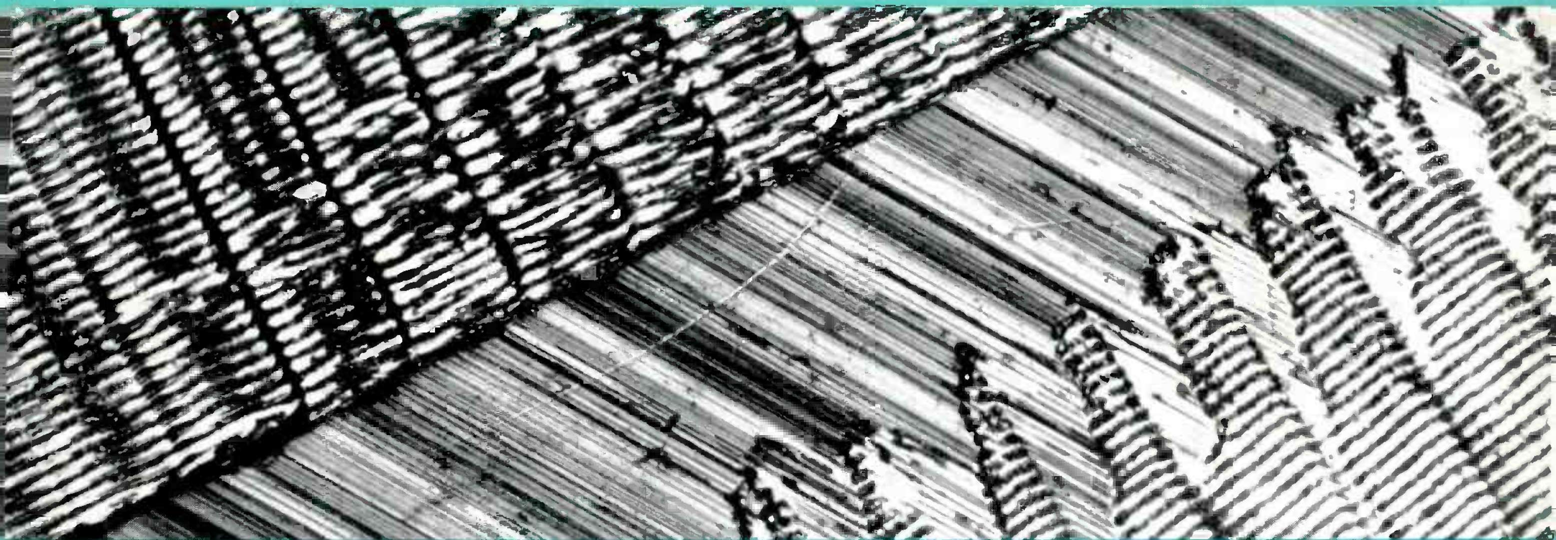
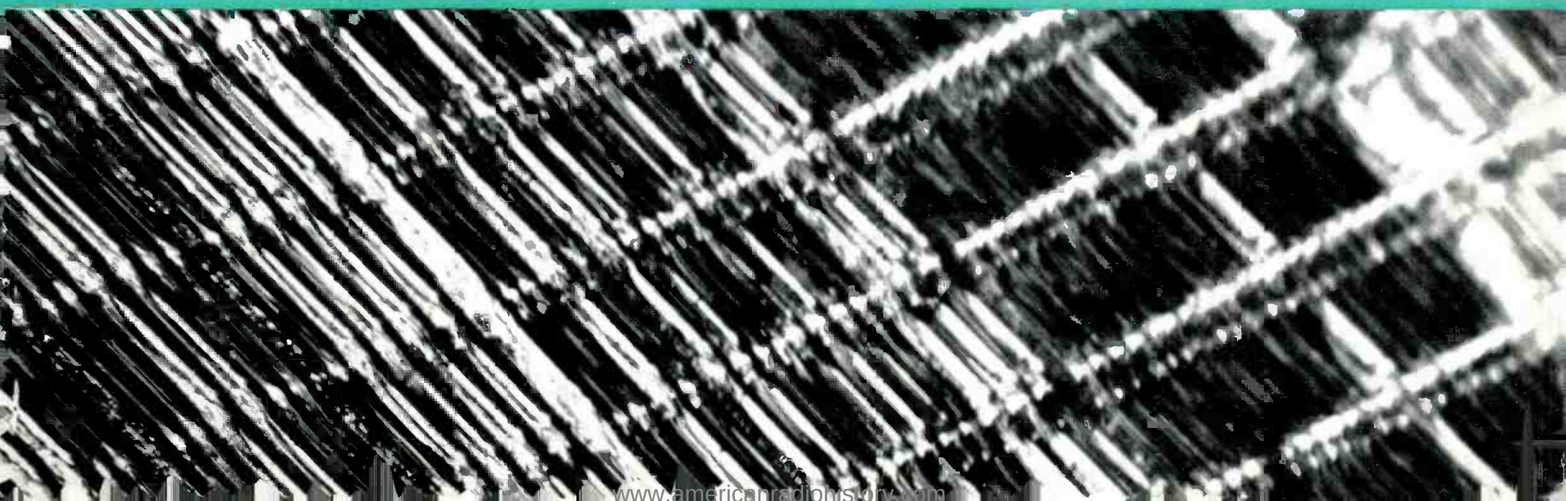
November 1961

Bell Laboratories RECORD





THE BELL LABORATORIES RECORD is published monthly by Bell Telephone Laboratories, Incorporated, 463 West Street, New York 14, N. Y., J. B. FISK, President; K. PRINCE, Secretary; and T. J. MONTIGEL, Treasurer. Subscription: $2.00 per year; Foreign, $2.95 per year. Checks should be made payable to Bell Laboratories Record and addressed to the Circulation Manager. Printed in U. S. A.

Bell Laboratories **RECORD**

Volume 39 • Number 11 • November 1961

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Cover

Photomicrographs of three areas on the surface of an ingot of silver antimony telluride, one of the new semiconductors described in the article on page 388. (These photomicrographs, as well as those on page 394, by E. E. Thomas and R. Wolfe.)

