide communication network. Computer simulation is used to determine methods of making optimum use of the TAGIS communication paths and to determine the accuracy and timeliness of messages during actual missions. In addition, the performance of the circuits having radio links is given special scrutiny to establish the effects of ionospheric propagation.

Aside from its technical challenge, work on Project Mercury at Bell Laboratories provided contact with the NASA personnel who were given the task of sending an astronaut into orbit and recovering him safely. This association convinced those involved that this task was being handled capably and that when the first astronaut journeyed into orbit around the Earth he would return safely. The performance of the Mercury Range during recent manned orbital missions amply justifies this conviction.

In solids, we know less about the surface than about the bulk. Since surface properties are important in many areas, they are being studied intensively at the Laboratories.

The Surfaces of Solids

H. D. Hagstrum

Many physical phenomena of vital interest to mankind occur at the surfaces of solids. For example, the surface or interface between phases of matter is of central importance in biology and catalytic chemistry. Electrons are released through the surfaces of both hot and cold cathodes in electron tubes. Crystals grow at their surfaces. Surfaces corrode and wear.

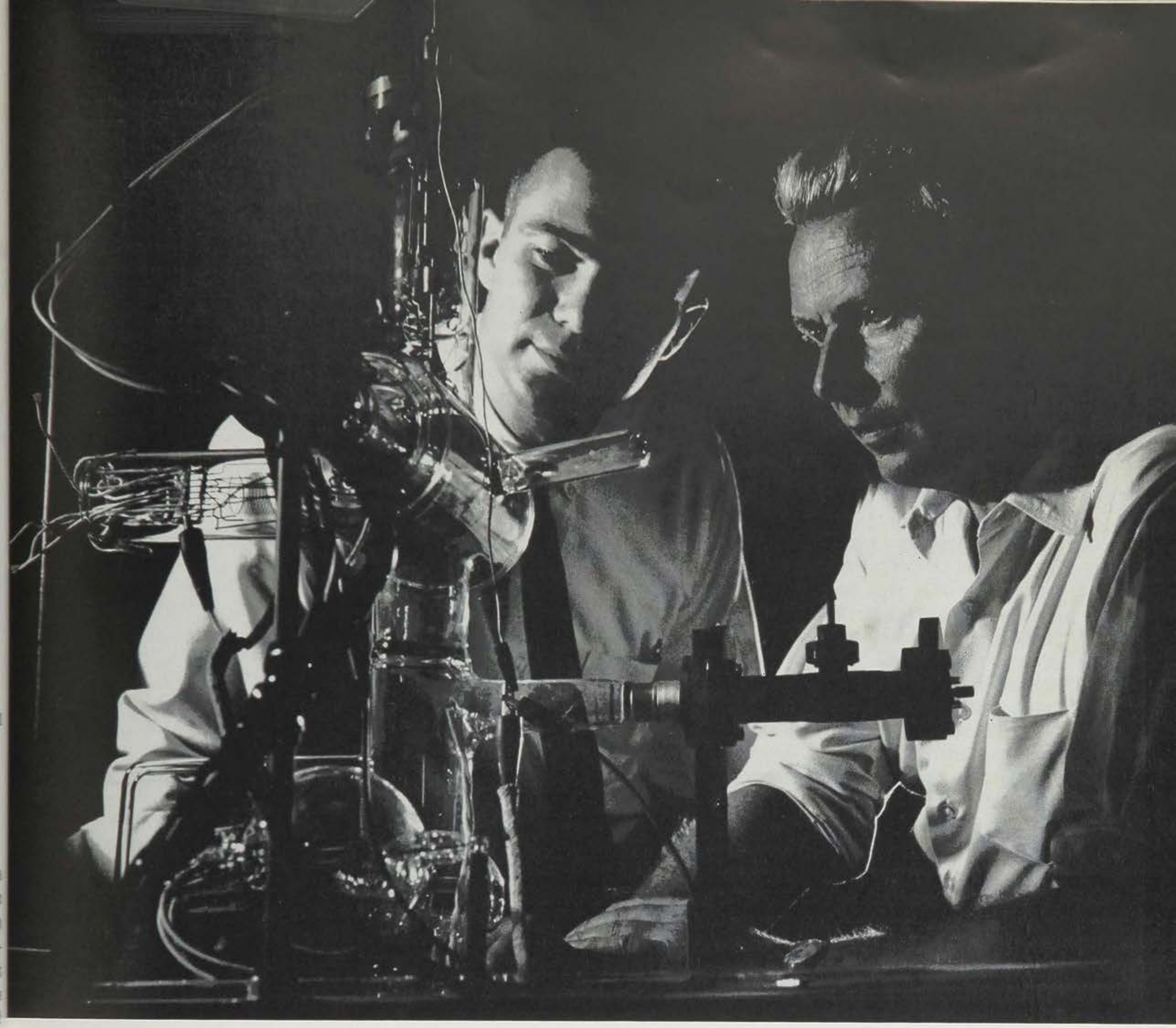
One basic interest of the Bell System in surfaces concerns properties important to electron devices. Much effort has gone into the study of thermionic, photoelectric, and secondary electron emission. Scientists have also studied the adsorption of gases or vapors which either enhance or deteriorate electron emission. When solid state electronic devices appeared, a whole new set of surface phenomena demanded understanding. Many of these are basic to the functioning of a device, as in the point-contact, field-effect, and epitaxial transistors.

In other ways, surface effects have to do principally, but no less importantly, with the malfunctioning of a device. The formation of surface channels, surface recombination of carriers, and long-term surface changes limiting the life of devices have been studied and minimized. It is safe to predict that the new field of thin film devices and circuits will be intimately bound up with surface science. There is preliminary evidence that the interaction of optical maser light (RECORD, *October,* 1960) with the surface layers of solids will show scientifically interesting and exploitable effects.

Viewed broadly, the basic phenomena concerned with the electrical properties of solid surfaces fall into three categories:

1. Surface chemistry,
2. Surface crystallography, and
3. Surface energy level structure.

Surface chemistry, as used here, does not include all of that vast area which these words imply to the chemist. We seek the answers to questions such as: What is the identity of any foreign atoms present on the surface? How strongly and by what type of forces are these atoms held to the surface? How do surface atoms move about and rearrange their chemical associations? What is the atomic "traffic" between the surface layer, the bulk lattice underneath,



A. U. MacRae (left) and J. J. Lander observe the pattern produced by a crystalline sample in a post-acceleration diffraction tube during an experiment in surface crystallography.

and a surrounding gas or liquid?

Surface crystallography relates to the geometrical structure of solid surfaces. We ask: Where in detail are surface atoms to be found? What are the two-dimensional structures into which surface atoms, whether of the bulk crystal or foreign, can arrange themselves? At what rate does transformation occur from one such configuration to another, especially as a function of temperature?

Surface energy level structure specifies where electrons may reside on an energy scale at the surface of a solid. We should like to know what electronic energy levels or states exist at a surface because the solid terminates, has surface imperfections, or because known foreign atoms are adsorbed at the surface in a known array. What effect, if any, does the surface have on electronic states in the bulk? How much work must be expended to remove a specific electron from the solid? How rapidly do surface electron levels or traps fill and empty?

Two points should be made with respect to the categories listed above. First, there is a direct analogy between the chemical, crystallographic, and energy level information about the surface and the bulk of a solid. Thus, one might say that the "surface scientist" is trying to do for the surface what has been and is being done so successfully for the bulk. But we must not press this analogy too far. Because he wants to study the surface and *not* the bulk, the surface scientist must devise experiments and equip himself with diagnostic tools which are *specific to the surface* and which enable him not only to observe but to control what is happening there. Thus, the experiments undertaken and the tools used might differ drastically from those employed in the studies of bulk properties.

A second point, which also applies to the bulk, is that the most fruitful experiments are those which do not limit themselves to a single one of the above categories. Thus, surface chemistry is strongly illuminated by surface crystallography. The electronic energy level structure must be related to the crystallography and chemistry of the surface, and so forth.

Work of the type we are discussing began prior to World War II. Various electron emission phenomena were used to study the electrical effects of adsorbed atoms, as well as the nature of the interaction between atoms and solid surfaces. An example of this is the classic work of Irving Langmuir of the General Electric Company and Joseph Becker of Bell Telephone Laboratories on the interaction of cesium atoms and ions with a tungsten surface using thermionic emission as the detector. In 1928, following the first demonstration of low-energy electron diffraction from crystalline solids, Lester Germer at the Laboratories showed that such techniques could detect the presence and reveal the configuration of gas atoms adsorbed on a crystal surface. This was the earliest surface crystallography. Prof. Farnsworth and his associates at Brown University have continued work of this type in the intervening years.

Since World War I, interest has been renewed in surface studies for two basic reasons. First, the developing semiconductor science and technology provided highly surface-sensitive materials exhibiting many new phenomena. Second, improvement in the techniques for producing ultrahigh vacua made possible a variety of experiments hitherto questionable at best. In the remainder of this article we shall discuss briefly some of the recent work, principally done at Bell Laboratories, concerned with fundamental understanding of the chemistry, crystallography, and energy level structure of solid surfaces.

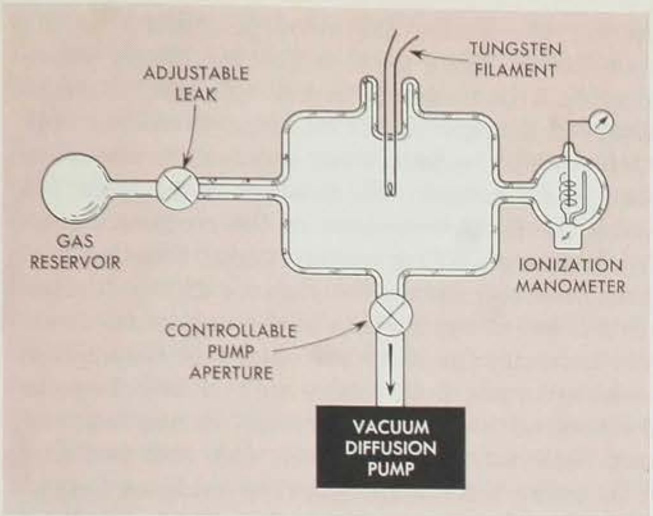
Basic to progress in surface science is the production and identification of an atomically clean surface. This is as fundamental to surface studies as was the production of the pure, intrinsic semiconductor to understanding bulk properties. Several cleaning methods, executed in ultrahigh vacuum with the use of several "surface-sensitive" phenomena as monitors, have made it possible to produce semiconductor surfaces which are atomically clean. These methods are heating, bombardment with ions (sputtering), cleavage, and chemical interaction with specific gases. Means used to "observe" the surface are adsorption, photoelectric emission, low-energy electron diffraction, field emission of electrons and ions, reflection of polarized light, internal reflection of infrared radiation in semiconductors, and electron ejection by ions. Adsorbed species have also been detected by their radioactivity, by dissociating them from the surface by electron impact, and by weighing either with a microbalance or by detecting the shift of piezoelectric frequency.

The magnitude of the vacuum problem in surface work is indicated by the fact that an atomically clean tungsten surface will cover over with a monolayer of adsorbed atoms in 1 second when exposed to nitrogen at a pressure of only 10^{-6} torr (mm Hg). Thus, it is necessary to do this work at considerably lower pressure (10^{-10} torr). Previously, it was possible to be sure of an atomically clean surface only for refractory metals which could be heated hot enough to break thermally the bond between the surface and any foreign atom upon it. The range of materials for which atomically clean surfaces can be produced has now been extended considerably.

Surface Chemistry

When one has produced an atomically clean surface, he may proceed with confidence to study its interactions with its environment. When clean, many solids readily adsorb a surface layer from the surrounding gas. Since the study of adsorption is a basic surface experiment, we shall indicate briefly one method by which it may be carried out for the case, say, of nitrogen on tungsten.

The vacuum system needed consists of an enclosure, a pump with controllable aperture, an ionization manometer, a tungsten filament, and a controllable gas inlet leak, as shown at top, next page. When the surface of the filament is covered, as is the case after long exposure to an adsorbable gas, the ambient pressure will be p_0, as plotted at lower right. If the filament is then heated to a high temperature, the surface will release its adsorbed gas into the enclosure, increasing the pressure by an increment, Δp. After this gas has been pumped out, the filament is cooled to room temperature. At this point, the pressure drops below the ambient



Simplified vacuum system, adsorption experiment.

p_0, because the adsorption onto the clean, cold filament surface acts as another pump. This condition prevails until the surface is completely covered, at which time the adsorption cycle is complete, and the pressure has returned to p_0. If one heats the filament before the whole monolayer forms, a smaller pressure increment will be produced which is proportional to the time interval during which the filament was cold, and thus to the amount of gas adsorbed. Plotting the pressure increment against the "cold interval," Δt_c, yields the curve shown at lower right.

This experiment is simple, yet it measures a basic adsorption parameter, the sticking probability, s, of the ambient gas on the clean surface. This is a measure of the probability that a gas atom or molecule arriving at the surface will stay there. The combination of the sticking probability and the pressure (which determines the arrival rate of molecules at the surface) determines the time required to form a monolayer.

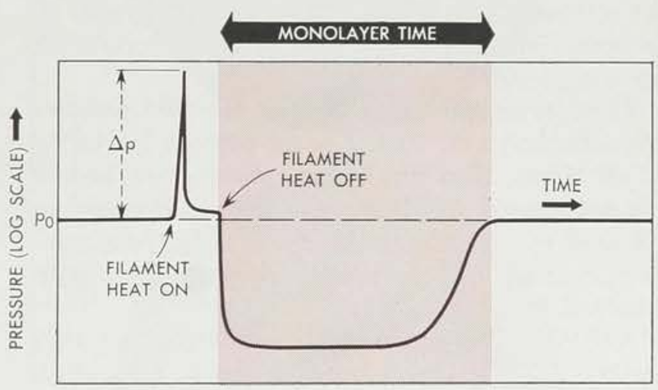
Measurement of the adsorption cycle is now standard in surface work, and is used in many more complicated surface experiments, such as photoelectric emission or low-energy electron diffraction. The adsorption experiment in each case helps describe the state of the solid surface with regard to its coverage with a foreign gas.

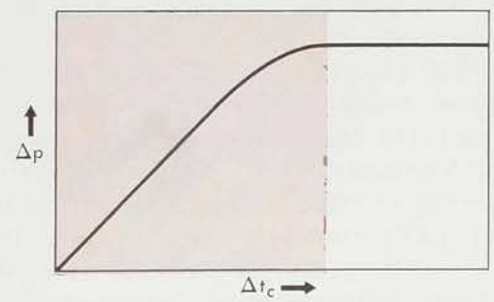
Other surface chemical experiments include the measurement of rates of oxidation, rates of desorption of known gases from the surface, and the energies with which adsorbed atoms are held at a surface. An interesting problem concerns the state of molecular aggregation on the surface; for instance, does a nitrogen molecule (N_2) maintain its identity on the surface or does it split up into completely independent N atoms? The migration of adsorbed atoms over the surface and how this is related to the underlying crystallographic structure has been studied with the field emission microscope. With this instrument we can also determine the electrical dipole moment of adsorbed atoms on different crystallographic planes.

Although much has been said about the importance of atomically clean surfaces and such surfaces with known atoms adsorbed upon them, studies can also be carried out with reproducible surfaces whose detailed chemical identity is less certain. An example of such a surface is the interface between a semiconductor and an electrolyte, which will be discussed later. Here it may eventually be possible to deduce the nature of the surface composition from chemical evidence. Many other problems in the chemistry of surfaces also remain to be solved.

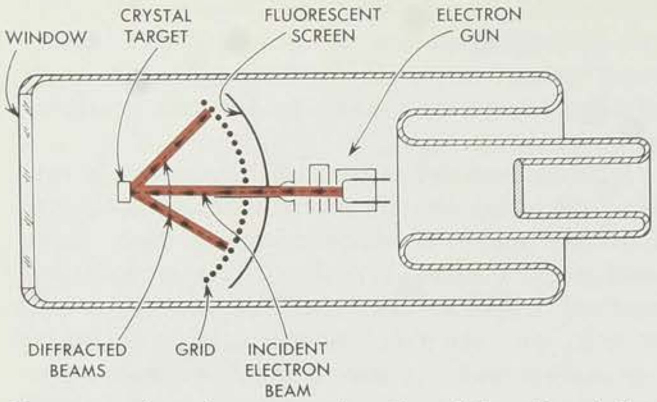
Surface Crystallography

Turning now to surface crystallography, the study of the geometrical arrangement of surface atoms, we are witnessing a remarkable resurgence of interest. Much of this has developed from the so-called post-acceleration diffraction tube, first devised by W. Ehrenberg in Europe in 1934 and recently perfected at Bell Laboratories. Such a device, in its simplest possible form, is shown schematically on page 286, and is shown in use by J. J. Lander and A. U. MacRae on page 283. In this tube, electrons of controllable energy in the range 5 to 500 electron-volts impinge on the





Above: pressure variation as a function of time during adsorption. Below: pressure increase on heating plotted against the "cold interval."



Cross-section of post-acceleration diffraction tube used in surface crystallography experiments.

crystal target surface where many are scattered back away from the surface. Because of the wave nature of the electron, the majority of the back-scattered electrons are diffracted and appear in certain discrete directions only, determined by the speed (or wavelength) of the electrons and the geometrical arrangement of the scattering surface atoms. The diffracted beams pass through a grid and strike a fluorescent screen. Between the grid and screen the electrons are accelerated sufficiently (by several thousand volts) to excite the phosphor and thus make their presence known. One then sees a pattern of diffraction beam spots on the screen like the simulated representations shown on the next page. These simplified drawings have been included to illustrate the method as discussed below. A photograph of an actual diffraction pattern is also reproduced for comparison.

Three principal advantages of the post-acceleration method are: 1) the beam pattern is visible at all times, thus weak and unsuspected beams are not missed, 2) changes in the pattern can be followed rapidly as conditions on the crystal surface change, 3) permanent records are easily obtained by photography.

Although the successful development of this method is quite new, a number of interesting observations have already been made. As an example, we may cite the adsorption of oxygen on nickel. Several two-dimensional arrangements of nickel and oxygen atoms have been observed on the (110) crystallographic face of a nickel crystal. The nature of the electron diffraction evidence for two of these is shown at right. In these simulated diffraction patterns, the four spots at the corners of the rectangle are those which result from beams diffracted by the atoms in the outermost layers of the nickel crystal which are in the bulk lattice positions. These spots are indicated by the letter B. Any pattern of adsorbed foreign atoms on the surface having the same periodicity as the bulk lattice atoms gives diffracted beams which coincide with these spots. Periodicities of either adsorbed foreign atoms or atoms from the bulk lattice which extend over greater distances on the crystal surface will produce spots lying between the B spots because of the reciprocal relation between surface pattern and diffraction pattern. In the drawing, the absence of any further spots between the B spots in the horizontal direction indicates the same periodicity in the surface layer as in the bulk lattice *in this direction.* In the vertical direction, however, we see one new spot between the B spots in (a) and two new spots between the B spots in (b)—evidence for two surface arrangements in which rows of nickel and oxygen atoms alternate (a), and rows of nickel atoms are separated by two rows of oxygen atoms (b).

We can not only identify what two-dimensional configurations are possible, but can study how one arrangement transforms into another, and determine with high precision the geometrical placement of the surface atoms with respect to each other and to the atoms underneath. Atomic arrangements involving only 5 per cent of a monolayer can be detected. Studies of semiconductor surfaces yield interesting evidences of faceting and displacement of surface atoms on the clean surface. The diffraction pattern of a germanium surface on the cover shows both diffraction *spots,* indicating long-range two-dimensional order, and *streaks,* indicating disorder in one direction among the surface atoms. Epitaxial growth of one crystal upon another (nickel oxide on nickel, for example) has also been observed.

Low-energy electron diffraction and the surface crystallography which it makes possible will play, without question, a very important role in the investigation of surface phenomena. Certainly it will be no less fundamental here than X-ray crystallography has been to the understanding of bulk solids (RECORD, *March,* 1962). Catalytic chemistry, epitaxial growth, electronic states at solid surfaces—all will ultimately be understood in terms of the detailed atomic configuration possible at surfaces.

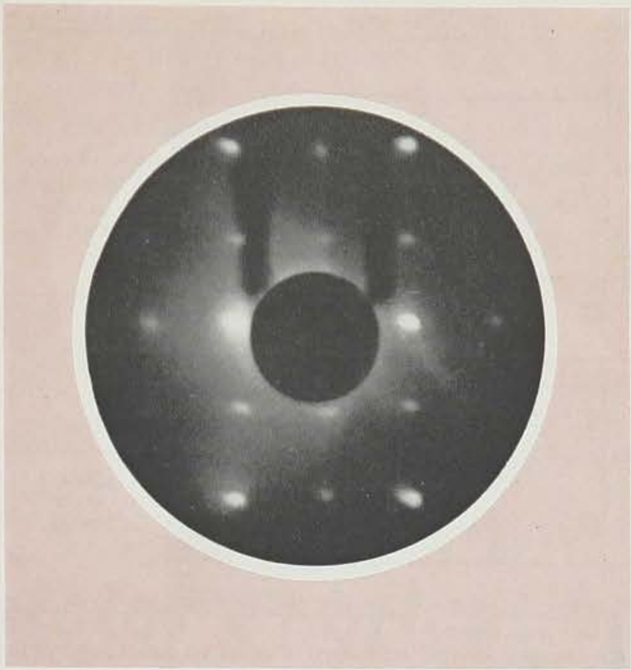
Surface Energy Level Structure

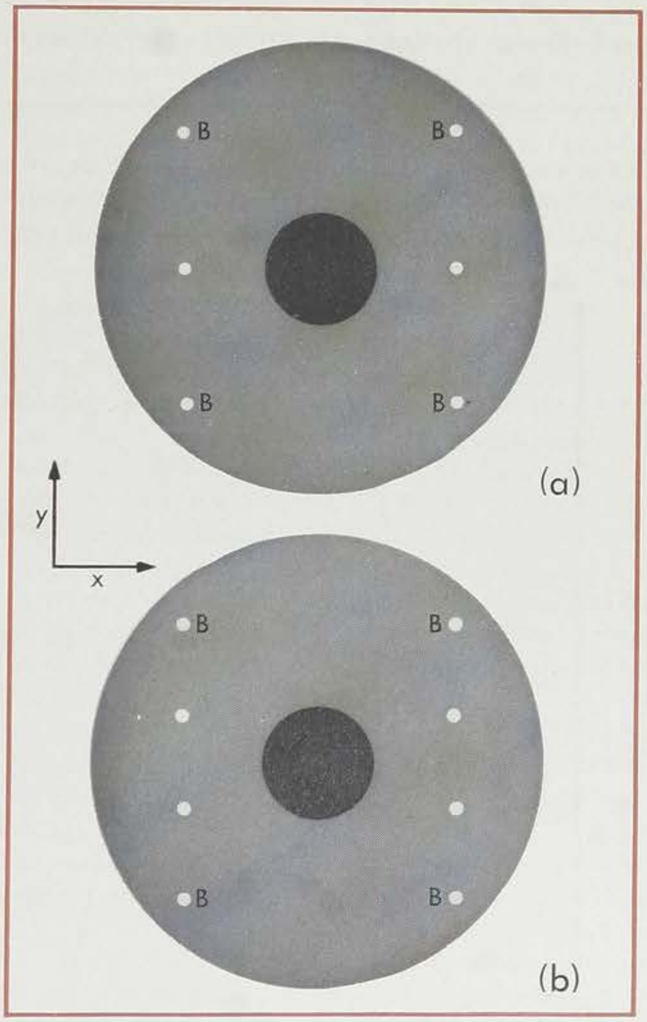
Our final category of fundamental surface information concerns surface electronic energy levels. Here the semiconductor has been all important because in these materials, surface levels can be filled or emptied more or less at will. Also, the electrical charge at the surface profoundly affects the characteristics of the semiconductor in a region extending several thousand atomic layers into the solid. In contrast, the electrical surface charges in metals are compensated within one or two layers of atoms.

The existence of surface states for semiconductors had been postulated by theoretical physicists, but it was John Bardeen, then at Bell Laboratories, who first made use of them to explain an experimental observation, namely, the insensitivity of the rectifying metal-semiconductor contact to the work function of the metal. This suggestion was followed by an extensive series of classic experiments by Walter Brattain and others to determine the physical properties of the surface states on semiconductor surfaces.

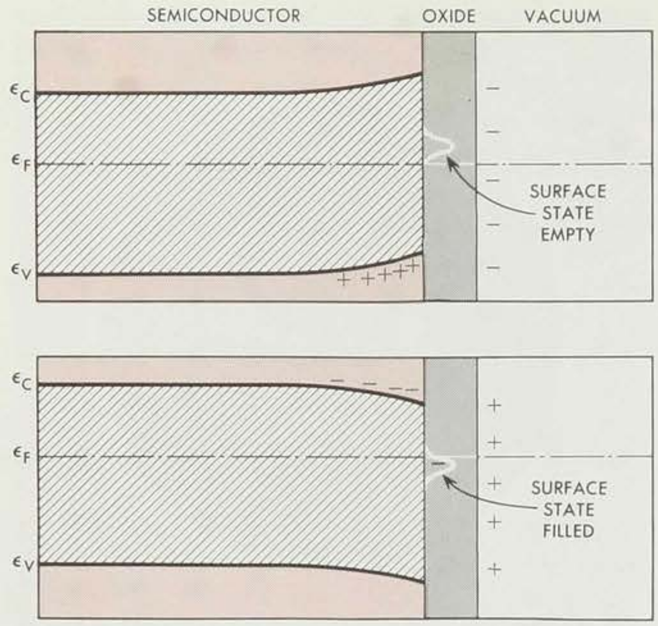
Semiconductor surface states are filled and emptied by variation of the chemical environment and by the application of strong electric fields at the surface. We may explain this briefly with the aid of the energy level diagram on page 288. Here, for the surface region, we show the bottom of the conduction band (at energy ϵ_c) and the top of the valence band (at ϵ_v), separated by the so-called forbidden gap in which lies the Fermi level (at ϵ_F). An electron-accepting state, such as that indicated at the oxide semiconductor interface, will be empty when sufficiently above the Fermi level, and filled when sufficiently below the Fermi level. In the upper drawing the field at the surface bends the bands up and the surface state is empty. In the lower drawing, with the electric field at the surface reversed, the surface level moves below the Fermi level and is now filled. When the Fermi level passes through the surface state, both the capacitance of the space-charge layer and the rate of recombination of electrons and holes at the surface are altered. The presence of the surface state, through its effect on surface potential, will also alter the lateral conductivity in the surface space charge region.

Using the band-bending technique, a sophisticated series of experiments was performed and interpreted during the 1950's, principally for germanium surfaces. The distribution of surface energy levels in the forbidden gap was determined and the rates of interchange of carriers between these surface states and the conduction and valence bands were measured. Electrical noise in semiconductors was studied and shown to be surface sensitive. Perhaps the principal deficiency in all this work was the lack of detailed knowledge of the chemistry and crystallography of the surfaces used. In work now underway in both electrolyte and vacuum ambients, we hope to acquire at least some of this knowledge. Some measurements of the type indicated above have been made for clean surfaces and for cleaned sur-



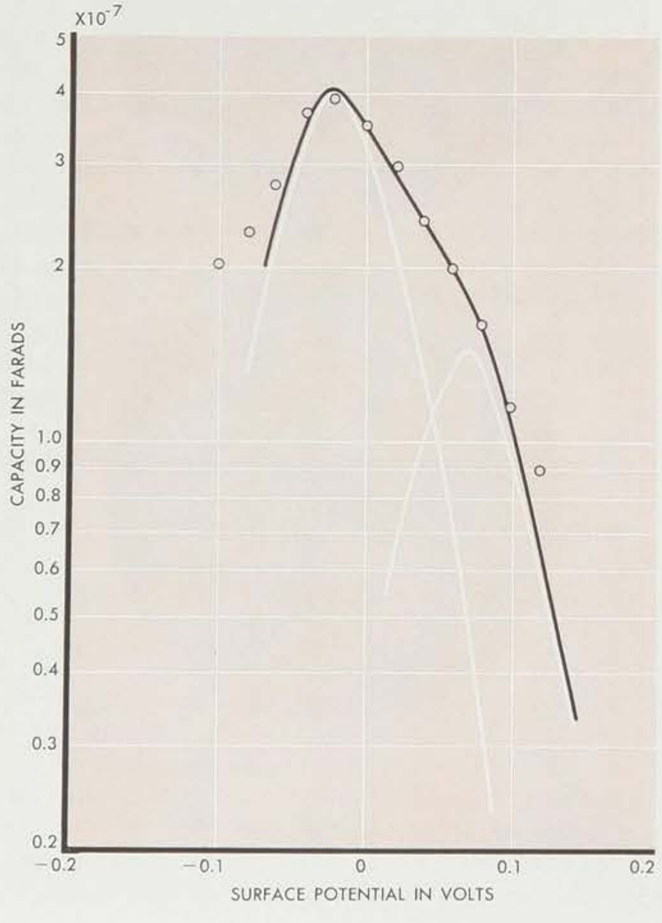


Bottom diagrams are simulated diffraction patterns typical of evidence of structures of nickel surface with adsorbed oxygen. Top photo shows actual diffraction pattern from clean nickel surface.



Bending of band edges produced in semiconductor by external field with consequent emptying (top) and filling (bottom) of surface energy level.

Diagram illustrates the surface capacitance produced in the semiconductor germanium by two surface states lying at different energies in band gap.



faces with known atoms adsorbed upon them. Determining contact potential across a p-n junction at a freshly cleaved surface, or at a sequence of cleaved surfaces along a bar of semiconductor which has been progressively doped, also yields information about the density and distribution of surface states in the forbidden gap.

The most promising result to date in identifying the chemical nature of the adsorbed atom producing surface states has come from work with the germanium-electrolyte interface. Here it recently has been possible to produce surface states of measurable characteristics by allowing the surface to interact with a known heavy metal ion such as copper, Cu^{++}, from the electrolyte. The surface states disappear when the metal atom is removed from the surface. The states have been detected by the change of capacitance of the surface space-charge region. The graph at lower left shows the excess capacitance produced at the surface by the two surface states which are attributable to the adsorption of copper. We note that the surface states affect the capacitance only when the Fermi level is passing through them, and transfer of charge into and out of these states is possible. The surface potential, the abscissa in the figure, is the energy difference between the positions of a band edge at the surface and in the bulk.

Clearly, one of the basic goals of surface science is to measure the properties of surface states produced by known adsorbed atoms in a known crystallographic configuration on the surface. Long strides have been taken toward this end. Much remains to be done in the characterization of the electrical and chemical properties of the clean surface without adsorbed species.

Another interesting area of surface work has to do with what surface phenomena can tell us about the bulk electronic properties of the solid. External photoelectric techniques have now been shown to yield information about band structure at energies above the vacuum level. The kinetic energy distributions of electrons released on the neutralization of ions at a surface yield information about the density of filled bulk states. It is now clear that a known and controlled surface will provide a "window" into the bulk of the solid through which information will be extracted that is unobtainable in any other way.

The experimental and theoretical hurdles to a basic understanding of surface phenomena are formidable. But the stakes are high, too. Clearly, our mastery of important segments of technology will ultimately depend upon how fundamentally we understand the surfaces of solids.

Research on methods of preparing pure semiconductors made today's reliable transistor possible. New ways of growing thin films now open the door to a newer faster device—the epitaxial transistor.

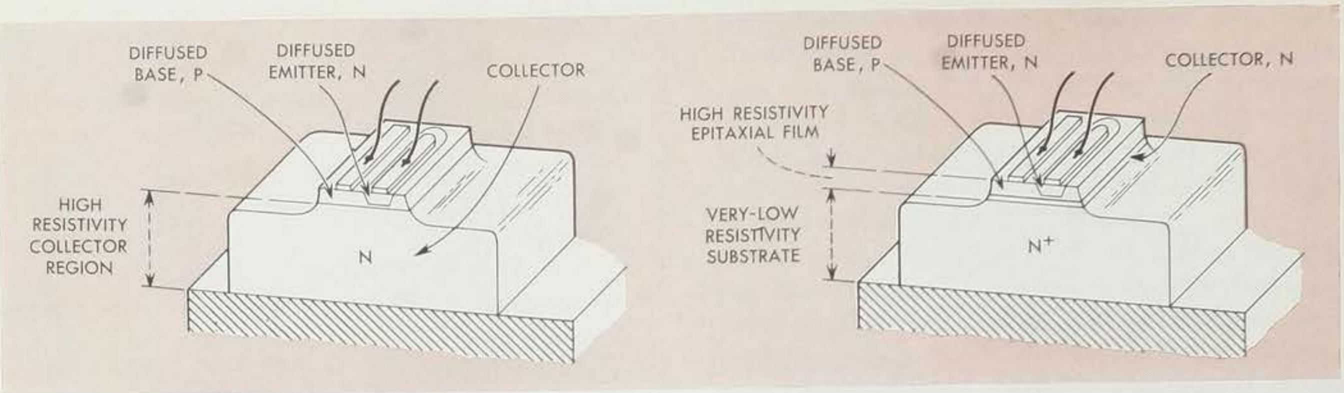
J. J. Kleimack and H. C. Theuerer

Epitaxy and Transistor Fabrication

New techniques for preparing semiconductor materials often lead to significant advances in transistor technology. The two go hand in hand, each a stimulus to the other. The progression from early point-contact transistors to the diffused-junction types, for example, required single crystals of a perfection undreamed of a decade ago. Semiconductor research has made the preparation of such materials possible and they have been a major factor in the design and fabrication of the reliable transistors being mass produced for the Bell System today.

One such transistor is the double diffused n-p-n silicon mesa. Although this transistor has electrical characteristics which enable it to meet most circuit requirements, it does have slower switching speeds, higher saturation resistances, and lower power capabilities than often desired. These limitations are primarily the result of the transistor's high collector series resistance, which is produced by the relatively high-resistivity material used to form the collector body. The choice of this material is dictated by the necessity for a low collector capacitance and a high breakdown voltage. On the other hand, a low collector series resistance, necessary for higher speed and current capability, requires that the bulk of the collector body region be made of low-resistivity material. A major breakthrough in materials technology, namely, controlled epitaxial growth (RECORD, *July*, 1960), has provided the means by which the collector requirements of high breakdown voltage, low capacitance and low series resistance can reasonably be met.