Th

W. H. Tidd

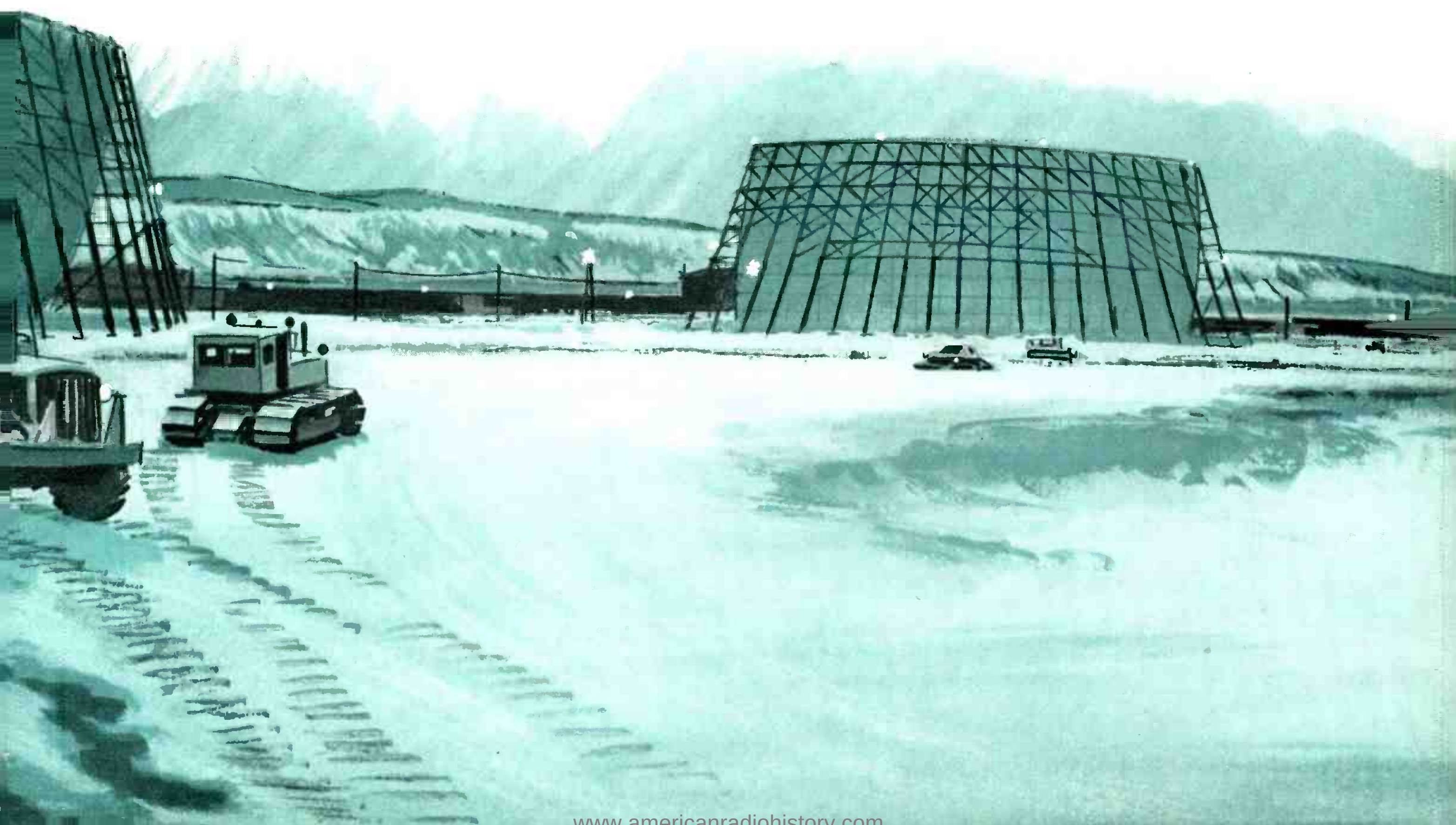
BMEWS Communications System

The Ballistic Missile Early Warning System (BMEWS) is a vast defense complex which ultimately will cover nearly half of the Northern Hemisphere from England to the Bering Straits. Every moment of the day and night, its radars scan the space over another part of the globe. With its ultra-sensitive "eyes" watching for the approach of enemy ballistic missiles, BMEWS is the first line of defense for the North American continent.

Some believe that if there is a third world war, it will be a short one. With ballistic missiles traveling at speeds of more than 14,000 miles an hour, the outcome of another war could be decided—not in days—but in a matter of minutes. An enemy missile detected by BMEWS could strike its target up to about 25 minutes later. This is why the BMEWS Communications System is vitally important. This huge network of circuits transmits information in seconds from BMEWS radar sites to the headquarters of the North American Air Defense Command (NORAD) at Colorado Springs; it is one of the fastest and most reliable military communication system ever devised.

When BMEWS is fully operational there will be three forward detection sites, two in the Arctic at Thule, Greenland, and Clear, Alaska, and the third in Fylingdales, England. In addition to data-processing equipment for reducing data, each site has scanning or tracking radars and sometimes both. The scanning radars, with antennas 400 feet long and 165 feet high, have a range of more than 2000 miles. The tracking radar has a similar range and uses a steerable antenna 85 feet in diameter.

The information from the detection sites is



brought together at the BMEWS Central Computer and Display Facility presently located at NORAD headquarters. Here, Armed Forces personnel from the United States and Canada collect and compare the information from the detection sites and evaluate the strategic threat.

The warning information from the detection sites is transmitted to the Central Computer and Display Facility by the BMEWS Rearward Communications System. This system, designed at Bell Laboratories, is the subject of this article. In view of the extreme importance of the warning information to the air defense agencies, the objectives of this communication system, as for BMEWS as a whole, are extraordinary reliability, continuous operation, and high speed.

Transmission Facilities

The BMEWS communication circuits, running up to 6000 miles, are twice as long as most long-distance circuits in the continental United States. Many of these circuits include military systems in remote and inaccessible arctic regions. The facilities are owned and operated by many communications companies and military agencies. All types of transmission facilities are involved: microwave radio, tropospheric scatter radio, submarine cable, aerial cable, and coaxial cable. Despite the difficulties of integrating these facilities, the BMEWS Communications System continuously provides very high quality voice, high-speed data, and teletype service.

The first step was to modify many of the existing transmission systems so that they could provide increased reliability before being included in the BMEWS communication complex. In several cases, entirely new systems were constructed. Laboratories engineers designed such new major systems to be compatible not only with BMEWS, but also with the rapidly developing world-wide network of military communications facilities. This, in itself, occasioned some revision in transmission objectives for such facilities, since the military network will encompass many circuits more than 6000 miles in length, and, ultimately, circuits extending to 15,000 miles.

A major consideration in providing the reliability required for BMEWS was that information from each site should be transmitted over multiple, independent routes. This means that the failure of one communication link will not interrupt the system. As an added safeguard, it was essential to use different types of transmission facilities wherever possible.

One of the first new systems installed as part of BMEWS Rearward Communications System was the submarine cable from Thule, in the northern part of Greenland, to Newfoundland. In the Arctic regions, this cable route parallels the existing military radio-relay route from Thule to the inhabited regions of Canada. The channel capacity of this submarine cable is the same as the first and second transatlantic cables when originally laid. The difficulties of laying this cable in the northern waters, where icebergs and sea ice are a continuing peril, is a story in itself.

Another major new system being integrated into the BMEWS Communications System is a radio-relay route from Cape Dyer to Goose Bay. This route uses tropospheric-scatter propagation with stations up to 200 miles apart. It replaces two earlier military systems, the Pole Vault System and the DEW (Distant Early Warning) Rearward System. Pole Vault was the first major system to use tropospheric-scatter transmission. It was built in 1954 to demonstrate the feasibility of this mode of radio transmission for highly reliable communications systems. The DEW Rearward System from Cape Dyer to Resolution Island was put in as part of the DEW Line communications complex a year later. Neither of these original systems had adequate channel capacity for BMEWS.