Epitaxial growth is a technique by which thin, high quality semiconductor films with controlled resistivities and thicknesses can be grown on semiconductor wafers of low resistivity. The films are called "epitaxial" because their crystal lattice structure is an extension of that of the substrate. The high-resistivity film grown on a low-resistivity wafer produces the basic starting material for transistor fabrication. Subsequent base and emitter diffusions, by conventional processes, form the collector and emitter junctions in the film, leaving only a thin layer of undiffused high-resistivity material. The major part of the collector body, therefore, is composed of the low-resistivity



Cut-away drawings show the non-epitaxial transistor on the left and on the right the modern epitaxial transistor in general use today. Note thin high resistivity film in the transistor on the right.

substrate. The drawings appearing above illustrate the physical differences between the epitaxial and non-epitaxial transistor.

To understand the advantages of using epitaxial material, one must review the construction and characteristics of a non-epitaxial mesa transistor. The starting material is a piece of relatively high-resistivity n-type silicon, where the dominant electrical carriers are electrons. The surface of the silicon is highly polished and cleaned so that the subsequent diffusions will result in layers of uniform thickness.

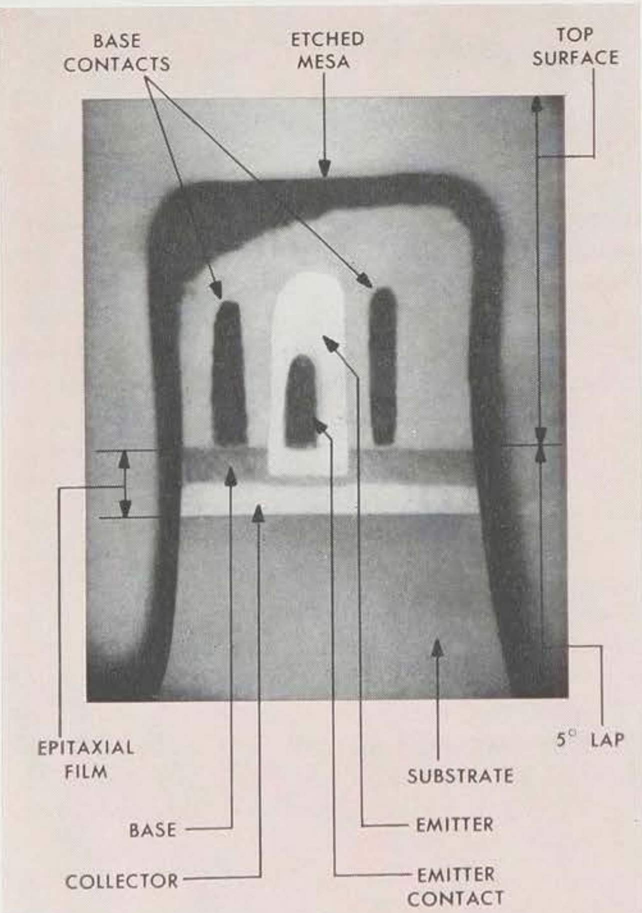


Photo above is a mesa epitaxial transistor, angle-lapped and stained to show internal structure.

An element such as boron is first diffused into the whole silicon surface to a depth of about 0.15 thousandths of an inch to form a large area junction. Boron is a p-type impurity and acts as an acceptor of electrons. Other group III elements such as aluminum and gallium also may be used. Phosphorus, an n-type impurity or donor of electrons, is then diffused in many small areas into the boron layer to a depth of about 0.1 thousandths of an inch to form emitter regions (RECORD, *November*, 1960). The p-type regions between junctions, 0.05 thousandths of an inch thick in each case, are the base regions. The resulting structures, after mesas have been etched to define the area of the collector junction at each emitter location, are n-p-n devices. To complete the fabrication, electrodes are attached to each of the three areas, the wafer is cut apart, and the transistors are sealed into cans with insulated lead-throughs.

The n-type collector region is made very much thicker than the emitter and base layers to provide both mechanical strength and ease of handling during fabrication. Since it is also made of relatively high-resistivity material, it adds a high resistance in series with the collector. When the transistor is conducting, or "ON," current flows through this collector series resistance and produces a power loss and a voltage drop. The voltage drop reduces circuit margins and, consequently, the design of switching circuits is complicated.

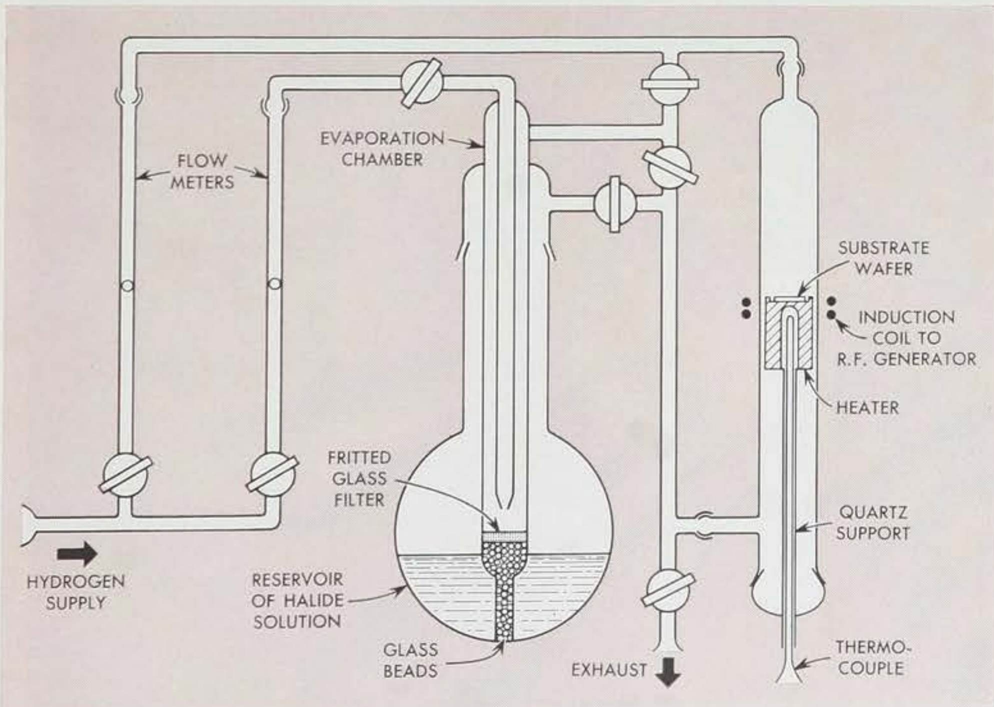
In addition, the thiek high resistivity collector region reduces switching speed. When the transistor is "ON," this region becomes filled with excess charges. When a signal intended to switch the transistor "OFF" is applied, current continues to flow in the external circuit until these excess charges are removed and, therefore, the transistor turn-off time is prolonged. Although transistor turn-off time depends on the circuit being used, non-epitaxial transistors typically require about one-tenth microsecond. Laboratories engineers saw that the ideal solution to this problem was to form the main body of the collector from very-low resistivity material leaving a thin layer of relatively high resistivity in the immediate vicinity of the collector junction.

A number of methods for producing such a structure were explored and the expected improvement was obtained. However, the method which proved to be easiest to control and most economical was the epitaxial technique.

Hydrogen reduction of silicon tetrachloride ($SiCl_4$), the method used to form the epitaxial films, is an adaptation of the one used by the Laboratories to prepare very high-purity bulk silicon (RECORD, *September*, 1955). This method is convenient, since it is a surface-catalyzed process with a reaction rate low enough for easy control of film thickness. In addition, either n- or p-type films of desired resistivity may be grown by using silicon tetrachloride with added amounts of phosphorus trichloride or boron tribromide, respectively. All these materials are in a general class known as halides.

The epitaxial growth apparatus is shown schematically on this page. Basically, it consists of a source of pure hydrogen, a halide saturation system, a reduction chamber, and a radio-frequency generator for external heating. The tank hydrogen gas first passes through a trap containing a catalyst to combine any residual oxygen with hydrogen. The gas then passes through a second trap containing an adsorbent refrigerated with liquid nitrogen, to remove water and other condensable gases. Flowmeters and stopcocks are used to separate the hydrogen into two streams. One of the streams flows directly into the reduction system; the other stream flows into the saturator and then into either the reduction system or the exhaust line. The unique saturator design uses the principle of steady state evaporation. In this system, the hydrogen passes over a capillary mass (fritted glass filter) at a fixed rate. The glass filter is wetted continuously by the mixed halide liquid contained in the reservoir. When the hydrogen first flows, the halide vapor is enriched with the higher-vapor-pressure constituent. However, after a very short time the evaporation reaches a steady state and the evaporating halide vapor then has the same composition as the liquid in the reservoir. The halide concentration depends on the hydrogen rate of flow and the halide evaporation temperature. The reduction occurs in a water-cooled quartz tube within which the wafer to be treated lies on a silicon pedestal mounted in a quartz holder.

The n-type silicon substrates used for epitaxial growth are usually five thousandths of an inch thick and a half inch square. The wafers are ground flat with carborundum and are polished by chemical etching to expose a flat undamaged crystal surface. Prior to film deposition, the silicon wafer is treated in dry hydrogen at a high temperature to remove residual surface oxide. At



Schematic drawing showing the major parts of the apparatus for controlled epitaxial growth.

this time the silicon reacts with silicon dioxide (SiO_2) to form silicon monoxide (SiO) which evaporates and condenses on the tube walls. Following this treatment, the wafer is brought to deposition temperature, and the $SiCl_4$-H_2 mixture is introduced. The variables controlling the deposition rate are the temperature, $SiCl_4$-H_2 ratio, and flow rate.

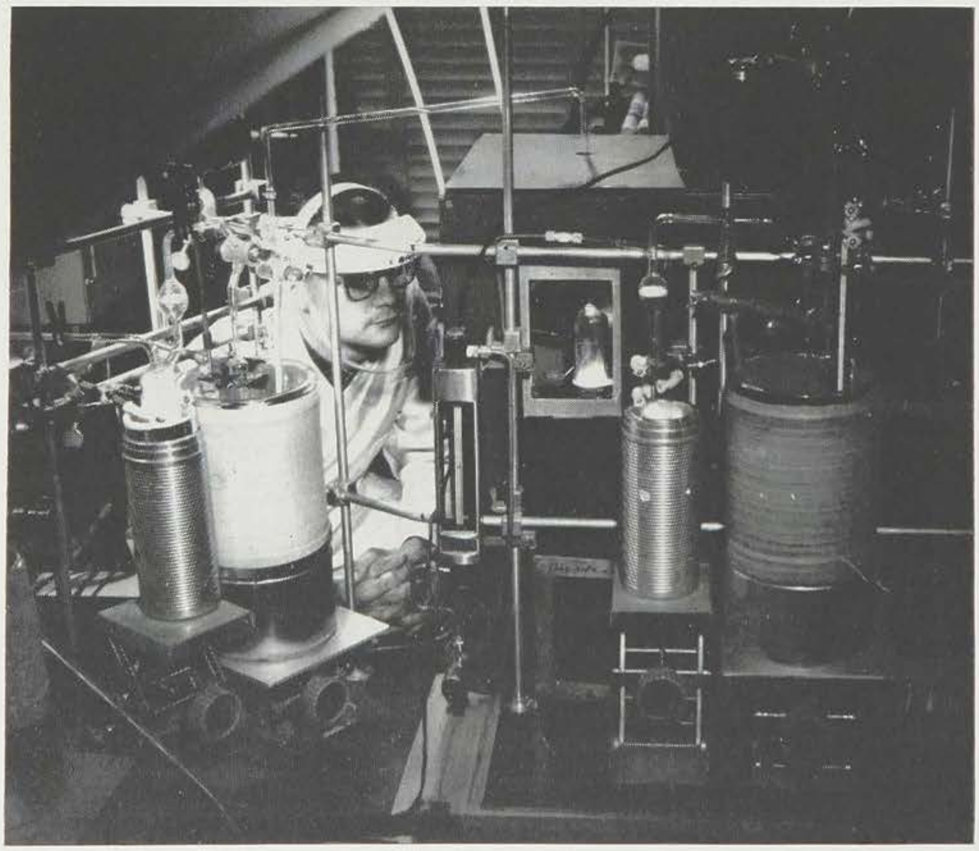
The thickness of the epitaxial film may be measured by counting interference fringes produced along a beveled edge of the wafer. A polished bevel, lapped at an angle of two or five degrees, is made on the surface of the wafer. A chemical which stains different resistivities different colors is used to delineate the film region at the top of the bevel. By using an optically flat glass laid on the wafer, a microscope, and sodium light for illumination, one can count the fringes along the beveled surface and determine the film thickness. The weight gain of the wafers may also be used for thickness determination.

A number of transistor designs using epitaxial material have been fabricated. These transistors have all the desirable features of conventional diffused-base structures, including high breakdown voltage and low capacitance. As predicted theoretically, the collector series resistance, switching speed, and collector-to-emitter voltage drop of epitaxial transistors are significantly improved over those of conventional transistors.

In a comparison of two similar medium power structures, one conventional and the other using epitaxial materials, switching time in a typical circuit dropped from 200 to 20 nanoseconds. The series resistance of the collector and the "ON" collector-to-emitter voltage drop in the epitaxial transistor were reduced by a factor of more than 10. In a comparison of low-level switching transistors, a decrease of more than a factor of six in the "ON" drop was observed.

Epitaxial transistors are more nearly ideal than non-epitaxial and are therefore easier to understand and design. Thus, it is now much easier to meet device specifications for telephone systems in development. In addition, rapid advances in film-growth technology have led not only to further improvements in silicon transistors but also to major improvements in many other semiconductor devices.

Today many transistors produced use the new improved epitaxial design. The virtual elimination of collector series resistance and the large decrease in turn-off time have increased performance considerably. The application of epitaxial deposition techniques to transistors and other semiconductor devices is possibly the greatest processing improvement since diffusion techniques were first used for making mesa transistors.



R. H. Hey, Semiconductor Device Laboratory, examines a reduction chamber while an epitaxial film is being grown.

A new wire connector designed at Bell Laboratories promises to save operating telephone companies millions of dollars a year. In addition to being economical, the new connector is as reliable as a soldered joint even with voltages as low as 25 millionths of a volt.

The B Wire Connector For Cable Splicing

S. C. Antas

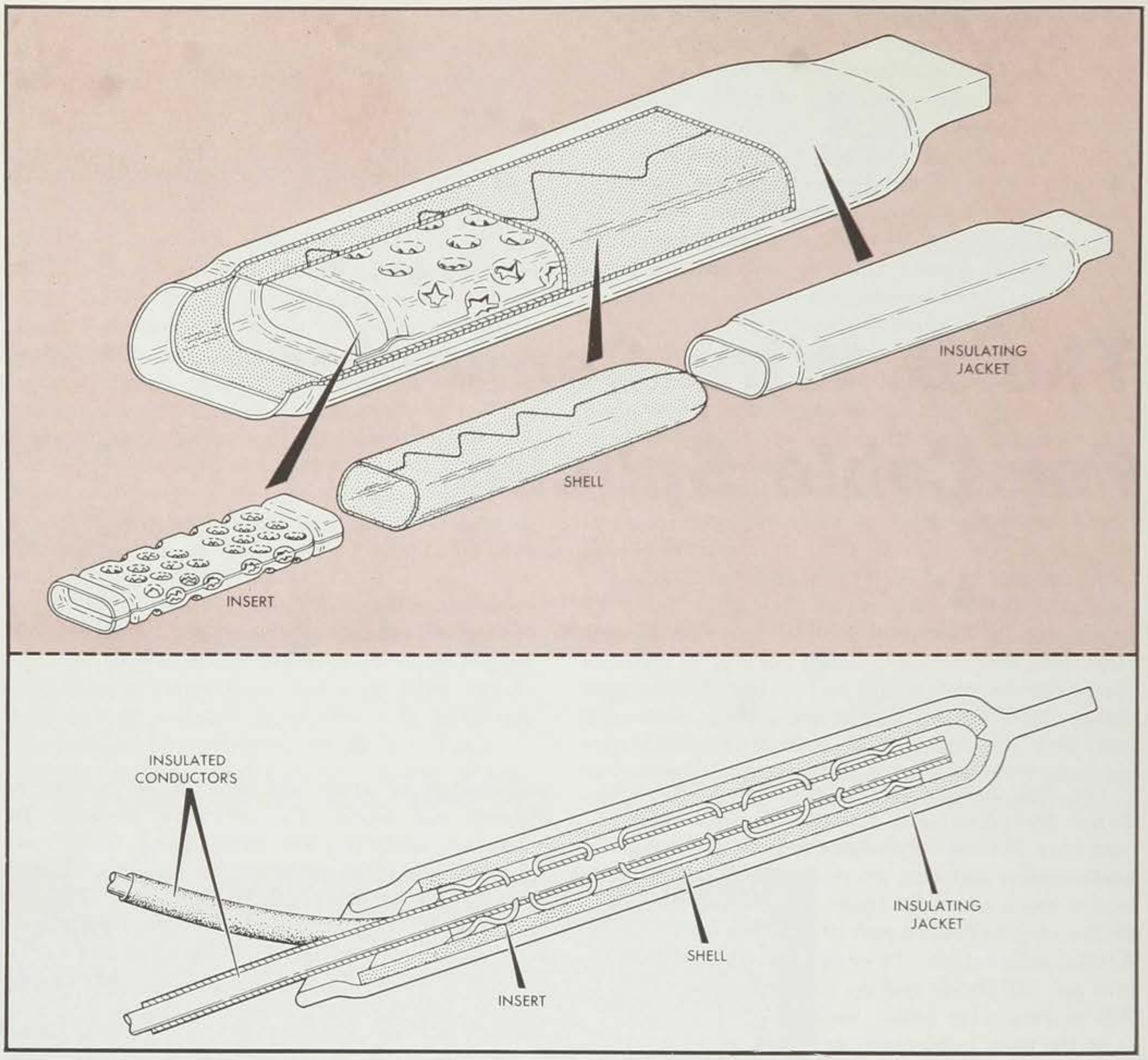
The Bell System adds about 125 billion conductor feet of cable to its outside plant network each year. If these conductors were paired and connected end to end, they would reach from the earth to the moon about 50 times. The miles of cable shipped to the field in reel lengths must be spliced during installation. To connect these cable pairs into the telephone system requires an estimated 250 million wire joints each year.

In the past, a telephone craftsman had to strip insulation from the ends of conductors and join them by twisting the ends of the lines together. This hand operation, called the "pig-tail" method of splicing, has been used for decades. The twisted joint has served its purpose well, although for the more critical circuits, the joint is also soldered. The anticipation of new transmission systems, which require better connections, made it desirable to modernize the joining method. Accordingly, Bell Laboratories engineers began work on the development of a connector for joining cable conductors. Their objective was to design a reliable, high quality connection—as good as a soldered joint—but at less cost than the pig-tail joint. Because of the large number of splices in series in most cable runs, such a connector must maintain high reliability throughout the service life of the cable which is frequently more than 40 years.

Finding and correcting bad connections during installation or after the cable is in service is difficult and costly. For example, suppose 10 splices are made in a run of 2424-pair (4848 conductor) 26-gauge cable; this requires 48,480 connections. If 0.1 per cent, or 48, of these connections become defective, 48, or 2 per cent of the 2424 circuits, would almost certainly be lost since the chance of having two or more bad connections in the same circuit is very remote. Even at a failure rate of 0.01 per cent, or one in 10,000, five circuits would be inoperative. Therefore, the designers specified a failure rate of less than one in 10,000 connections.

The only material required for a pig-tail joint is an insulating cotton sleeve, which costs about 0.1 cent; therefore, if the connecting device costs more than this, it must save installation time to achieve the objective of lower over-all cost. To do this, the designers developed an insulation-piercing connector which eliminated the insulation-stripping operation.

A device meeting the requirements for reliability and lower cost was introduced into the field during 1961. Designated the B Wire Connector, it consists of a tin-plated, phosphor bronze insert, a soft brass outer shell and an insulating plastic covering, as illustrated on page 294. The insert has an array of sharp pierce-formed tangs that resemble the teeth on a kitchen nutmeg grater.



Cutaway diagram shows the simplicity of design of the B Wire Connector which is essential to such a low-cost, mass-produced item. Lower diagram shows how tangs pierce insulation of conductors.

These tangs make the electrical connection with the conductors when the connector is pressed onto the insulated conductors. The tin plating on the insert prevents the formation of a high-resistance film on the phosphor bronze and it also provides a low-resistance current path with low contact resistance. The soft brass shell keeps the insert from springing away from the conductors after the connector is pressed.

When a joint is made, dozens of tangs pierce the insulation and make contact with, or penetrate into, the conductors. By acting as independent springs, the tangs store energy and thus maintain intimate contact with the conductors in spite of the effects of creep and relaxation of the metal parts, and expansion and contraction caused by temperature changes which may occur.

Another important feature shown in the lower part of diagram above is the effect of the taper in the dies used to press the connector. The tangs penetrate deeply into the conductors at the end of the connector, whereas they barely contact the conductors at the entrance, thus guarding against conductor cutoffs. However, the shallow penetration of the tangs at the open end of the connector and the clamping action of the smooth embossed ridge hold the conductors rigidly enough to prevent external motion of the conductors from disturbing the critical contact areas. Accordingly, the resistance of the connector remains stable during vibration and handling of the external portion of the conductors.

Innovations in testing apparatus and analytical techniques were required to demonstrate that the device met the design objectives. Laboratories engineers developed a new technique for measuring the contact resistance of the connector. Previous methods were sensitive to about one milliohm or at best 0.5 milliohm. This new technique has a sensitivity of several microhms and represents an improvement of several hundred fold. It is sensitive enough to detect *daily* changes in the resistance of good joints and of course readily detects the changes in poorer connections.

The heart of the new measuring technique is a modified Kelvin bridge circuit with a sensitive electronic galvanometer shown below. This simple circuit has a number of unique features which reduce experimental error. For example, the resistance of the connection is compared with the resistance of a "standard"—a very accurately controlled length of one of the lead wires in the connection itself. This minimizes errors that might otherwise be introduced by variations in wire diameter, and the resistance of lead wires included in the measurement. Similarly, errors caused by fluctuations in temperature are minimized because the "standard" and the joint are normally at the same temperature.

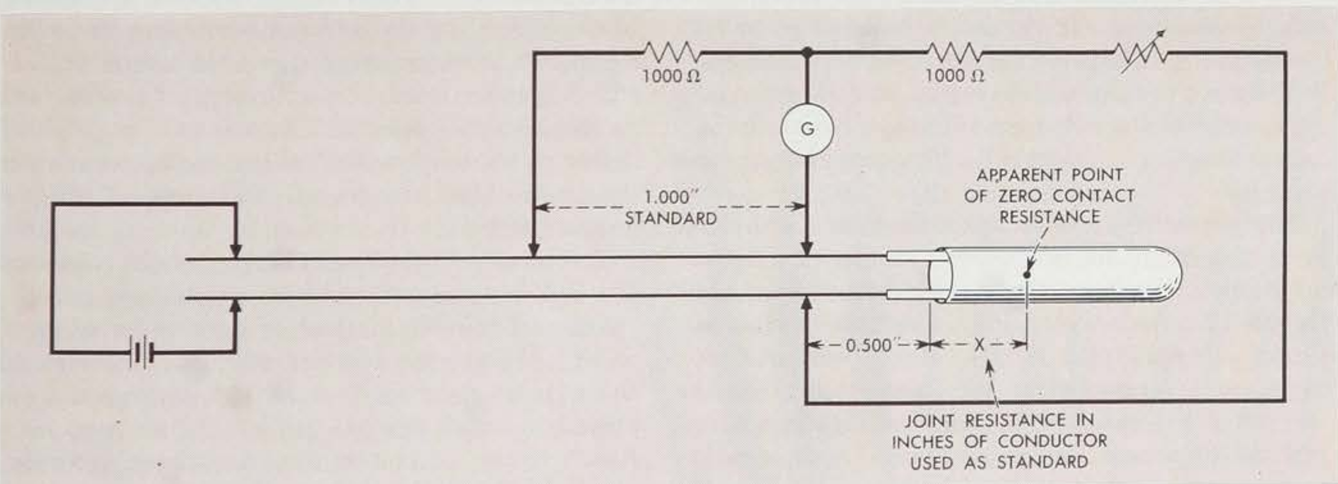
A particularly important feature of the test method is the reduction of errors caused by the contact resistances normally encountered when the sample is connected to the test set. The circuit is arranged so that these undesired resistances are in series with the high impedance arms of the bridge and thus can be made to cause an arbitrarily small error. Important savings in development time were achieved and the chances for human error reduced by automating the bridge circuit with a self-balancing servo system and digital read-out apparatus. The data were analyzed by computer.

The automated bridge was used to measure and record the aging data for various connector designs. Planned experiments and statistical methods facilitated the selection of the most promising design. Because of these techniques and the precision of the measurements, relatively few samples sufficed in studying the effect of most of the design variables. Less precise techniques would have required the evaluation of many thousands of samples.

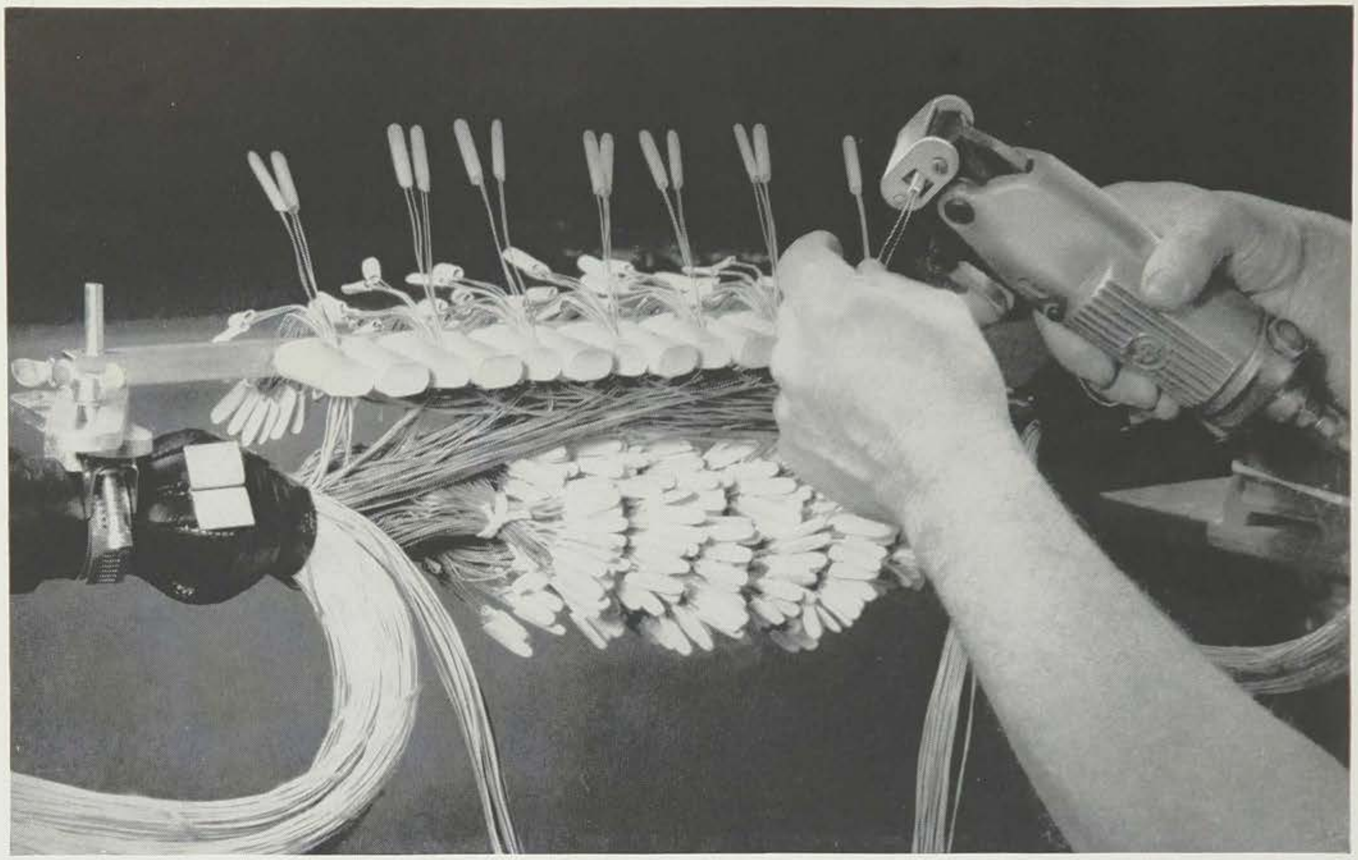
After the B Wire Connector was designed, Laboratories engineers had to estimate its performance. Under natural aging conditions, the contact resistance of a connection increases because of the formation of oxides at the metal interfaces. Daily and seasonal temperature changes cause expansion and contraction of the metal parts; this, in turn, may permit the entry of oxygen or corrosive gases which hasten the formation of high-resistance corrosion products at the contact areas. To simulate many years of aging in a short time, they built a machine which automatically cycles the temperature of connectors under test in an accelerated corrosive environment.

By conducting such accelerated aging tests at various temperatures and by comparing the results with natural aging tests in a non-corrosive environment, they estimated that fewer than three B Wire Connectors in 10,000 can be expected to have resistances as high as 1.5 milliohms in pulp cable after 40 years of service. Resistances of this order would be quite negligible in their effect on transmission.

As stated earlier, a failure rate of less than one in 10,000 was set up as a design objective. For



The highly sensitive yet simple circuit shown above uses an accurately controlled length of the conductor itself (joined in the connector) as a standard when making resistance measurements.



Here, a telephone craftsman uses the B Wire Connector and the B Wire Holder to make a cable splice.

long-time aging, the estimates cited above will not be confirmed until the parts are in service for many years. A measure of the initial reliability, however, was determined during early field usage. Out of the first 6,000,000 connections actually made in the field, only three opens were reported and none of these failures was caused by functional difficulties attributed to the design. From these results, the design objective has been met with an adequate factor of safety.

To meet the objective of low cost, it was obviously necessary for the conductor design to be compatible with efficient mass-production methods. With this in mind, collaboration was established very early in the development stage between the Laboratories and Western Electric manufacturing planning.

Many features were introduced to facilitate manufacture as the design evolved. As one typical example, Western Electric engineers suggested the use of a "saw-tooth" brass shell, which can be produced from rolls of strip stock, rather than seamless tubing which had been the original concept. This resulted in substantial savings in raw material and fabricating costs with equally satisfactory connector performance. With this cooperation, mass-manufacture was achieved much earlier than would otherwise have been possible.

The B Wire Connector accommodates the standard range of cable conductor gauges: 19 through 26. There are two sizes: one for combinations of 22-, 24- and 26-gauge conductors and a larger size (not yet in production) for combinations of 19-, 22-, and 24-gauge conductors.

To meet the objective of saving time, the B Wire Holder was introduced to aid in the manipulation of cable conductors and the installation of the connectors. This device provides a systematic means of holding the wires and building the splice bundle. It is mounted on the cable and is adjustable to permit efficient positioning of the various units in a splice bundle. The soft rubber grips of the wire holder immobilize the conductors while the connectors are placed and pressed with a pneumatic tool.

Telephone Operating Companies have found the B Wire Connector to be an economical, efficient, and reliable method of connecting of cable pairs. When the connectors are distributed throughout the Bell System, net savings are expected to reach several million dollars per year. Apart from economic considerations, improvements in the quality of all new cable circuits will result from the use of the B Wire Connector.

The "concentration" of telephone lines outside the central office is an old concept but a comparatively new art. Development of this idea has resulted in a device that can save operating telephone companies millions of dollars in capital expenses.

M. E. Krom

The 1A Line Concentrator

The telephone plant is in a large measure designed with the knowledge that only a small percentage of telephone customers want service at the same time. This is a broad concept relating to the over-all system, but here we will apply it specifically to the method of connecting telephone customers with a central office. In recent years, the cost of customer lines in the outside plant has increased rapidly, while the cost of central-office equipment has remained relatively constant. This is basically attributable to the increasing size of telephone exchanges, and the greater distance that their customers live from a central office. The result of the increase is manifest economically in terms of such things as more telephone poles, more wire, and more maintenance.

As early as 1908, and perhaps earlier, development engineers tried to devise a method of reducing the number of paths between telephone customers and the switching plant without affecting service. But not until recently has telephony advanced to the point where this concept could be put into practice. Three developments underlie its success: (1) mechanically or magnetically latching switches and relays which use power only during the set-up and disconnect intervals, (2) new power stores, such as large capacitors or nickel-cadmium batteries, and (3) better metal finishes which permit electromechanical apparatus to be installed outdoors in housings.

By connecting say, 100 telephone lines in a specific area to a remote switching unit, we can reduce the number of lines from customers to the central office. Such a switching center operates on the principle that only a few of these customers use their telephone at the same time. This means

The 1A Line Concentrator is a compact switching system designed to decrease the number of lines between a given area and a central office.

that only a few lines between the line switching center and the central office assure all customers of regular service whenever they pick up the phone. These lines, which now become trunks, are used first for one call and then for another.

The 1A Line Concentrator, developed by Bell Laboratories, does precisely this: it takes a relatively large number of lines, and, in effect, "concentrates" them on to a few lines or, more correctly, trunks. Of course, the practicality of installing a line concentrator depends on telephone usage, the distance of telephones from each other and from a central office, and the rate of increase of telephones in an area. When these factors indicate that a 1A Line Concentrator should be installed, annual savings in capital can be considerable. For example, the installation of 1000 line concentrators results in potential savings of four million dollars in capital expenditure.

The 1A Line Concentrator consists of a control unit within a central office, and a remote unit, which connects customer's lines to trunks. A block diagram of the system is shown on page 299. The remote unit can be mounted on a pole or on the wall of a building. Twenty trunks and two control pairs connect the remote unit to the control unit in the central office. Although the concentrator does not reduce the amount of equipment within a central office, it does allow a relatively large number of customers to share a small number of trunks to the central office. In other words, it affords a considerable reduction in outside-plant facilities.