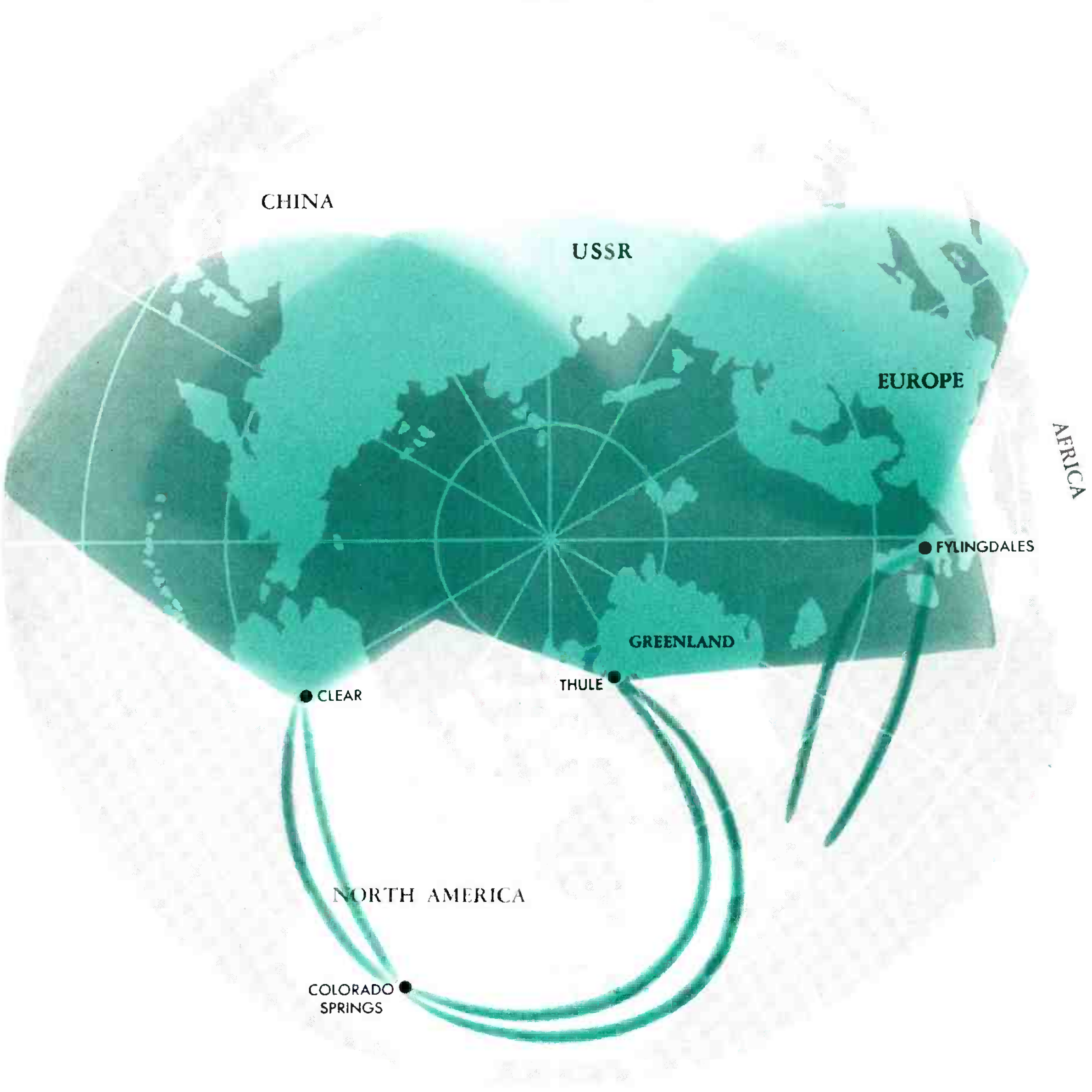
A third major link in the chain of communication for BMEWS is a tropospheric-scatter radio-relay system along the southeast coast of Alaska. When this system is completed, it will link the White Alice communication network with the submarine-cable terminal at Ketchikan. This will be the first high-capacity, high-quality communication system linking central Alaska to the continental telephone network.

A microwave radio route along the Alcan highway is the fourth major system for transmitting BMEWS information. This will begin at the BMEWS detection site in Clear, Alaska and connect with the commercial telephone network in Canada. The Alaskan portion will use conventional Western Electric microwave equipment with some special features for military applications. The Canadian portion will use a newly developed RCA microwave system.

Several new pieces of equipment were developed for the new tropospheric-scatter radio systems mentioned previously. These include a new radio set, 30-, 60-, and 120-foot antennas, and a number of filters, diplexers, and isolators. Previous equipment used in White Alice had a maximum capability of 132 voice-frequency channels. The new radio set has a maximum capability of 240 voice-frequency channels. Also, the new equipment, which operates in the 750- to 950-mc band, has a higher transmission performance which makes it suitable for integration into world-wide military networks.

The new radio equipment includes several advanced features. The receivers, using the new parametric-amplifier techniques, have very low noise figures (RECORD, *October*, 1959). Also, they are designed to operate under more adverse propagation conditions and at considerably lower signal levels than previous receivers. New developments were required on the 10-kw transmitter to meet the higher performance requirements.

In the past, 30- and 60-foot reflectors were used with tropospheric-scatter systems, but for BMEWS, new feedhorns were needed with greater bandwidth, better matching impedance, and with the capability of radiating both horizontally and vertically polarized signals. In addition to developing these feedhorns, Laboratories engineers spearheaded the development of a new 120-foot



Map shows overlapping radar coverage from the three BMEWS *sites. Also shown are general indications of the multiple communication routes from each to NORAD headquarters in Colorado.*

"billboard" antenna to transmit signals over the extremely long hops. All of these antennas can withstand winds of 200 miles an hour. Small steel sheds are attached to the rear of the antennas. Inside these sheds, oil furnaces with a capacity of 1.5 million Btu's per hour are arranged to de-ice the antennas, where climate requires.

High-powered isolators were included in the waveguide (connecting the transmitter to the antenna) to absorb transmission-line echoes. These isolators can handle power up to 100 kw. A number of other transmission-line components with extremely good impedance match were developed for this system as well as filters and diplexers.

System Performance

To achieve the accuracy and reliability objectives of the BMEWS system, a new data-transmission system was required. Heretofore, no system was available which could transmit high-speed data over 6000-mile circuits and provide almost complete insurance against errors introduced by the communication system. Bell Telephone Laboratories has developed a system that meets these standards.

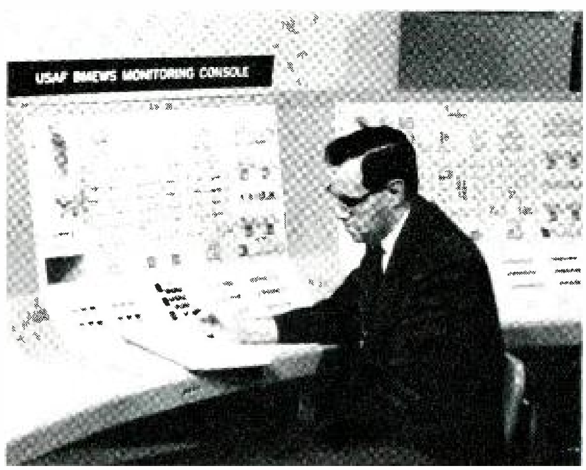
This system is continuously operated and monitored. It includes completely duplicated equipment. Data messages are sent simultaneously over two geographically separate routes. To provide further reliability, regenerative repeaters or monitoring devices are included at several points along the route.

At the transmitting terminal parity check bits are added to all messages. When the message is received, it is scanned and the parity bits at the receiving terminal are checked against the parity bits transmitted. This system, known as "triple interleaved parity," has a very high capability of detecting errors in transmission even under severe circuit noise conditions.

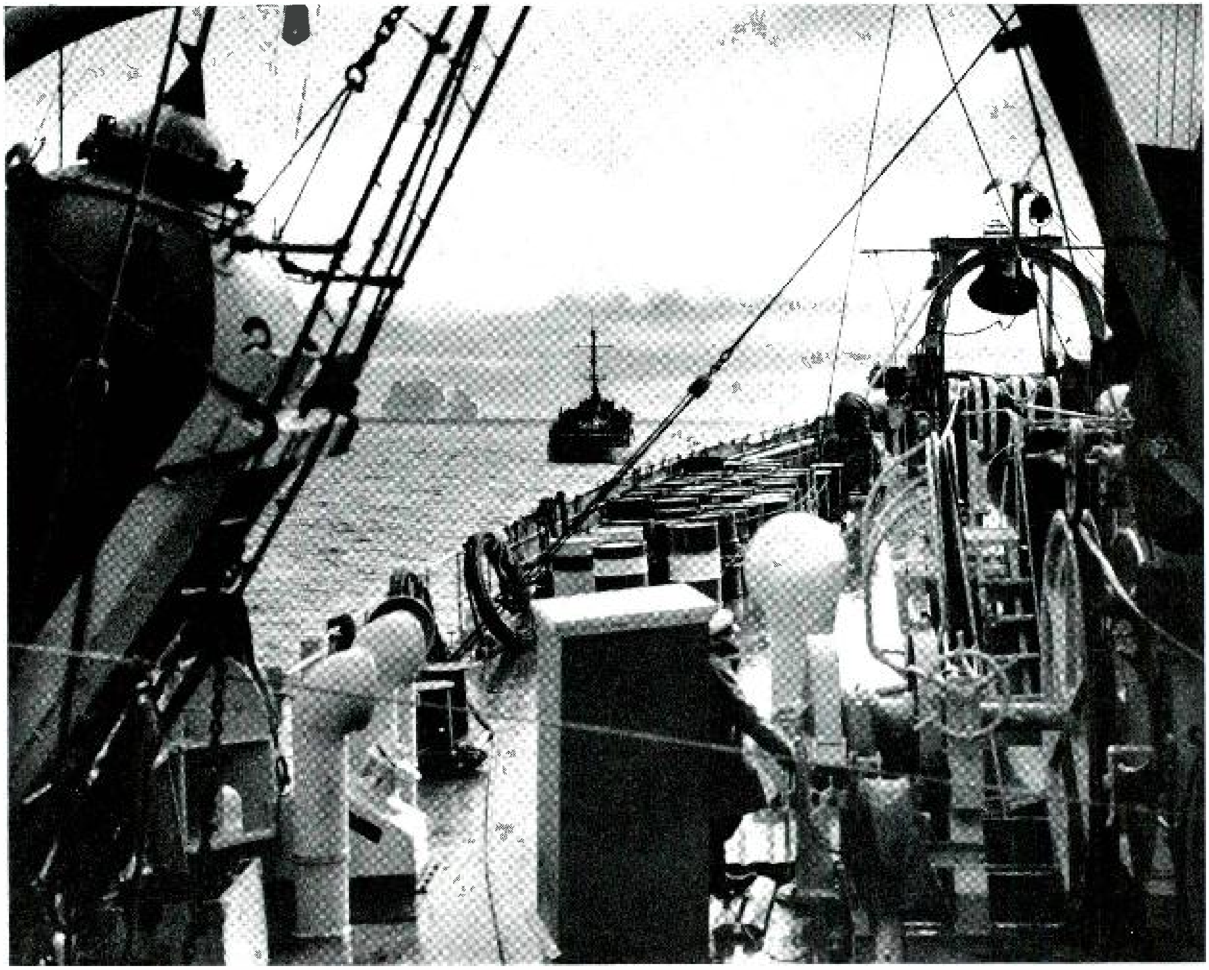
If a correct message is received by either of the two routes, it is transmitted to the data processor. If messages on both routes contain errors, a request for a repeat transmission of the message is sent to the transmitting end of the system via the report links on each route. Messages are repeated until they are received correctly. This system, of course, requires four-wire transmission channels. This is the normal mode of transmission. Two emergency modes of operation are available wherein messages are transmitted twice on each route. If a correct message is received, it is transmitted in the usual manner to the data processor. However, if both messages on each route contain errors, the last one received will be transmitted to the data processor with a tag indicating that an error has been detected.

The system contains a monitoring arrangement whereby any difficulties in transmission are indicated in lights and the trouble typed out on a teletypewriter. The rate at which data are transmitted over the system is continuously monitored. Normally, the system can transmit information at somewhat faster than the required rate. When messages have to be repeated due to adverse conditions, the rate of information transfer is reduced. Lamps at the receiving station indicate when this rate is partially impaired, when it has reached the minimum requirement, and when it has been reduced to a very low rate or to zero. Monitoring devices and the regenerative repeaters are also equipped to indicate the rate of information transfer. This monitoring information is transmitted automatically to the Central Computer and Display Facility at NORAD headquarters, Colorado Springs, where it is used in determining which portion of the system is in trouble.

The emphasis on high reliability and very short periods of out-of-service time (outage) made it necessary to design special maintenance facilities and devise special operational features. In addition to the multiple routes, very rapid restoration of equipment is necessary if a portion of the system fails. This minimizes outage for the entire system. Also, it is imperative that the system be controlled from a single point. To do this, Laboratories engineers developed a control and status-reporting system that automatically and instantly transmits status information to the Central Computer and Display Facility. A control



Consoles for monitoring the status of the BMEWS *routes are at NORAD headquarters in Colorado.*



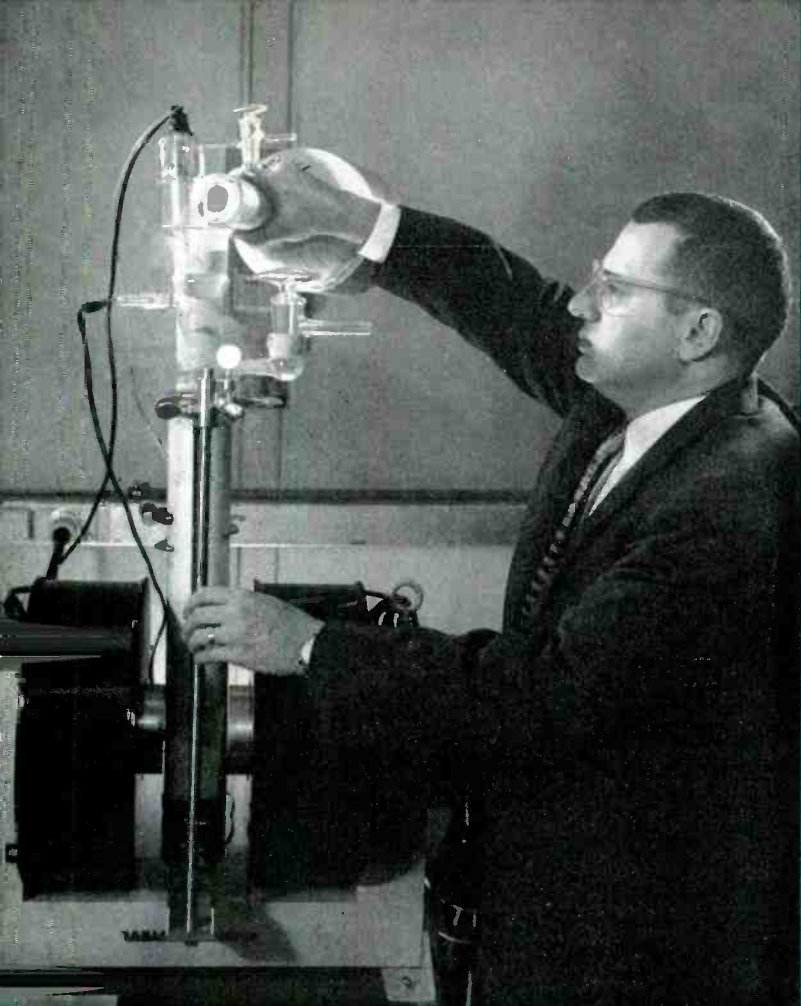
Cable ship Monarch laying cable between Thule, Greenland and Canada. Installation of submarine cable in these icy waters was a hazardous operation; note icebreaker and iceberg in background.

and monitoring console indicates, by lights, the status of the information being received. In addition to a telephone "order" circuit, Laboratories engineers included certain remote control features on the console. They also designed the monitoring circuits to indicate the condition of the telephone and the telegraph circuits on a continuous basis.

Control and status-reporting equipment at the transmitting terminal and at the repeater points automatically transmit equipment alarms and system-status indications to the central station. These signals are transmitted on two carrier-frequency telegraph channels, multiplexed at the top end of the order-circuit channel. At the Central Computer and Display Facility, these signals are interpreted according to their degree of importance, and red or amber lights appear on the monitoring console when trouble occurs.