The control portion of the concentrator is made up of two items of equipment. One is an inexpensive steel framework with associated fuse panels, terminal strips, and local wiring. This item may be ordered and installed before the concentrators are actually needed, thereby postponing capital expenditures until the equipment is put to use. The other item is the switching apparatus. This is an integral unit which can easily be attached to the central-office framework. This unit is installed by making simple cross connections on matching terminal strips.

Laboratories engineers designed the concentrator for virtually all types of central offices with very few modifications to existing central-office equipment. The concentrator is arranged for direct connection to lines having sleeve leads that are at negative 48-volt potential when the lines are idle and at ground potential when the lines are busy. Other types of lines require minor auxiliary apparatus to provide a compatible sleeve condition.

The transmission characteristics of a line will be unaffected by the concentrator. Standard tones, ringing voltages, pulsing arrangements, and data sets are accommodated. In fact, the unit can handle all types of lines except PBX and ground-start coin lines, which would normally be excluded anyway because of the high number of calls they handle.

The 1A Line Concentrator was designed to meet standard working limits of the connecting offices and to operate with standard message-charging equipment. Outside-plant facilities may consist either of loaded or non-loaded cable. Conventional electromagnetic apparatus—relays and crossbar switches—constitute the majority of the apparatus and assure long life, quality performance and minimum maintenance.

Power Supplied From Central Office

One of the most difficult problems encountered in designing the concentrator was that of supplying power to the remote unit. For reliability, it was decided that the power should be supplied from the central office via cable pairs. This means that the average current drain must be kept very small (actually about 0.1 ampere). This amount of current, however, is insufficient to hold as many as 20 hold magnets and 20 cut-off relays in the operated position. This problem was solved by developing a magnetic-latching crossbar switch and a magnetic-latching cut-off relay. Both devices are actuated by a pulse of current in one direction, released by a pulse of current of opposite polarity, and held in the operated position without any current flow. The switch is a conventional crossbar switch in which the standard hold-magnet core is replaced by a core having a high residual flux density. The standard armature of the hold magnet is replaced by a nickel-plated armature to improve magnetic properties. Some reed-type relays in the remote unit contain a small

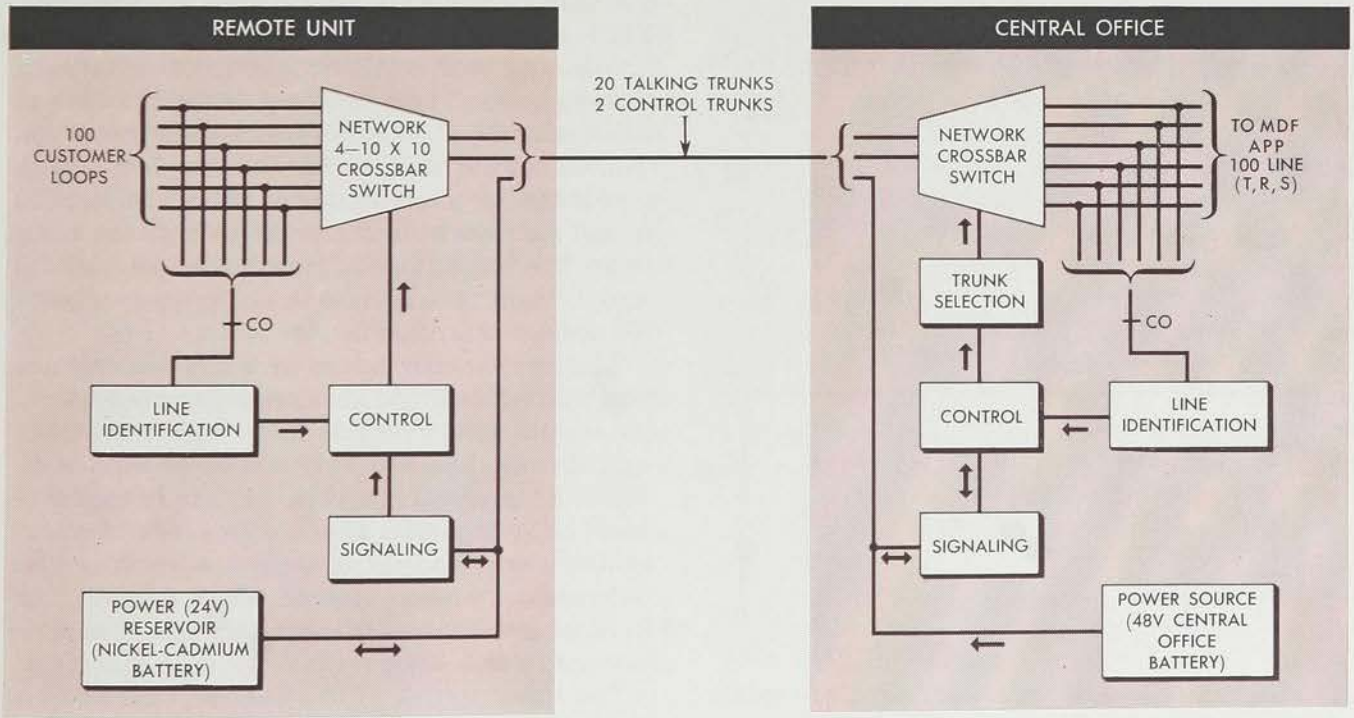


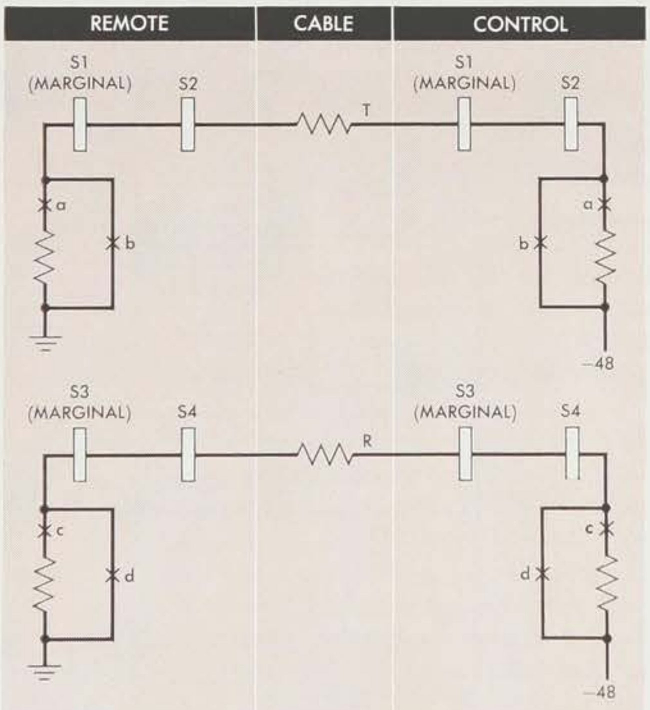
Diagram of the 1A Line Concentrator. Remote unit "concentrates" a number of calls on to a few lines. Central-office equipment "expands" incoming lines and routes them to called party.

permanent magnet. This magnet provides a flux insufficient for operating the relay but sufficient to hold the contacts closed after the relay is operated by a current pulse of proper polarity.

The use of these two new components means that the only local power needed is that required to connect or disconnect a line and to compensate for line leakage. Since a call can be set up or disconnected in less than ½-second, the power requirements for this use are small. Normal limitations on line insulation resistance (combined resistance of all lines shall not be less than 400 ohms) result in only a small current drain, thus permitting the remote unit to be powered by a small 24-volt battery. This battery is "trickle-charged" (over idle trunks) from the negative 48-volt battery in the central office. These are the only voltages required by the concentrator.

The crosspoint network used to associate lines and trunks in the remote unit consists of four six-wire, 100-point crossbar switches, having three lines (two leads each) per crosspoint. Lines appear on the switch horizontals and trunks on the verticals. Three steering levels serve to select one of the three lines in a crosspoint. The lines are divided into two groups of 50 lines each, with each group having full access to an individual group of ten trunks.

The control circuit in the central office requires



The signaling circuit uses two wires for transmission of line and trunk number information and two to control the sequence of transmission.

three leads per line, thus limiting the number of lines per crosspoint to two. Three 200-point, six-wire switches are required. Lines appear on the horizontals of these switches also.

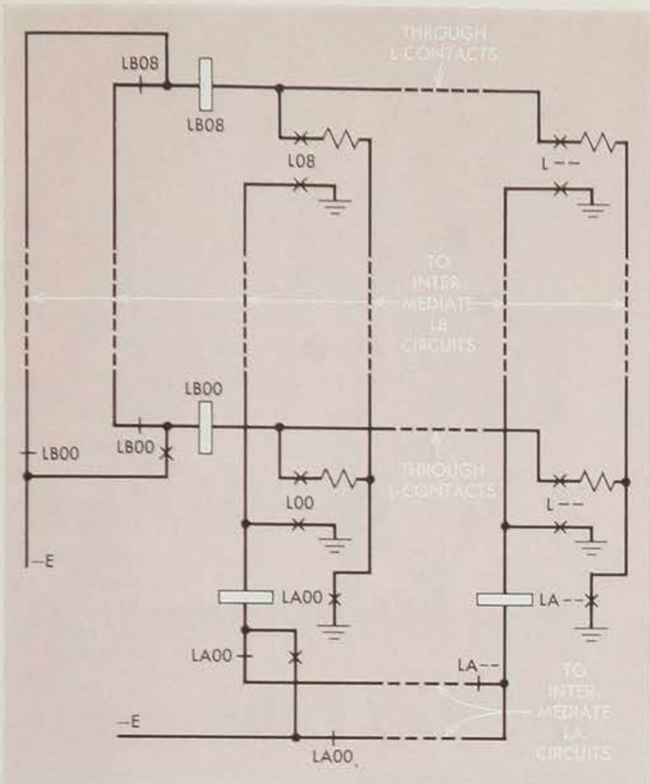
The concentrator control circuit monitors both originating and terminating traffic and controls the process of establishing and disconnecting calls. In the remote unit, switching is controlled by signals sent between the two units over two control pairs. One of these pairs transmits information for identifying line and trunk numbers. A simplified form of this signal pair is shown below, at left.

This is a symmetrical circuit, permitting signals to be sent in either direction. The circuit operates in this way: a, b, c and d represent contacts on many relays that control the sending of information. Now, assume that contact b is closed at the control end; it will be seen that three signals can be sent over the tip (T) conductor under control of contacts a and b at the remote end. When neither contact is closed, all relays are normal. When contact b is closed, all relays will operate; when contact a is closed, both S2 relays will operate. When two circuits are combined as shown above, nine different signal combinations can be derived. The second control pair provides sequence control, checking and release functions, and also an indication as to whether trunk 0 or 9 is to be chosen.

The manner in which information is sent over the first control pair is indicated on page 302. There are four successive steps used to send the information and establish a connection between the two units. There are four types of information transmitted: (1) class of call and line group number, (2) B part of the line number, (3) A part of the line number and (4) trunk number. The second pair controls the progress between these steps. The left column in this figure indicates the signal relays that operate in each step to provide the desired information.

When a customer served by a line concentrator lifts his handset, the line relay for his line (in the remote unit) operates. The concentrator then identifies his line and locks out other service requests by means of the circuit shown in the lower drawing on page 301. This circuit subdivides each 50-line group into six A groups, all having nine lines each except for the last which has only five. Each of these nine lines is assigned a B-number between 0 and 8.

The identification of the line and transmission of the information to the central office is accomplished as follows, using line 08 as an example:



The remote unit of the 1A Line Concentrator identifies a customer's line and locks out other requests for service with circuit shown above.

Operation of line relay 08 operated LA00 relay and LB08 relay. No other LA- or LB-relay can operate. The line group number and the line number (A and B information) are then transmitted to the central office over the signal circuit.

The information sent in each step is recorded in registers and checked both in the control and the remote units before proceeding to the next step. Finally, the information in the remote register is checked to see that it matches the information in the line lockout circuit before the circuit proceeds.

While the above information is being recorded and checked, the control circuit selects an idle trunk in the proper group and then transmits the number of the trunk to the remote unit in step four. When this information is registered and checked at each location, the hold magnets operate and the cutoff relay is released at the central office. The same sequence of operations occurs at the remote unit. When these operations are checked, the circuit releases, leaving only the magnetic-latching hold magnets operated at each end of the connection.

A call incoming to the concentrator operates a relay connected to the central-office line sleeve and proceeds in a way similar to a service request except that all information signals emanate from the control unit. A line lockout circuit, similar to that at the remote unit, identifies the number of the called line.

Conventional relays and switches are released by opening the operating circuit, but the magnetic-latching equipment in the line concentrator must be released by means of a current pulse having a polarity opposite to that of the operate pulse. Therefore, when a call is to be disconnected, that line and its associated trunk must be identified and this information outpulsed to the remote unit.

A trunk may be disconnected at any time when it is not actually being used by a customer. The idle condition is indicated by the release of a relay (normally held operated under control of the customer or the central-office equipment) when the associated trunk hold magnet is in the operated position. Release of this relay activates the disconnect circuit. The disconnect operation is similar to that for an incoming call, except that a disconnect instead of a connect indication is set up in Step 1 (page 302). This causes a reversal of current to the cutoff relay and hold magnet. These devices are respectively operated and released. After these operations are checked at the remote unit, similar functions are performed in the control unit. Both units then return to the normal state, awaiting other calls.

Minimum of Six Lines Connected

A minimum of six concentrator lines in the 100-line concentrator will always be cut through the concentrator to the central office. This is accomplished by means of a trunk load control circuit which disables the disconnect circuit when three or less lines per group are cut through to trunk circuits. This feature insures that some lines can always obtain service even if the control circuit becomes disabled. This means that the line will remain cut through even though not in use. It also prevents repeated connect and disconnect of trunks to lines having low insulation resistance. The latter condition can occur when the resistance is low enough to engage the concentrator but too high to engage the central-office equipment.

The remote unit is housed in a weather-tight, hardened-aluminum casing. Ventilation holes, covered with filters, guard against dust and insects. These holes in the bottom and back of the casing provide enough air circulation to prevent the accumulation of moisture in the housing.

The apparatus in the remote unit is mounted on two gates which open forward, thus making all wiring available from the front of the cabinet. The rear gate contains the four crossbar switches: the front gate contains relays, power equipment and terminal strips. The front gate also contains carbon protectors for protection of lines and trunks against high, foreign potentials and lightning surges. Connection to the outside lines and trunks is made through a connecting block in the bottom of the cabinet.

The concentrator underwent field trials in Gulfport, Miss. and Eau Claire, Wis. These geographic areas represent the near extremes of climatic conditions in the United States. The trials were conducted for extensive periods to ascertain the effect of climatic variations, to check circuit performance thoroughly, and to accumulate traffic information that will assist in installing line concentrators. The results of the trial were very gratifying in view of the limited laboratory testing that preceded installation. Only minor circuit modifications were found to be necessary, performance met all expectations, and much useful traffic information was obtained.

Today, the concentrator is the first of a new type of switching system. Tomorrow, it may be the prototype of a new line of systems that take advantage of new concepts and provide more economical telephone communication.

STEP →	1	2	3	4
Signal Relay Operated	Class of Call and Grp. No.	B Part of Line No.	A Part of Line No.	*Trunk No.
None		0		0 or 9
S4	Disc. Grp. 1	1	0	1
S3, 4		2	1	2
S2	Disc. Grp. 0	3	2	3
S2, 4		4	3	4
S2, 3, 4	Conn. Grp. 1	5	4	5
S1, 2		6	5	6
S1, 2, 4	Conn. Grp. 0	7		7
S1, 2, 3, 4		8		8

*This number in combination with G0 selects trunks 0 to 9, and in combination with G1 selects trunks 10 to 19.

Information is transmitted from the remote unit to the central office in four successive steps.

Bell Laboratories scientists have developed a "traveling-wave" optical maser which amplifies light directly. The device has a net gain of 13 db—amplification of twenty times.