The console has lights representing each monitor or repeater station along the several routes, as well as lights representing the transmitting and receiving terminals. With this facility, the communications controller knows instantly of any difficulty in the system. If a station is in trouble, he can communicate with it and determine the appropriate action. This procedure keeps outages to a minimum and provides a means of immediately informing the responsible groups at Colorado Springs of the status of the system.

The Rearward Communication System for BMEWS provides a communications system of the highest quality and reliability. It is the forerunner of many others to come, and many of its links will serve the global mission of the United States Department of Defense.



The Searc

J. H. Wernick (above) and R. Wolfe evaluating properties of new semiconducting compounds.

New semiconductor devices flow constantly from many research laboratories. While silicon and germanium, the standard semiconducting elements, still offer many possibilities, devices of the future will probably come from yet unknown materials.

J. H. Wernick and R. Wolfe

or New Semiconductors

Each month, new semiconductor devices come out of research and development laboratories around the world. This outpouring of devices stems from one main fact—that the electrical properties of semiconductors can be controlled over very wide limits. Control is achieved through "doping," or intentional contamination of otherwise pure material with variable minute amounts of foreign atoms or molecules. With these additions, the electrical properties can be moderated or controlled by electric, magnetic, or electromagnetic fields; by heat; or by mechanical forces.

In addition to this control over the properties of single-element semiconductors such as the now classical materials, germanium and silicon, there is another aspect of control—that of selecting new semiconducting elements, or producing compounds and mixtures of new materials with properties suited to specific new devices. This in fact will probably be the source of the important devices of the future.

Some of these devices are already being developed and tested. They include thermoelectric power generators and refrigerators, Hall effect gyrators and circulators, photoelectromagnetic (P.E.M.) infrared detectors, solar batteries, and Esaki diodes.

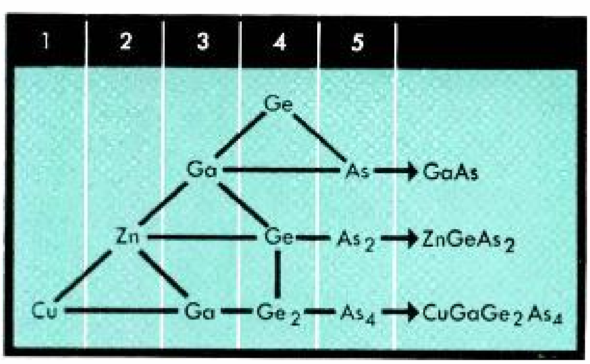
To obtain the desired characteristics in each new device, a particular material is chosen which has the best combination of electrical and physical properties. For example, materials with high electron mobility and large energy gap are desirable for transistors. For thermoelectric devices, low thermal conductivity is of primary importance, but high mobility, high effective mass and high energy gap are also useful. For each device, however, a compromise must be reached, because no known semiconducting material is superior in all the required properties. For instance, if a new semiconductor were discovered which had the electron mobility of indium antimonide combined with the electron effective mass of bismuth telluride, the thermal conductivity of silver antimony telluride, and the energy gap of silicon carbide (a most unlikely combination), thermoelectric power generators could be built which would quickly make every diesel engine and steam turbine obsolete.

The need for new combinations of properties for various devices prompts the continuing research on new compound semiconductors. This research also leads occasionally to the discovery of new properties and phenomena which may suggest still further additions to the list of devices, as well as contributing to the basic understanding of the nature of semiconductors and matter in general.

Literally thousands of scientists and engineers have studied the elemental semiconductors germanium and silicon since the discovery of transistor action in these materials at Bell Laboratories in 1948 (RECORD, *August*, 1948; *July*, 1958). After years of intensive effort, deeper understanding and new devices continue to come from such research. The Esaki diode (RECORD, *April*, 1961) is a notable example of a recent device based on an effect observed in germanium.

In addition to the single-element semiconductors, a rich source of promising materials exists in compounds made of two elements, i.e., binary compounds such as indium antimonide or bismuth telluride. The unique properties of some of these compounds have been utilized in such applications as infrared detectors and thermoelectric devices. Many common, naturally-occurring minerals fall into this group, as well as materials existing only as laboratory-synthesized samples.

Recently the search has been extended to include compounds of three elements, as well as more complex materials. With 103 elements available to the chemist or physicist, it might seem at first that the list of possibilities is practically infinite. However, the search is not a blind one; there are rules which enable new semiconducting compounds to be predicted. In this article we shall describe the methods which have been used at the Laboratories to predict new semiconducting compositions, as well as the metallurgical problems involved in producing these materials, and the physical measurements which must be made to evaluate them. A particular ternary compound, silver antimony telluride, will be used as an example to illustrate the problems which are involved.



Method of combining elements to form semiconductors with 4:1 valence electron-to-atom ratio.

The nature of the "bonding" in solids, and therefore the properties of the solids, are determined mainly by the interactions of the valence or outermost electrons of the constituent atoms. In the simplest semiconductors, silicon (Si) and germanium (Ge), each atom has four valence electrons. These elements are from the fourth group in the periodic table. In the solid state each Si or Ge atom is surrounded by four other atoms in a "tetrahedral" configuration, i.e., at the points of a triangular-based pyramid centered on the atom. Each electron is shared by two atoms to form a "covalent" bond. There are therefore four covalent bonds per atom, and the electron-to-atom ratio is 4:1. These properties, an average of four valence electrons per atom and a tetrahedral configuration, can be used as two criteria in predicting new semiconducting compounds. For example, if instead of two Ge atoms (8 valence electrons) we take one gallium (Ga) atom with three valence electrons (Group 3), and one arsenic (As) atom with five valence electrons (Group 5), we form the semiconducting compound, gallium arsenide, GaAs. All of the 3-5 binary compounds can be formed in this manner (RECORD, *July*, 1956). Similarly, by combining Group 2 and Group 6 elements, one can form the semiconducting compounds zinc sulfide, cadmium selenide, and cadmium telluride. This procedure can be continued in a manner shown on this page.

Element Substitution in Minerals

One can also examine the crystal structure of naturally-occurring minerals, and test those which have tetrahedral atomic configurations for possible semiconducting properties. For example, the minerals Enargite (cuprous arsenic sulfide), Tetrahedrite (copper antimony sulfide), and Tennantite (cupric arsenic sulfide) have tetrahedral configurations and are indeed semiconductors. The presence of covalent bonding in certain elements is also of interest in this regard. For example, the bonding in the element of Groups 4b (carbon, silicon, and germanium), 5b (arsenic, antimony, and bismuth) and 6b (sulfur, selenium, and tellurium) is essentially covalent. The bonding in compounds which contain these elements is also frequently covalent. This leads to a second approach in predicting new semiconductors: In naturally-occurring compounds containing any of these elements, chemically similar elements from the same column of the periodic table may be substituted. In a mineral which is an insulator, for example, the substitution of a heavier element in the same structure may lower the energy

	Melting Point in Degrees C		Melting Point in Degrees C
Cu_3AsS_4	655	$AgSbSe_2$	636
Cu_3SbS_4	555	$AgSbTe_2$	576
Cu_3SbSe_4	425	$AgBiS_2$	810
Cu_3SbS_3	555	$AgBiSe_2$	765
Cu_3AsS_3	640	Ag_3SbS_3	486
$CuSbS_2$	535	Ag_3AsS_3	480
$CuSbSe_2$	460	Ag_3AsSe_3	385
$CuAsS_2$	625	$AgAsSe_2$	390
$CuAsSe_2$	415	$AgAsTe_2$	325

Ternary semiconductors first synthesized here.

gap to the point where the new compound shows semiconducting behavior. An example is the substitution of the heavier selenium atom for sulfur in the mineral Matildite, silver bismuth sulfide. This produces the new semiconductor silver bismuth selenide, which has a crystal structure identical to its naturally occurring relative.

The properties of the new compounds will, of course, be different from those of the compound on which they are based. In general, as the molecular weight of a compound increases, its melting point, thermal conductivity and energy gap decrease, and its carrier mobility increases. There are exceptions to this generalization, but it is a useful rule, particularly in the search for new thermoelectric materials. Solid solutions, or alloys of two or more semiconductors, will also exhibit properties which will be different from those of the original compounds. Thus, another research avenue is opened.

The new compounds are usually prepared in sealed quartz tubes because of the volatility of one or more of the constituent elements. Occasionally, the partial pressure of the volatile constituent must be limited by holding one portion of the sealed system at a constant lower temperature. After the molten mixture cools, metallographic, x-ray, and thermal analysis techniques establish the single-phase nature of the solid ingot, or the presence of any second phase. X-ray analysis of single crystals will also establish the crystal structure of the material.

After the existence of a new compound is established, one must zone refine it, grow single crystals, and determine its intrinsic properties. Following this, the materials are doped, where possible with known quantities of impurities, so the extrinsic properties can be determined.

Some of the semiconducting ternary compounds which were first synthesized at Bell Laboratories are listed in the table at left. Our information concerning these materials (and all other ternary semiconductors) is far from complete, and much important research remains to be done. Only when some of these gaps in our knowledge have been filled will it be possible to add a list of potential applications for each material in this table.

After a new compound has been predicted and prepared and good single-phase specimens are available, various physical measurements must be made. These measurements determine whether the compound is actually a semiconductor. Further experiments indicate how the particular semiconductor may be used in devices. One of the first such properties which is quickly measured on each ingot is the thermoelectric power. This property can be used to produce local, or spot, refrigeration. Conversely, it can be used for direct conversion of heat into d-c electric power.

For a rough and rapid measurement of the thermoelectric power, two metal probes are pressed onto the specimen—one warm and the other cool—and the voltage produced between these probes is measured. The sign of this voltage indicates whether the material is n-type or p-type; if the warm probe is positive, the material is n-type, and vice versa.

Point contact rectification is another characteristic of semiconductors. If an electrical potential is applied to a specimen between a large-area metal contact and a sharp metal point, rectification may be observed. If easy current flow occurs when the point contact is negative, the material is p-type (and vice versa). In contrast, metals (and impure semiconductors) show symmetrical, or ohmic, conduction.

Additional Measurements

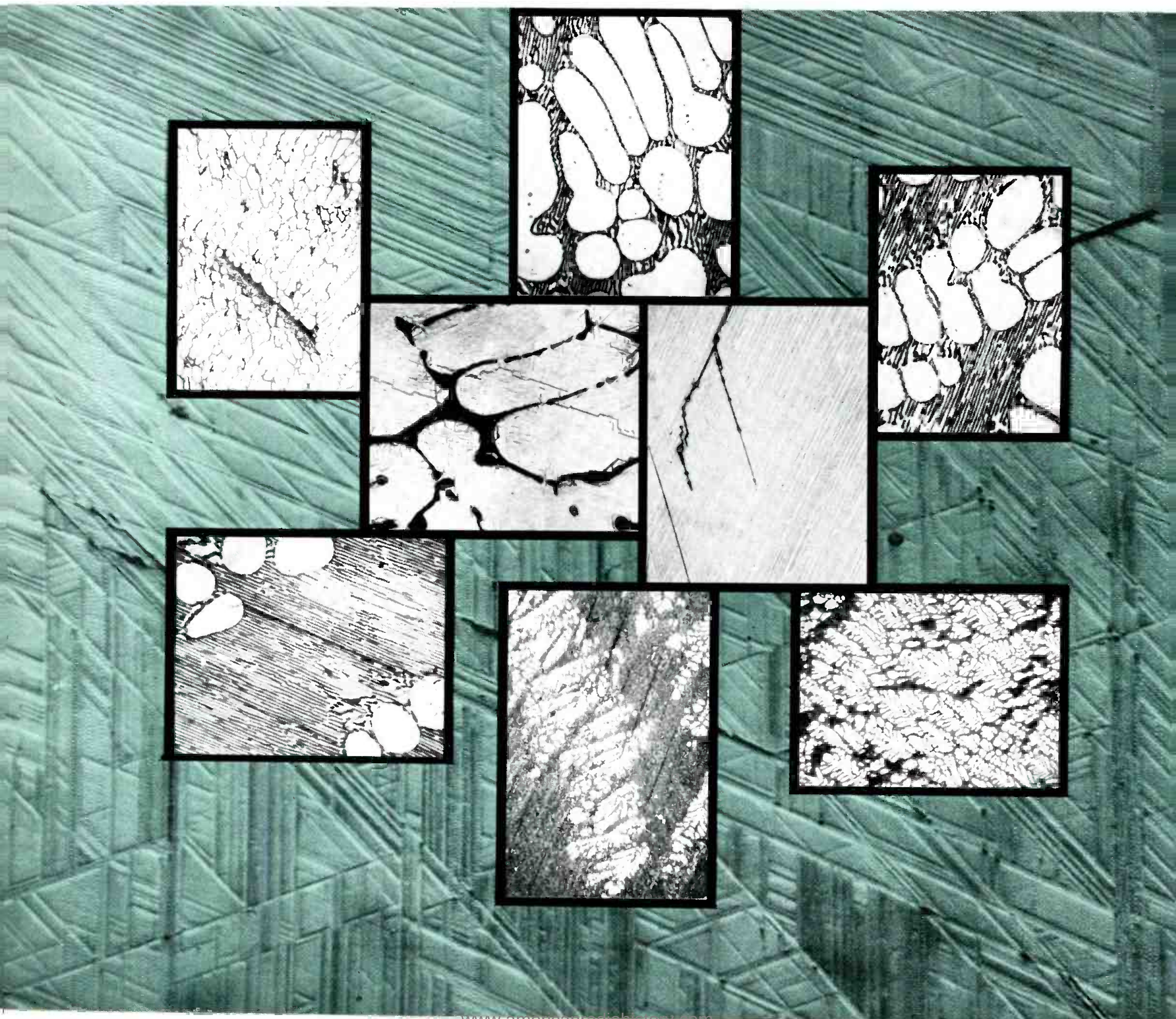
Electrical conductivity and its variation with temperature are basic to the definition of a semiconductor. The measurement of conductivity is therefore essential in any semiconductor investigation. The conductivity depends on the density, or concentration, of free electrons or holes, known as "carriers," and on the velocity with which they move in an applied field (their "mobility").

Another very useful property to measure is the Hall coefficient (RECORD, *March* 1955). The Hall very low thermal conductivity. We suspected that the heavy atoms and the disordered structure would result in low thermal conductivity in this material. Experimental results bore this out. The measured lattice component of the thermal conductivity is about one hundred times smaller than that of germanium, and three times smaller than the best previously known thermoelectric compounds such as lead telluride. This material is therefore potentially useful for thermoelectric refrigeration and for power generation at moderate temperature (it melts at 575 degrees C).

For this reason, silver antimony telluride is being actively investigated in a number of laboratories in this country and abroad, (in Belgium, France, Germany, Japan, and the U.S.S.R.) Recent results obtained in some of these studies indicate that silver antimony telluride is the best p-type material available for thermoelectric power generation between 200 and 500 degrees C.

Thus, silver antimony telluride not only has been added to the growing list of new semiconductors, but appears to have won a place on the much shorter list of most useful semiconductors. The other ternary compounds have yet to earn this distinction. However, as research on these and other new semiconductors continues, novel and improved devices may result, as well as advances in fundamental knowledge.