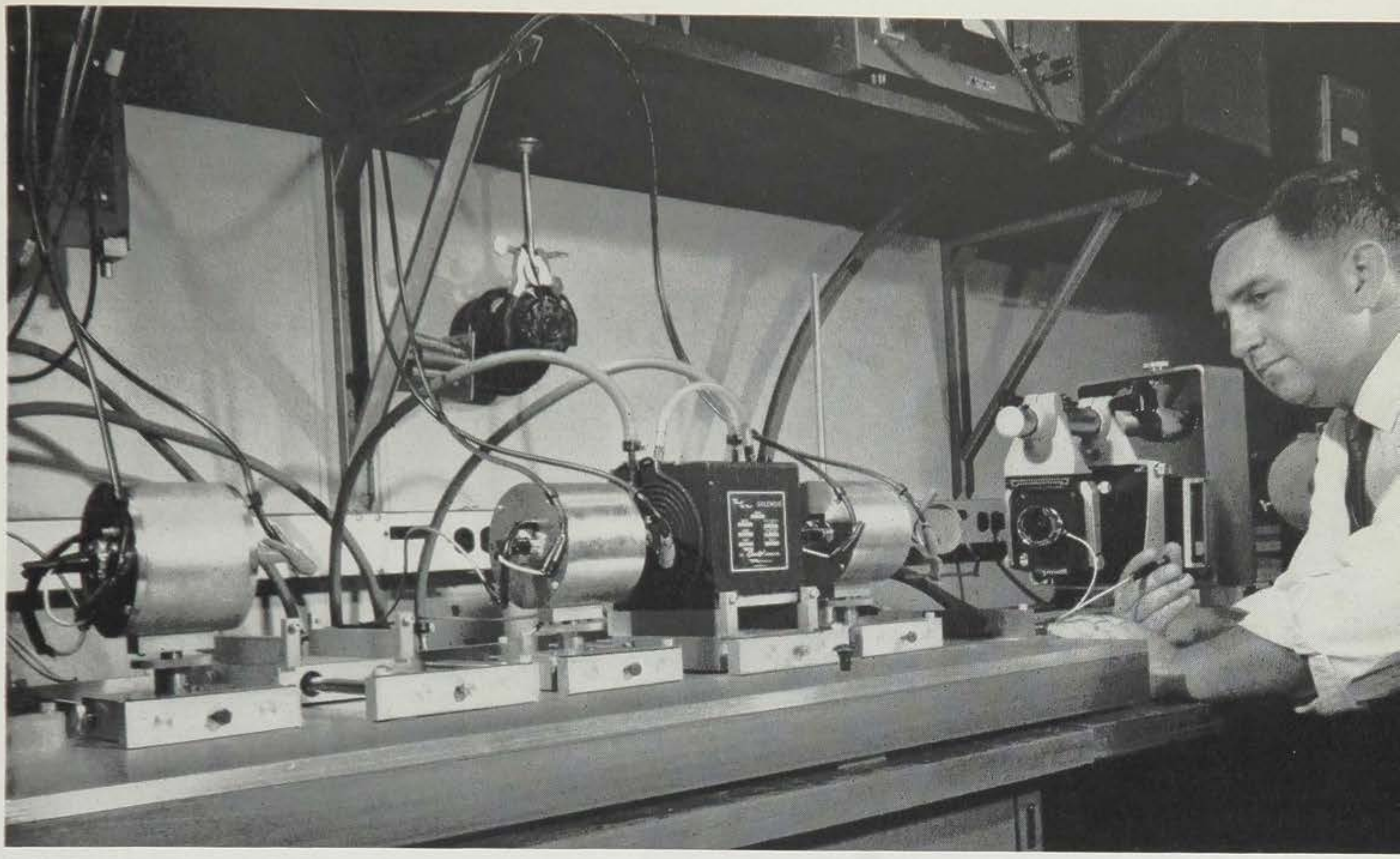
Optical Maser Amplifier Announced By Bell Laboratories

A solid-state optical maser amplifier has been designed with techniques that are similar to those used in microwave maser amplifiers. The Laboratories announced recently that it has constructed a "traveling-wave" pulsed ruby optical maser which can amplify the intensity of light directly. The device has a net gain of 13 db—an amplification of 20 times.

This optical maser amplifier preserves the spatial relationships of an input image. If a suitably illuminated object is placed at the input of the amplifier, its intensified image will appear at the output. This property was demonstrated with a small transparency whose intensified image was recorded photographically.

The experiments were carried out by the Laboratories with support from a contract with the U. S. Army Signal Research and Development Laboratory. They are described in the July, 1962 issue of the Bell System Technical Journal in an article by J. E. Geusic and H. E. D. Scovil of the Solid State Device Laboratory.

The new device is composed of two maser amplifying sections with an "isolator" between them.



J. E. Geusic with laboratory model of the optical maser amplifier which produced a gain of 13 decibels.

The active maser material is ruby and the active isolator material is lead-oxide glass (flintglass), a material whose bandwidth extends over most of the optical range.

One of the prime interests in communications at optical frequencies is the potentially large information handling capacity. This can be expressed in terms of bandwidth—the width of the frequency band which the optical system can handle. The new amplifier has a bandwidth of one hundred kmc, larger than that of the entire range of radio and microwave frequencies.

This bandwidth is applicable to each resolvable part of the image. Thus each such component beam is a separate channel of its own. The information handling capacity, already enormous for each channel, is extended even more by the number of such channels that can be resolved. In addition, this spatial separation of simultaneously amplified channels may prove useful in simplifying the switching of specific channels into various receiving centers along a transmission route.

The use of optical masers for high power applications is also enhanced by this development. High peak-power levels can be obtained from solid-state optical maser oscillators, but it is difficult to obtain this energy and still keep the divergence of the beam small. A narrowly divergent beam can, however, be selected from the output of an oscillator and fed into an amplifier where it can occupy a large fraction of the amplifier's "cross section". By this procedure it would be possible to obtain at least the same power levels available in an oscillator and simultaneously achieve a smaller beam divergence.

The image amplifying property of the amplifier was demonstrated by illuminating a transparency with the output of a maser oscillator and comparing amplified and unamplified photographs of the image. The optical maser performed closely to theoretical predictions and is expected to produce much higher gains by "cascading" additional stages.

The optical maser amplifier is an important step in the extension of radio-frequency techniques to the optical region. With continued development of these and other devices, a large amount of day-to-day communication may someday travel over the optical portion of the frequency spectrum.

Beginning in early 1963, a new submarine cable system will be laid between Florida and Jamaica, and then on to Panama. The system will use armorless cable and a new repeater to provide two-way communication.

New Two-Way Repeater Amplifies 128 Telephone Conversations

Bell Laboratories Submarine Cable Laboratory has developed a repeater for underwater cable that will amplify 128 two-way telephone calls simultaneously. This not only represents an increase of more than twice the number of calls being handled by the flexible repeaters now in use, but also means that a single cable can handle calls in both directions.

The repeater amplifies signals 100,000 times and will operate reliably for at least 20 years. Designed for use with the Bell System's new "armorless" cable, this is a rigid repeater shaped like a miniature torpedo, tapered at both ends. It weighs 500 lbs., is 50 in. long and has a maximum diameter of 13 in. Its outer casing of beryllium copper can withstand pressures up to 11,000 psi, the pressure at 4000 fathoms.

A heavy rigid repeater such as this would have been impossible to use with an armored cable which twists when placed under tension during laying operations. Armorless cable twists very little and thus can be mated with a rigid repeater.

Beginning early in 1963, these repeaters will be used in a new submarine cable linking Florida and Jamaica, and later in the year in another cable from Jamaica to Panama. They will also be used in a new trans-Atlantic cable scheduled for completion in 1963, and in Pacific cable projects to be completed in 1964.

Repeaters will be spaced on an average of every 20 miles along the undersea armorless cable. This spacing will vary slightly according to the ocean's temperature and pressure.

The two-way repeater is divided into five sections. In the center is an amplifier with directional filters on each side. At each end of the package are the power separation filters. A signal entering from either end of the repeater passes first through the power separation filter where the information signals are separated from the power required to operate the system. The information signals then enter the directional filters where the low-band signals (116 to 512 kc) are separated from the high-band signals (652 to 1052 kc). Each band carries 128 telephone conversations. After separation, the signals pass through the broad-band amplifier. The signals then pass through the second directional filter where the information signals are recombined with the power and pass through the cable into the next repeater.

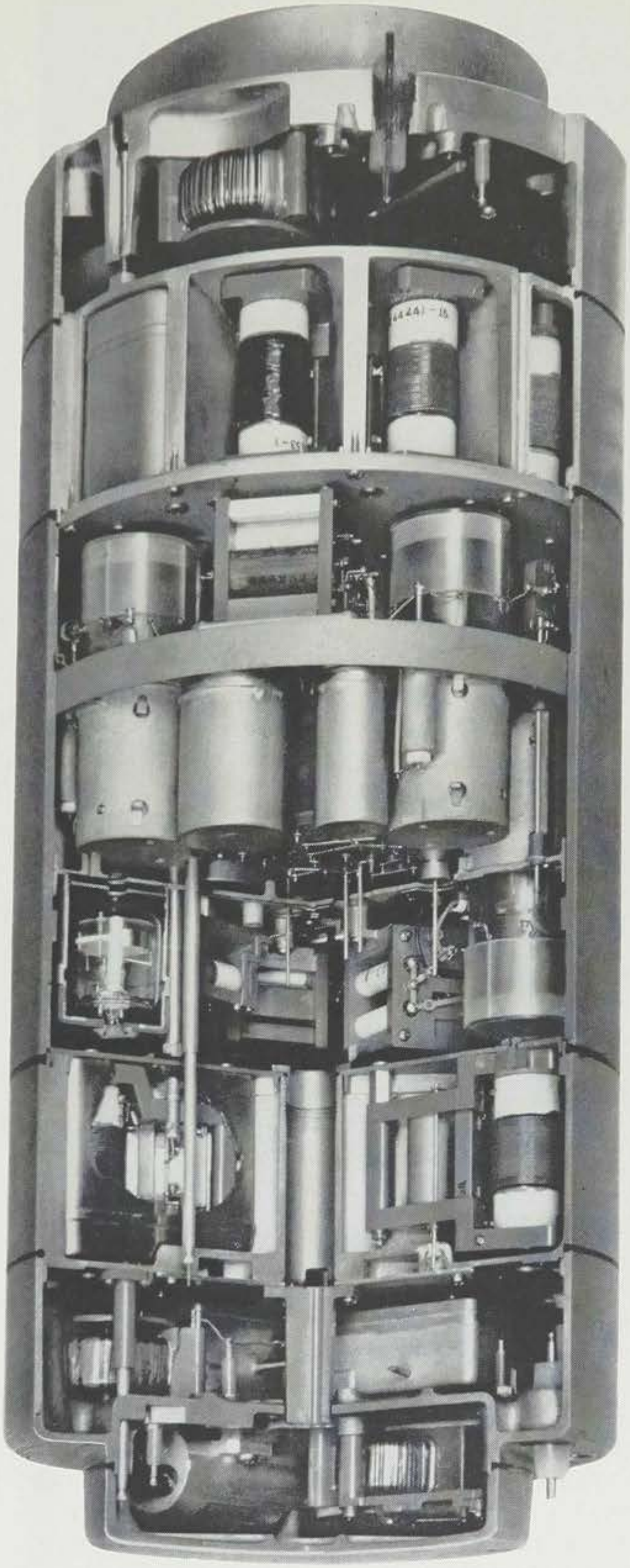
Interfering signals from unwanted transmission paths are at least 90 db below the power of the desired signals. The amplifier uses series feedback to stabilize gain and suppress modulation. At 100 kc feedback is about 61 db; at 1100 kc it decreases to 30 db.

Electrical connections to the repeater are carried through the end covers by seals using polyethylene as the insulator in the beryllium copper shell. These seals tighten as the water pressure increases.

A flexible joint permits the cable center line to deviate from the repeater center line by 30 to 40 degrees. This allows the repeater to be carried around the drum during cable-laying operations. The center conductor of the cable is connected to beryllium copper, which is then embedded in polyethylene and inserted in a housing to form part of a gimbal joint. The repeater end of the joint has a flexible pigtail lead connected and molded to the repeater seal.

The repeater uses specially designed tubes with long-life cathodes made of nickel, 2 per cent tungsten, and 0.02 per cent magnesium. The tubes use the same glassware as a Bell System electron tube which has been operating without failure since 1956 in the first trans-Atlantic telephone cable system.

Several safeguards are built into the repeater: Two parallel amplifiers are used so that if a tube in one develops trouble, the other amplifier circuit can carry the load. If a cathode heater opens in one path, a fusible alloy device bypasses the heaters and inserts a compensating resistance. Gas tubes connected across input and output protect the device from high-voltage surges caused by accidental damage to the cable. These tubes can carry short-duration surges of up to 100 amperes.



Cutaway view of the two-way submarine repeater showing the amplifier unit in the center section with the directional filters on each side. The power separation filters are located at each end.

A Western Electric technician uses a dental mirror and jeweler's magnifying glass to inspect a soldered connection in the amplifier unit used in the newly-designed two-way submarine repeater.

The repeater unit at left has been encapsulated in epoxy resin. The unit at right is being prepared by technician for similar encapsulation.

Technician communicates with data collection center regarding transmission of electrical test data on directional filter units, part of the "life history" taken on each component and sub-assembly.

Manufactured under super-clean conditions in which the atmosphere dust count is only 1/50 of the average home or office, the new repeater is deceptively simple in external appearance but is packed with more than 5,000 parts, including about 200 intricate electrical apparatus assemblies.

Each component and assembled unit is a product of careful attention to selection of raw materials and extraordinary manufacturing technique.

Some of the components are assembled under microscopes. Some are tested by means of radioactive isotopes or checked by X-rays. Each repeater is subjected to 12,000 psi to simulate the pressures at the bottom of the ocean. This test, in which helium is employed, is capable of detecting leaks so tiny that it would take 26 years to fill a thimble with the amount of gas that would leak into the casing.

Each repeater contains 25 paper and aluminum foil capacitors, 57 capacitors of other types, 48 inductors, six electron tubes, three gas tubes, six transformers, a crystal unit and thousands of other parts. These components are assembled into a sealed aluminum casing which is bolted and welded. The unit is dried under vacuum for 100 hours, then is further sealed with an external epoxy coating.

It is placed inside the beryllium copper casing and cushioned on fiberglass "springs" to protect the repeater unit against the shock of striking the ocean floor when the cable is laid. Heavy dome-shaped covers of beryllium copper are placed over the ends of the cylindrical casing and welded to the casing.

The components which go into each repeater take about 15 months to assemble, but much of this time is consumed by extensive tests—some lasting up to six months—to insure dependability. About 1700 test readings are made during manufacture of each repeater. At full production, Western Electric's new plant at Clark is expected to turn out about 400 repeaters each year.

Connecting the two-way repeaters will be 20-mile lengths of a special "armorless" cable. This 1¼-inch diameter coaxial cable will be manufactured in a new plant at the Baltimore Works of the Western Electric Company. The design structure of the cable is distinctly superior to previous Bell System designs for underwater telephone transmission systems.

Armorless submarine cable owes its strength to a steel spine running through its center. By placing the steel in the center instead of around the cable, engineers at the Laboratories were able to increase the thickness of the insulation without enlarging the diameter of the cable. The thicker insulation helps reduce transmission losses 60 per cent.

Transmission losses in the cable increase as the square root of the frequency, but can be reduced by increasing the size of the conductors and the insulator. In present undersea armored cables this would mean also increasing the outside steel by a proportional amount. The armorless cable makes more efficient use of available space. Since a conductor can be made hollow without reducing its signal-carrying capacity, the strength-providing spine of the armorless cable is contained inside the inner copper conductor.

The cable's inner spine consists of 41 wires of high-carbon steel with a tensile strength of around 300,000 psi. The steel strand has a breaking strength of 16,000 lb. The other elements of the cable add to this strength, so the cable can withstand 18,500 lb. without breaking.

Surrounding the steel spine is the inner copper conductor, hermetically sealed by inert gas welding. Variations in the thickness of the conductor do not significantly affect transmission losses because the copper is relatively thick for the frequencies transmitted. D. C. resistance is 1.64 ohms per nautical mile at 3 degrees C. A low density polyethylene, highly resistant to environmental stress cracking, lies over the inner copper conductor.

Around the polyethylene is the return conductor, a 10-mil copper tube with a simple overlap longitudinal seam that withstands bending to a three-foot radius without buckling or changing its electrical characteristics.

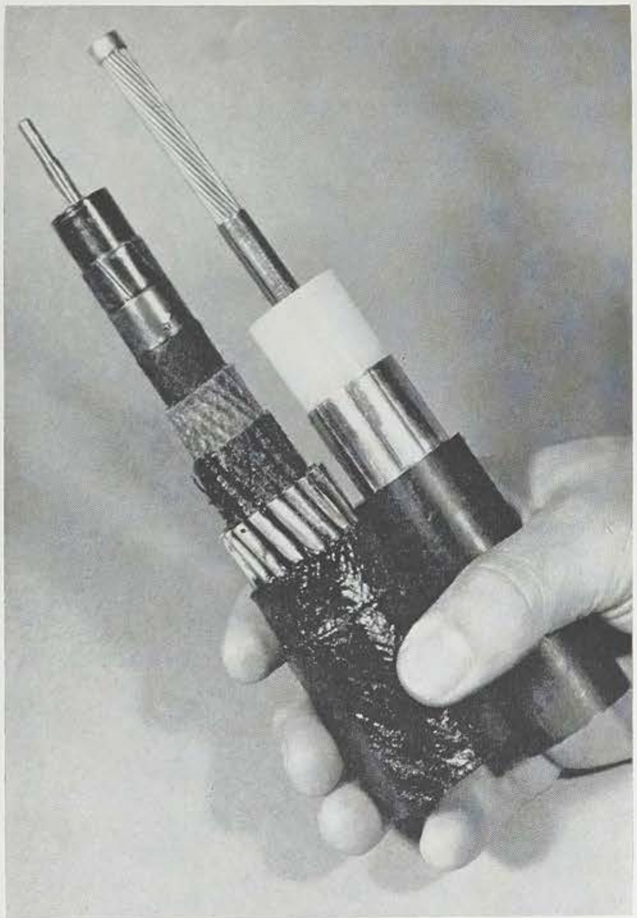
Finally, a high density black polyethylene, approximately an eighth of an inch thick protects the cable. The polyethylene also holds the return conductor against the insulator when the cable is bent.