Photomicrographs of various sections from ingot of silver antimony telluride reveal the presence of darkly stained second phase which confused measurements of changes in the Hall coefficient.



Optical Maser Symposium At Bell Laboratories

The Murray Hill Laboratories was the scene recently of two symposiums on optical masers. On October 5-6, members of the industrial community interested in optical-maser technology were guests of the Western Electric Company. On October 10, the Laboratories was host to representatives from nearly fifty colleges and universities and from many government laboratories.

News of Maser Research

The optical maser symposiums were designed so that Bell Laboratories scientists and engineers could share their knowledge of recent achievements in optical masers. Work was reported on both solid-state and gas masers, including their application to communications technology and to scientific research. Specifically, the speakers talked about the materials and methods of constructing masers. At the first meeting they also discussed possible techniques of modulation and detection of optical radiation, information theory with respect to optical masers, and problems related to using optical masers in communications.

The optical maser has introduced a new family of sources and amplifiers of light (RECORD, *November*, 1960). It operates on the principle of stimulating the excited atoms in a material to radiate energy in phase. One widely used solid-state configuration is a rod whose extremely flat and parallel ends are silvered and whose sides are left open to admit "pumping" radiation. A surrounding flash lamp provides the pumping power; when flashed, it causes a nearly parallel beam of light to emerge from the ends of the rod. This light is highly monochromatic and "coherent"—having a definite phase relationship from point to point in all parts of the beam.

One of the subjects discussed at the meetings was a new material for solid-state masers—neodymium in calcium tungstate. The potentialities of this material were revealed by the discovery by L. F. Johnson of the Solid State Electronics Research Laboratory that it showed a strong infrared fluorescence. K. Nassau of the Metallurgical Research Laboratory pulled crystals from the melt and the two scientists constructed an optical maser that operates at room temperature with as little as five joules of input power. The emission line is in the photographable part of the infrared region—10,600 angstroms.

The symposium revealed some of the knowledge of basic physics that has grown out of research with ruby masers, such as a two-quantum process in which an atom in a material is made to absorb two quanta, or photons, of energy simultaneously. In recent experiments, C. G. B. Garrett of the Solid State Electronics Research Laboratory and W. Kaiser of the Semiconductor Research Laboratory focused a ruby maser beam on a crystal of calcium fluoride containing di-valent europium and obtained a blue fluorescence. The blue emission is possible with a red beam because the crystal attains a state accessible only by the simultaneous absorption of two quanta of energy. The high intensity of the maser beam makes possible this excitation of the crystal.

Another recent accomplishment has been to increase the power of the maser by several times, by exploiting a scheme that essentially delays the oscillation mechanism in the ruby rod. R. J. Collins and P. P. Kisliuk, of the Solid State Research Electronics Laboratory, constructed a maser with external mirrors replacing the silvered ends of a ruby rod. A rotating "chopper" wheel placed in front of one mirror serves to "hold back" the oscillation until a larger-than-normal excess of upper state atoms builds up in the crystal. This results in a much more powerful peak emission than ordinarily possible.

The gaseous optical maser is a continuously operating device which receives its exciting energy from an electrical discharge of relatively low power (RECORD, *March*, 1961). This maser material is a mixture of helium and neon gases enclosed in a long glass tube. The applied RF discharge excites the helium atoms which transfer their energy to the neon atoms by collision. Then, the neon atoms radiate their energy, on demand, as a highly coherent stream of infrared light. The beam is thousands of times sharper than other spectroscopic lines in the optical region and thus provides a new tool for research in the structure of materials.

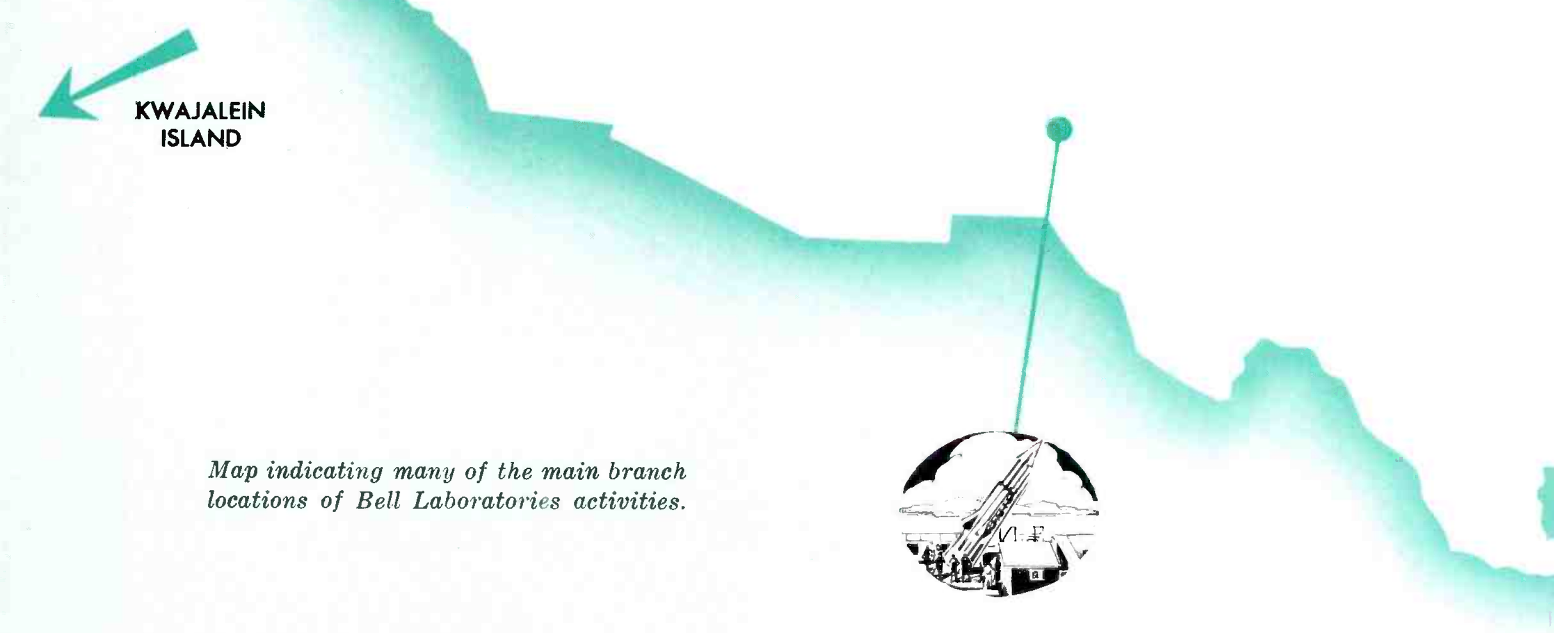
DECENTRALIZATION
A Feature of Today

Bell Telephone Laboratories is now operating in more than twenty locations. This situation is in decided contrast to the one which existed at the time of its incorporation in 1925, when practically the entire force was concentrated in lower Manhattan, at 463 West Street. The changes which have occurred in the intervening years emphasize some of the features of growth and evolution which have characterized the functions of the Laboratories and its place in the Bell System, particularly in its relations with the Western Electric Company. The considerations which have led to our present plan of organization point up the responsibility of management to anticipate and to meet the demands of a changing business and technological environment.

The predecessor of the Bell Telephone Laboratories was the Western Electric Engineering Department, originally located at 463 West Street in close association with a considerable part of the Western Electric manufacturing activities. Because of this proximity, engineering personnel had a good background of manufacturing experience, and the transition from development and design to manufacture was made with only minor interruptions. The communication technology of the time was such that reasonably complete and accurate design information could be expressed by drawings, specifications and descriptions.