At laying tensions, the inner strand twists less than one-half turn every 100 feet. Thus, since twisting is retarded during the laying of the two-way rigid repeater designed for this system, there is little chance of damage to the armorless submarine cable.

Current in the armorless cable is 389 milliamperes. For the maximum route the total drop of 11,000 volts requires two power supplies to operate at plus or minus 5500 volts.

The high-voltage capacitors, after being hermetically sealed, are X-rayed to insure that no foreign matter is present which might cause failure under operating conditions. After the X-ray inspection, the capacitor is ready for trial. It undergoes a 10-day temperature-cycling and aging period, more severe than normal operation will require, and a 26-week life test.

Finally, the capacitors, along with the vast array of other thoroughly tested components, are fitted together in the aluminum casings which are joined to make the repeater unit.



Comparison of present undersea cable (left), and new armorless cable designed by Bell Laboratories.

news in brief

Laboratories Develops New Method For Growing Beryl Crystals

A new method for rapidly growing large beryl single crystals has been developed by the Laboratories. Beryl crystals ($Be_3Al_2Si_6O_{18}$) with chromium impurities are called emeralds. These crystals may possibly be used in high frequency microwave masers.

R. C. Linares (presently associated with the Solid State Materials Corporation), A. A. Ballman, and L. G. Van Uitert of the Crystal Chemistry Research Department describe their method in a forthcoming issue of the Journal of Applied Physics.

They placed a sample of dehydrated beryl on the bottom of a platinum crucible, added small amounts of beryllium oxide, aluminum oxide, and ammonium chromium sulfate and then filled the vessel with vanadium pentoxide. They placed the crucible in a furnace so that the bottom was heated to 1050 degrees C and the top to 1000 degrees C. The beryl in the bottom part of the crucible dissolved and then crystallized out on a seedplate hung in the upper part (lower temperature region) of the solution. By varying the amounts of chromium impurities, the scientists were able to grow beryl single crystals of emerald green or lighter colors.

Since beryl crystals are highly resistant to thermal shock, they can be grown in large batches and removed quickly without damage from the 1000 degrees C solution to room temperatures.

L. G. Van Uitert examines a beryl crystal grown at the laboratories.

Book of Delay Tables Published

A. Descloux of the Traffic Studies Center has recently had a book published by McGraw-Hill. The book — "Delay Tables for Finite- and Infinite-Source Systems"—presents tabulated values which enable the operations researcher and engineer to deal quickly with important classes of delay systems. Delay tables are widely used in computing delays to be expected in making telephone calls, the stacking of aircraft, the use of freeways and turnpikes by automobiles, airline ticket reservations, inventory control, machine maintenance, docking facilities for oil tankers, and a variety of similar situations.

Erratum . . .

The caption under the color picture of oxide crystals in the July-August issue of the RECORD (page 244) unfortunately contained several errors because of a change in the numbering system introduced during the printing process. The correct listing should read:

- 1-2 Quartz (grown hydrothermally)
- 3 Zinc oxide (grown hydrothermally)
- 4-5 Yttrium iron garnets (grown from flux)
- 6-19 Yttrium gallium garnets (grown from flux — doped with various types of impurities)
- 20 Ruby (grown hydrothermally)
- 21 Sapphire (grown hydrothermally—doped with iron)
- 22-23 Yttrium iron garnets (grown hydrothermally)
- 24 Calcium tungstate (grown by Czochralski technique)
- 25 Calcium tungstate (grown by Czochralski technique—doped with neodymium)
- 26 Quartz (grown hydrothermally—doped with iron)

PATENTS

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

Beck, A. C. and Chinnock, E. L.—*Apparatus for Winding Wire into a Helix*—3,039,707.

Bostwick, L. G. and Strack, W.—*Selective Signaling System with Narrow Band Feedback*—3,040,256.

Brown, J. T. L.—*Wet Rest for Inking Stylus*—3,039,438.

Buhrendorf, F. G.—*Oscillatory Drive Circuit*—3,040,223.

Carbrey, R. L.—*Pulse Transmission of Alternate Interchange Code*—3,038,029.

Cagle, W. B. and Muroski, W. G.—*Transistor Test Set*—3,041,537.

Chinnock, E. L., see Beck, A. C.

Cioffi, P. P.—*Electron Beam Focusing System*—Re 25,189.

D'Asaro, L. A.—*Semiconductor Pulse Translating System*—3,040,196.

Davey, J. R.—*Telegraph System—Hub Coupling Circuit*—3,038,035.

Davis, T. E.—*Positioning a Transistor by Use of the Optical Reflectance Characteristics of the Electrode Stripes*—3,038,369.

Dillon, J. F., Jr.—*Translation Device having Ferromagnetic Core*—3,040,184.

Favin, D. L.—*Data Signal Distortion Measuring Circuit*—3,041,540.

Fisher, K. A.—*Phase Comparator Circuit having Integrating and Differentiating Input Means*—3,039,059.

Gianola, U. F.—*Magnetic Memory Circuits*—3,040,305.

Griffiths, H. D., Higgins, R. H. and Studdiford, W. E.—*Test Probe*—3,040,254.

Higgins, R. H., see Griffiths, H. D.

Kingston, P. E.—*Cable-Handling Equipment*—3,038,648.

Kompfner, R. and Weiss, M. T.—*Microwave Filter*—3,041,559.

Lockwood, W. H. and Peters, H.—*Method of Fabricating a Laminated Magnetic Recording Sleeve*—3,040,386.

McKim, B.—*Number Identifying System*—3,041,407.

Meitzler, A. H.—*Ultrasonic Strip Delay Line*—3,041,556.

Muroski, W. G., see Cagle, W. B.

Ohm, E. A.—*Wave Guide Taper*—3,040,277.

Ostendorf, B., Jr. and Parker, G.—*Receiving Selector for Permutation Codes*—3,041,396.

Parker, G., see Ostendorf, B., Jr.

Pearson, G. L.—*Light Sensitive Resonant Circuit*—3,040,262.

Peters, H., see Lockwood, W. H.

Sandberg, I. W.—*Active Multiport Networks*—3,041,557.

Schemel, R. E. and Tompos, A.—*Current Supply System*—3,040,235.

Seidel, H.—*Negative Resistance Amplifier Circuits*—3,040,267.

Strack, W., see Bostwick, L. G.

Studdiford, W. E., see Griffiths, H. D.

Tompos, A., see Schemel, R. E.

Trambarulo, R. F. and Turner, E. H.—*Waveguide Attenuator*—3,040,276.

Turner, E. H., see Trambarulo, R. F.

Van Uitert, L. G.—*Polycrystalline Garnet Materials*—3,038,861.

Weiss, M. T., see Kompfner, R.

Zarouni, A.—*Switching System*—3,041,409.

PAPERS

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

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Collins, R. J., and Kisliuk, P., *The Control of Population Inversion in Pulsed Optical Masers by Feedback Modulation*, J. Appl. Phys., 33, pp. 2009-11, June, 1962.

Compton, V. B., and Matthias, B. T., *The Crystal Structure of Scandium (3) Indium*, Acta Cryst., 15, p. 94, Jan., 1962.

Cooper, A. S., *Precise Lattice Constants of Germanium, Aluminum Gallium Arsenide, Uranium Sulphur, Quartz and Saphire*, Acta Cryst., 15, pp. 578-82, June, 1962.

David, E. E., *Amplitude Compression—Bandwidth Compression*, In—Susskind, C., Ed., *Encyclopedia of Electronics*, N. Y., Reinhold, 1962, pp. 131-3.

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

Eisele, K. M., and Rulison, R. L.,

Low-Noise Reactance Amplification Using Refrigerated Epitaxial Silicon Varactor Diodes, Proc. IRE, 50, p. 1523, June, 1962.

Faust, W. L., see Bennett, W. R.

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Frisch, H. L., Hammersley, J. M., and Welsh, D. J. A., *Monte-Carlo Estimates of Percolation Probabilities for Various Lattices,* Phys. Rev., 126, pp. 949-51, May 1, 1962.

Frisch, H. L., and Stillinger, F. H., *On the Adsorbtion of Polyelectrolytes at Planar Dielectric Substrates,* J. Phys. Chem., 66, pp. 823-8, May, 1962.

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TALKS

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

Ahearn, A. J., *Vacuum Spark Mass Spectrographic Analysis of Solids and Liquids*, Intern. Conf. on Spectroscopy, College Park, Md.

Anderson, T. C., see Favin, D. L.

Arthur, J. R., *Field Emission from Germanium*, Univ. of Notre Dame, Notre Dame, Ind.

Asaro, D., *Diffusion of Zinc into Gallium Arsenide by the Box Method*, L. A. Electrochem. Soc., Los Angeles.

Ashkin, A., *Thin Film Resonators for Solid-State Optical Masers*, Ann. Conf. Electron Device Research, Minneapolis.

Batdorf, R. L., and Lee, C. A., and Wiegmann, W., *Impurity Profiles in Thin, Lightly Doped, Vacuum Diffused Layers of Silicon*, IRE Solid State Device Research Conf., Durham, N. H.

Batdorf, R. L., and Weiss, M. M., *Radiation Hazards of Optical Masers*, Annual Mtg. Health Phys. Soc., Chicago.

Bennett, W. R., and Faust, W. L., and McFarlane, R. A., and Patel, C. K. N., *Dissociative Excitation Transfer and Optical Maser Oscillation in Gas Discharges*, Electron Device Conf., Minneapolis.

Black, H. S., *New Developments in Communications Research*, 1. Weco Grad. Engrg. Training Program, New York, Winston Salem, N. C., Chicago, 2. Weco., Burlington, N. C.

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

Bogert, B. P., and Healy, M. J. R., and Tukey, J. W., *The Quefrency Alanysis of Time Series for Echos—Cepstrum, Pseudo-Autocovariance, Cross-Cepstrum and Saphe-Cracking* [sic], Symp. on Time Series Analysis, Brown Univ.

Boyd, G. D., see Kogelnik, H.

Brattain, W. H., *Surface Properties of Semiconductors*, Mtgs. of Nobel Prize Winners, Lindau, Germany.

Brattain, W. H., and Boddy, P. J., *Surface States at a Germanium Electrolyte Interface*, Intern. Conf. on Physics of Semiconductors, Exeter, England.

Buchsbaum, S. J., *Resonant Absorption by Electrons and Ions in a Warm Plasma*, Am. Phys. Soc., Evanston, Ill.

Burbank, R. D., *A Redetermination of the Orthorhombic Iodine Heptafluoride Structure*, Am. Cryst. Assoc., Villanova Univ., Villanova, Pa.

Byrne, C. J., and Scattaglia, J. V., *A Buffer Memory for Synchronous Digital Networks*, Mil-E-Con, Washington, D. C.

Callaway, W. B., *Call Count Totalizer*, AIEE, Denver.

Chasek, M. B., *An Accurate Millimeter Wave Loss and Delay Measurement Set*, PGMTT Nat'l Symp., Boulder, Colo.

David, E. E., *Speech in the Computer Age*, Alexander Graham Bell Assoc. for the Blind, Detroit.

David, E. E., *Problems in Generating Spoken Outputs*, Am. Foundation for the Blind, New York.

Dewald, J. F., *Fermi Levels, Miscibility Gaps and the Mott-Transition to Metallic Behavior*, Calif. Inst. Tech, Pasadena.

Dietz, R. E., and Sturge, M. D., and Liehr, A. D., *The Absorption Spectrum of Tetrahedrally Coordinated Copper*, Symp. on Mol. Structure and Spectroscopy, Columbus, O.

Dow, R. J., *The Conjugate Function Approach for Describing Current Density and Resistance in Odd-Shaped Conductors*, 1962 Elect. Compon. Conf., Washington, D. C.

Early, J. M., *Semiconductor Devices for RF Generation and Amplification*, Natl. Telemetering Conf., Washington, D. C.

Eastwood, D. E., *Techniques of Program Organization*, Univ. Michigan, Engineering Conf. in Advanced Automatic Programming, Ann Arbor.

Espinosa, G. P., *A Crystal Chemical Study of the Rare-Earth Iron Garnets*, Am. Cryst. Assoc., Villanova Univ., Villanova, Pa.

Faust, W. L., se Bennett, W. R.

Favin, D. L., and Anderson, T. C., *A Versatile Random Data Signal Generator*, AIEE, Denver.

Ferguson, J., *The Electronic Absorption Spectrum of Cobalt Chlorine (4) in Three Different Crystal Environments*, Symp. Mol. Structure and Spectroscopy, Columbus, O.

Ferguson, J., and Wood, D. L., and Liehr, A. D., *Three Electron (or Hole) Cubic Ligand Field Spectrum, Part-2. Comparison with Experiment*, Symp. on Mol. Structure and Spectroscopy, Columbus, O.

Fiorito, L. E., *A Rapid Duct Corrosion Survey for Lead Sheath Telephone Cables*, Nat. Assoc. Corrosion Engrs., Toronto.

Flanagan, J. L., and Guttman, N., and Watson, B. J., *Pitch of Periodic Pulses with Non-Uniform Amplitudes*, Acoust. Soc. Am., New York.

Flavin, M. A., and Prins, G. C., *Medium-Speed Parallel "Data-Phone" System*, AIEE, Denver.

Foster, N. F., *A New High-Frequency Ultrasonic Transducer*, IRE-AIEE Solid State Device Research Conf., Durham, N. H.

Fox, A. G., *Coherent Wave Optics, New Frontier of the Microwave Art*, IRE Prof. Group on Microwave Theory Tech., Boulder, Colo.

Frisch, H. L., *The Equation of State for a Classical Hard Sphere Fluid*, Am. Phys. Soc., Evanston, Ill.

Fu, C., *Designing for Nuclear Blast Resistance*, U. S. Naval Petroleum Co., New York City.

Galt, J. K., *The Relationship Between Science and Engineers,* Engrs. Joint Council Symp., New York City.

Garrett, C. G. B., *Optical Masers,* IBM, Yorktown Heights, N. Y.

Geller, S., *Refinement of the Crystal Structure of Cobalt (9) Sulfur (8). The Crystal Structures of Palladium (17) Selenium (15) and Rhodium (17) Sulfur (15),* Am. Cryst. Assoc., Villanova Univ., Villanova, Pa.

Geschwind, S., *Optical Detection of Paramagnetic Resonance in the Excited Doublet-E-State of Chromium (III) in Aluminum Oxide,* Intern. Conf. on Magnetic and Electric Resonance and Relaxation, Eindhoven, The Netherlands.

Gibson, W. M., *A Detailed Study of Energy and Mass Division in Low-Energy Neutron Induced Fission Using Solid-State Detectors,* Gordon Research Conf., New London, N. H.

Giordmaine, J. A., *Nonlinear Optical Effects in Crystals,* MIT Summer Session on Optical Masers, Cambridge, Mass.

Giordmaine, J. A., *Notes—Harmonic Generation in Dielectrics,* MIT Summer Session on Optical Masers, Cambridge, Mass.

Gordon, E. I., see Rigden, J. D.

Guttman, N., see Flanagan, J. L.

Hagelbarger, D. W., *Recurrent Codes for the Binary Symmetric Channel,* Univ. of Michigan Course on Theory of Codes, Ann Arbor.

Hagstrum, H. D., *Two-Electron Transitions Involving Ions Near Solid Surfaces,* Westinghouse Electric Corp., Pittsburgh.

Ham, J. H., and West, F., *A TOUCH-TONE Caller for Station Sets,* A.I.E.E., New York City.

Harmon, L. D., *Neuron Models for Visual Research,* Intern. Cong. on Technol. and Blindness, New York City.

Haugk, G., and Yokelson, B. J., *Experience with the Morris Electronic Switching System,* AIEE, Denver.

Healy, M. J. R., see Bogert, B. P.

Helder, G. K., *Engineering Considerations of Subscriber Loop Testing,* AIEE, Denver.

Hensel, J. C., *Cyclotron Resonance Experiments in Uniaxially Stressed Silicon—Valence Band Inverse Mass Parameters and Deformation Potentials,* Naval Research Lab., Washington, D. C.

Hershey, J. H., *Reliability Analysis in Complex Systems,* 1962 SAE Natl. Automobile Week, Detroit.

Hight, S. C., *Communicating with Men and Machines in Space,* Old Guard of Millburn, N. J.

Hinderliter, R. G., *Transmission Characteristics of Bell System Subscriber Loop Plant,* AIEE, Denver.

Johnson, L. F., *New Optical Maser Materials Incorporating Trivalent Rare-Earths,* 1. Electrochem. Soc. Symp. on Optical Masers, Los Angeles. 2. Internat. Conf. on Magnetic and Electronic Resonance and Relaxation, Eindhoven, The Netherlands.

Johnson, L. F., *New Optical Maser Materials Incorporating Trivalent Rare Earths,* Electrochem. Soc. Symp., Los Angeles, Calif.

Jones, H. J., and Sturzenbecker, C., *High Performance Servo Magnetic Amplifier for Severe Environmental Applications,* AIEE, Denver.

Kane, J. V., *The Reaction Oxygen-16 (Alpha, 2-Alpha) Carbon-12 at 40Mev,* 1. Univ. of Maryland, College Park. 2. MIT, Cambridge, Mass.

Kennedy, J. T., and Rosson, J. W., *The Use of Solar Radio Emission for the Measurement of Radar Angle Errors,* IRE 6th Natl. Conv. on Military Electronics, Washington, D. C.

Kennedy, R. A., *Library Applications of Permutation Indexing,* Spec. Libraries Assoc. Conv., Washington, D. C.

Kiernan, W. J., *Color in Organic Finishes,* Symp. Am. Electroplaters Soc., Milwaukee.

King, J. C., *Acoustic Absorbtion in Alpha-Quartz,* IBM Watson Research Lab., Yorktown Heights, N. Y.

Kogelnik, H., and Boyd, G. D., *Forbidden Regions in Optical Maser Resonators,* 20th Ann. Conf. on Electron Device Research, Minneapolis.

Kuebler, N. A., see Nelson, L. S.

Kunzler, J. E., *High Field Superconductivity and Magnetic Fields,* Natl. Mtg. Inst. Aerospace Sci., Los Angeles.

Kunzler, J. E., *Superconducting Magnets,* Can. Assoc. Physics, Hamilton, Ont.

Laidig, J. F., *Systems Aspects of the TH Radio Relay System,* AIEE Conv., Denver.

Laudise, R. A., *Growth of Oxide Crystals,* Penn. State Univ., University Park, Pa.

Lee, C. A., see Batdorf, R. L.

Levenbach, G. J., *Multifactor Experimentation,* New York Univ. Statistics Inst.

Liehr, A. D., see Dietz, R. E.

Liehr, A. D., see Ferguson, J.

Liehr, A. D., *The Geometrical Instability of Cubo-Symmetric Inorganic Compounds in Degenerate Electronic States.* 7th Intern. Conf. on Coordination Chem., Stockholm.

Liehr, A. D., *Conformational Instability of Non-Cubo-Symmetric Inorganic Compounds in Degenerate Electronic States,* Symp. on Theory and Structure of Complex Compounds, Wroclaw, Poland.

Liehr, A. D., *A Topological Theory of Stereo Chemical Stability,* Symp. on Mol. Structure and Spectroscopy, Columbus, O.

Locke, W. J., *Microfilm Systems for Handling Engineering Drawings,* Assoc. Records Executives and Administrators, New York City.

Loomis, T. C., see Storks, K. H.

Macrae, A. U., *The Surface Structure of Clean Nickel Crystals,* Am. Cryst. Assoc., Villanova, Pa.

Manning, W. H., *Space-Age Electronics,* Univ. South Carolina, Columbia.

Mardis, T. E., *The U.S. Space Program,* 1. Kiwanis Club, Greenville, S. C. 2. Civitan Club, Greensboro, N. C.

Mathews, M. V., *Signal Detection for Human Auditory Perception,* Time Series Conf., Providence, R. I.

McFarlane, R. A., see Bennett, W. R.

McFee, J. H., *Ultrasonic Traveling-Wave Amplification in Cadmium Sulphide and Zinc Oxide,* Electron Device Research Conf., Minneapolis.

McLean, D. A., *Tantalum Film Circuits,* IRE Prof. Group on Electron Devices—Prof. Group on Prod. Eng. Prod. Local Sect., Boston.

Meiboom, S., *NMR Relaxation Methods in the Study of Chemical Kinetics,* Symp. on High Resolution NMR Spectroscopy, Boulder, Colo.

Morris, R., *Further Evaluation of Data Transmission on the Switched Telephone Network,* AIEE Mtg. and Aero-Space Transportation Conf., Denver.

Nassau, K., *Masers and Lasers,* Ceramic Assoc. of New Jersey, Harmony.

Nassau, K., *Crystal Growth for Optical Masers,* IBM, Yorktown Heights, N. Y.

Nelson, L. S., and Kuebler, N. A., *Absorption Spectra of Gaseous Species Formed at Flash-Heated Solid Surfaces,* Intern. Conf. on Spectroscopy, College Park, Md.

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Peter, M., *The Polarization of Conduction Electrons Around Paramagnetic Impurities,* Conf. on the Structure of Metallic Solid Solutions, Orsay, France.

Pierce, J. R., *Telecommunications by Means of Artificial Satellites,* 9th Intern. Cong. on Electronics, Rome.

Pollak, H. O., *The CUPM Recommendations for Engineering Mathematics,* Am. Soc. Engr. Educ., Colorado Springs.

Porto, S. P. S., *The Optical Maser as a Raman Source,* Intern. Conf. on Spectroscopy, College Park, Md.

Porto, S. P. S., *Recent Developments in Solid-State Optical Maser Research,* Physics Dept. Colloq., Univ. of Pittsburgh.

Porto, S. P. S., and Yariv, A., *A Comparison of the Maser Behavior of Trivalent Uranium in Calcium Fluoride, Barium Fluoride and Strontium Fluoride,* Electron Device Research Conf., Minneapolis.

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Rice, S. O., *Noise in FM Receivers,* Brown Univ. Symp. on Time Series Analysis, Providence, R. I.

Rigden J. D., and Gordon, E. I., *A Fabry-Perot Electro-Optic Modulator for Optical Maser Sources,* Electron Device Research Conf., Minneapolis.

Robin, M. B., *The Assignment of Electronic Transitions in the Starch-Iodine Complex and Related Systems,* Mol. Structure and Spectroscopy Symp., Columbus, O.

Rosenzweig, W., *The Energy Dependence of Proton Irradiation Damage in Silicon,* Naval Research Lab. Seminar, Washington, D. C.

Rosson, J. W., see Kennedy, J. T.

Scattaglia, J. V., see Byrne, C. J.

Sikorski, M. E., *Correlation of the Coefficient of Adhesion with Various Physical and Mechanical Properties of Metals,* Lubrication Conf., Miami, Fla.

Sikorski, M. E., *Tunnel Diode Pressure Tranducers,* IRE-AIEE Subcomm. Mtg. on Tunnel Diode Applications, Boston.

Sikorski, M. E., *Sensitive Tunnel Diode Pressure Tranducers,* Intern. Solid State Circuits Conf., Philadelphia.

Snyder, L. C., *The Use of Open and Closed-Shell Self-Consistent Field Molecular Orbital Programs to Describe Organic Molecules and Radicals,* Gordon Research Conf. on Theoretical Chem.-Molecular Quantum Mechanics, Tilton, N. H.

Storks, K. H., and Loomis, T. C., *Miniature Probe X-Ray Spectrograph,* Intern. Conf. on Spectroscopy, College Park, Md.

Stuart, J. C., *Magnetic Memory Devices,* IRE, N. Carolina Sect., Greensboro.

Sturge, M. D., see Dietz, R. E.,

Sturzenbecker, C., see Jones, H. J.

Tanenbaum, M., *Materials, Magnets and Masers,* Carnegie Insti. Tech., Pittsburgh, Pa.

Tanenbaum, M., *Metallurgy and Electronics,* Am. Soc. Metals, Winston-Salem, N. C.; Providence, R. I.

Tukey, J. W., see Bogert, B. P.

Tuomenoksa, L. S., see Ulrich, W.

Ulrich, W., and Tuomenoksa, L. S., *Coding and Information Identification,* AIEE, Denver, Colo.

Unger, H. G., *Waveguides with Anisotropic Impedance Walls,* Symp. on Electromagnetic Theory, Copenhagen.

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

Weiss, M. M., see Batdorf, R. L.

Wiegmann, W., see Batdorf, R. L.

Williams, G. A., *Alfven Waves in Bismuth,* Am. Phys. Soc., Evanston, Ill.

Wood, D. L., see Ferguson, J.

Wood, E. A., *The Vocabulary of Surface Crystallography,* Am. Cryst. Assoc., Villanova, Pa.

Yafet, Y., *Aspects of Spin Orbit Interaction in Solids,* Princeton Univ., Princeton, N. J.

Yariv, A., see Porto, S. P. S.

Yokelson, B. J., see Haugk, G.

THE AUTHORS

J. J. Hibbert

J. J. Hibbert, author of "Project Mercury and Bell Laboratories" in this issue, was born in Medfield, Massachusetts. After receiving his B.S.E.E. from M.I.T. in 1936, he did graduate work in Communication Engineering and Physics at Harvard. In 1941, he became a member of the Radiation Laboratory at M.I.T. working on airborne radar development in the United States and with Eighth Air Force in England. In 1946, he joined the Laboratories to work on the analysis of military systems including the NIKE missile system and Naval Intercept Systems, and was appointed Systems Engineer in June, 1959. Mr. Hibbert worked on Project Mercury from 1959, when he became a member of the Mercury Team at the Laboratories headed by Mr. S. C. Hight, until 1962 when he joined the newly-formed Bellcom, Inc. in Washington, D. C. Mr. Hibbert is a member of the American Physical Society, the IRE, and the American Association for the Advancement of Science.

Homer D. Hagstrum, born in St. Paul, Minn., attended the University of Minnesota where he earned the degrees of B.E.E. in 1935, B.A. in 1936, M.S. in 1939 and Ph.D. in 1940. After joining Bell Laboratories in 1940, he worked on the development of microwave magnetrons. Since 1946, Mr. Hagstrum has specialized in physical research. His work has included studies of molecular dissociation and ionization by electron impact. His recent major activity has been in the field of interaction of positive ions with solid surfaces on which he has published numerous technical articles. He presently heads a group engaged in research into surface phenomena which occur on metals and semiconductors.

A member of the American Physical Society, Mr. Hagstrum has served as secretary-treasurer, vice-chairman and chairman of the Society's Division of Electron Physics. He has served on the governing committee of the Gaseous Electronics Conference, is a member of the Editorial Board of the Journal of Applied Physics and a member of Eta Kappa Nu, Tau Beta Pi and Sigma Xi.

H. D. Hagstrum

J. J. Kleimack, co-author of "Epitaxial Silicon Transistors" was born in Bayonne, New Jersey and has been a resident of Scotch Plains, New Jersey since 1942. He joined the Laboratories in 1930 and became a member of the early research group on semiconductors which included W. H. Brattain and was headed by J. A. Becker. Mr. Kleimack has contributed to the development of copper oxide rectifiers, thermistors, high-speed thermistors and thermistor bolometers. Since 1950 he has been engaged in the development of point-contact and alloyed junction germanium transistors and diffusion type silicon transistors. He has studied Electrical Engineering and Physics at the Polytechnic Institute of Brooklyn and is a member of the American Physical Society.

J. J. Kleimack

Henry C. Theuerer, a native New Yorker, joined the Laboratories in 1928. Since that time he has been engaged in a variety of projects including the development of physical tests for organic finishes, the vacuum analysis of gases in graphite for electron tube research, and the development of methods for the preparation of high purity silicon and

H. C. Theuerer

germanium for transistors and related devices. During the past two years he has been working on methods for preparing thin films of silicon for epitaxial transistors as well as films of superconducting alloys for critical field studies. Mr. Theuerer received a B.S. in Chemical Engineering from Cooper Union in 1933 and an M.A. in Chemistry from Columbia University in 1939. He is a member of the American Society for Metals and for three years was chairman of the ASTM subcommittee for semiconducting materials. He is co-author of "Epitaxial Silicon Transistors" in this issue.

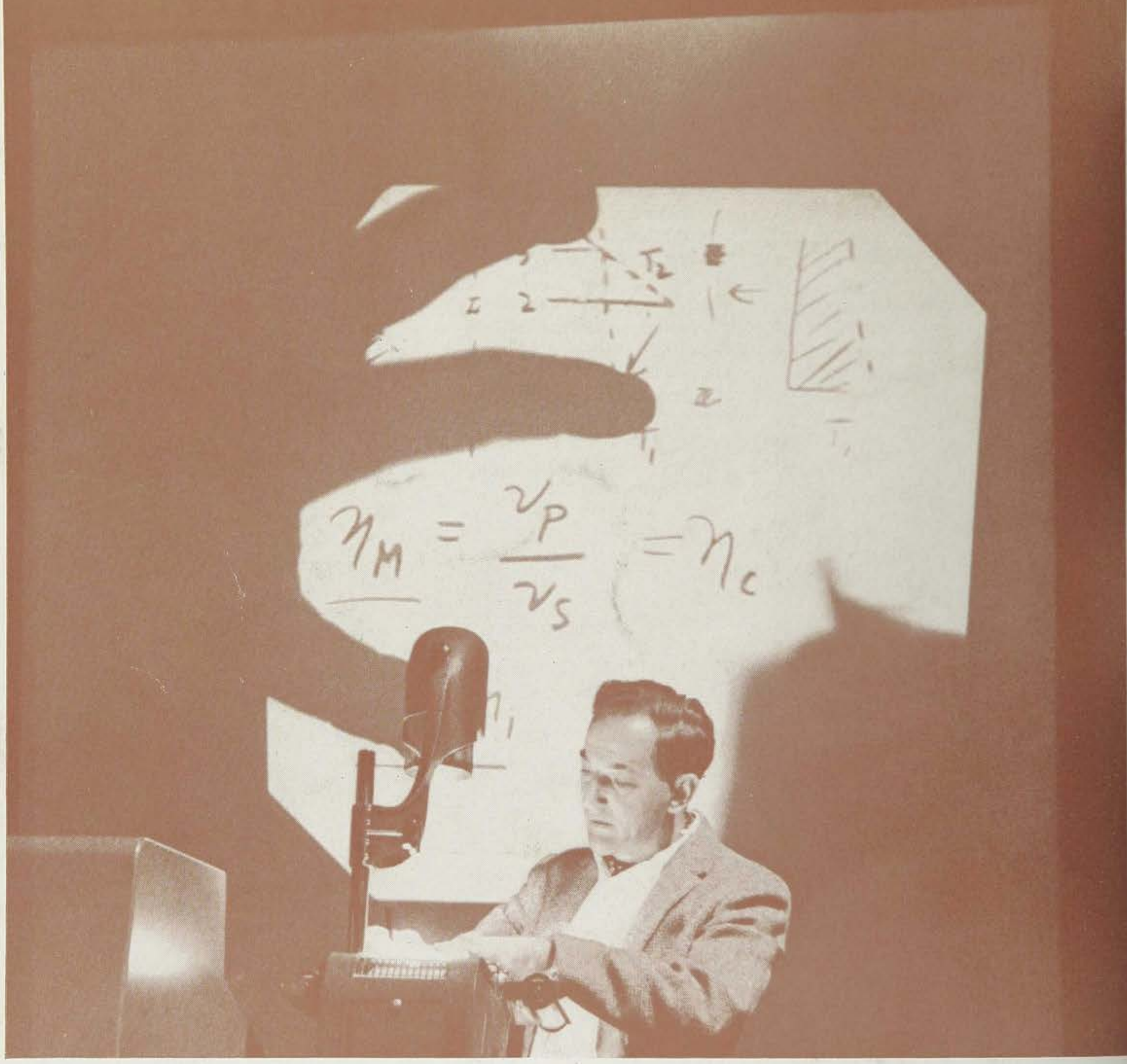
S. C. Antas

S. C. Antas, a native of Newark, N. J. and author of "The B Wire Connector for Cable Splicing" in this issue, graduated from Lehigh University in 1949 with a B.S.M.E. degree. He received his M.S.I.E. from Stevens Institute of Technology in 1957. Before coming to the Laboratories, Mr. Antas was employed as a Development Engineer specializing in recording and control mechanisms and instruments in handling bulk materials. An early interest in engineering was sparked by his work as a tool and diemaker where he was often directly associated with engineers on experimental or developmental jobs. Mr. Antas, who resides in Irvington and spends his summers in Spring Lake, is a member of the Advisory Board of the Newark Boys' Clubs and is active in fund-raising and other Boys' Clubs' activities.

Myron E. Krom, a native of Indiana, graduated from Purdue University with a B.S.E.E. in 1923. That year, he joined the Western Electric Company's Engineering Division, which later became a part of Bell Laboratories. He was initially involved with radio induction studies. During the war, he participated in the design and testing of radar equipment. After the war, Mr. Krom worked on the design of No. 5 Crossbar circuits and, in 1953, he was concerned with the design and development of the 1A Line Concentrator. He is presently engaged in exploratory studies of methods for providing special services, such as abbreviated dialing, temporary transfer, and call-waiting in the No. 5 Crossbar system. Mr. Krom, the author of "The 1A Line Concentrator" in this issue, is a resident of Minerva Park, Ohio and a member of the Laboratories technical staff in Columbus.

M. E. Krom

What sets the stage for scientific discovery?



H. E. D. Scovil, pioneer developer of the solid state microwave maser, explains a point at a symposium at Bell Telephone Laboratories.

There is no one answer. But surely discovery is more likely when people are stimulated to think in new ways. And nothing more powerfully stimulates scientists and engineers than up-to-the-minute discussion of the latest developments.

Bell Laboratories scientists and engineers make a point of exchanging information on their latest advances not only among themselves but with the great world-wide professional community to which they belong. Last year, for example, Bell Laboratories specialists delivered over 1200 talks to technical societies and universities. The stimulating exchange of new ideas plays an indispensable role at the world center of communications research and development.

Bell Telephone Laboratories