As the business grew, Western Electric transferred its manufacturing operations from New York to the Chicago area, into the then new Hawthorne Plant. Because most of the engineering personnel were familiar with manufacturing problems and practices, and because the predominantly electrochemical communication equipment was still relatively simple, the separation of manufacture from development and design was not initially a serious impediment.

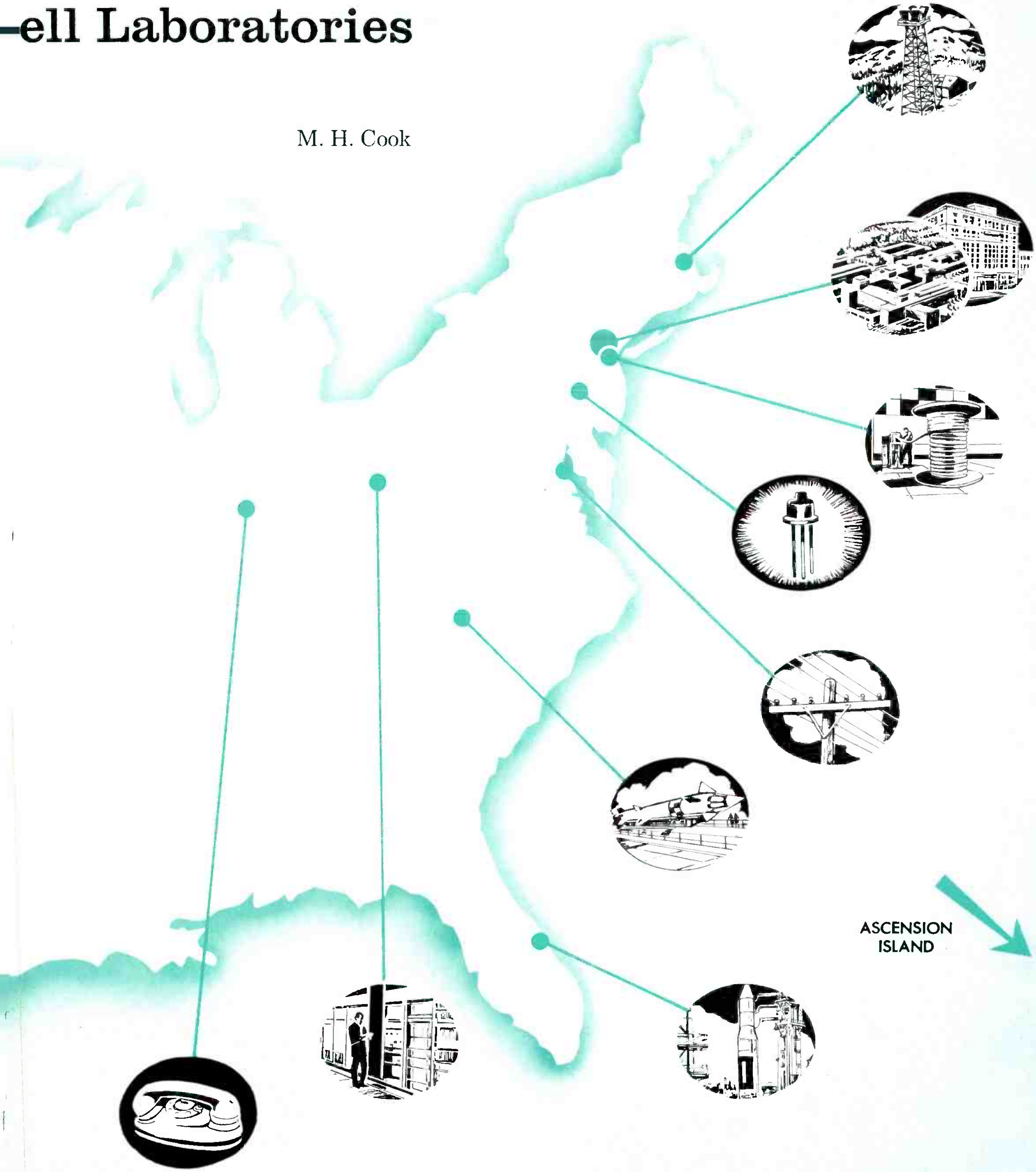
(Continued)



Map indicating many of the main branch locations of Bell Laboratories activities.

-ell Laboratories

M. H. Cook



Meanwhile, certain changes in the character of the business were taking place. For several years, young men with graduate training in physics, mathematics and chemistry had been recruited into the engineering department. The problems of long distance telephony were growing with the rapid expansion of the communications system. The solutions to these problems called for the application of new developments, new devices and new materials, all of which increased the precision and the complexity of communication equipment.

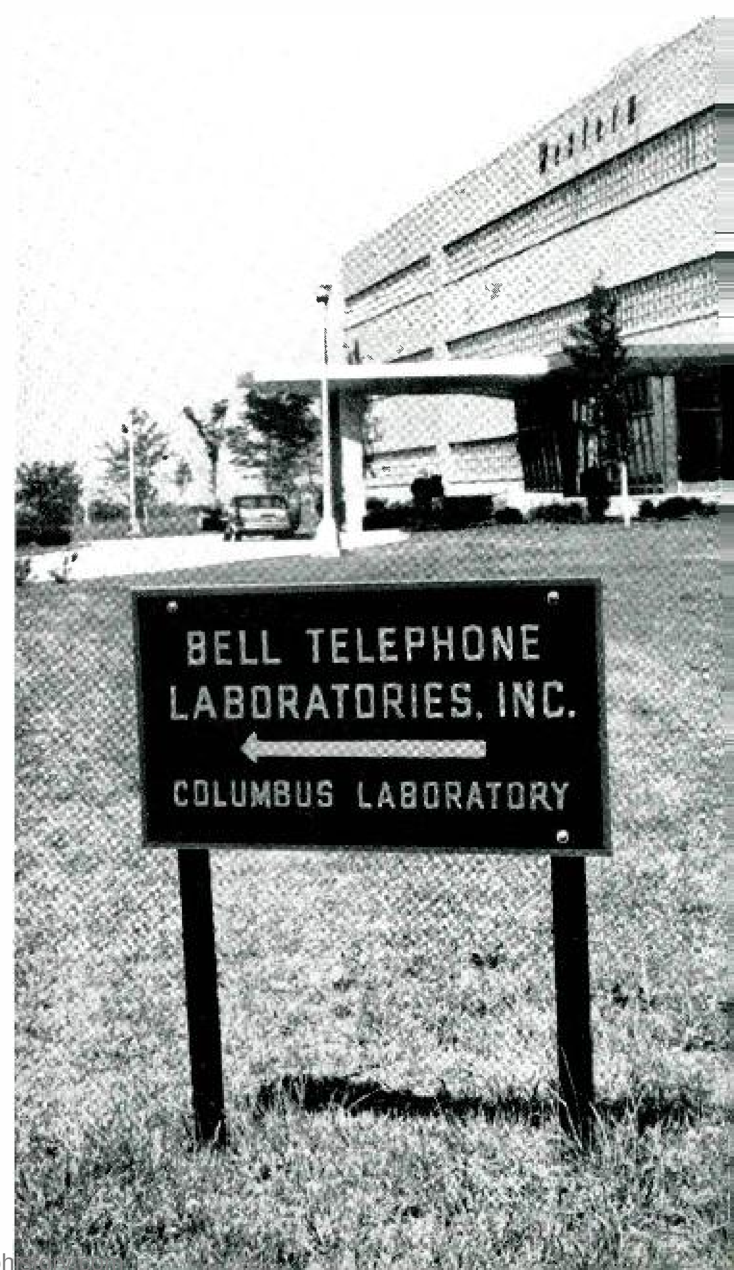
Incorporation of Bell Laboratories

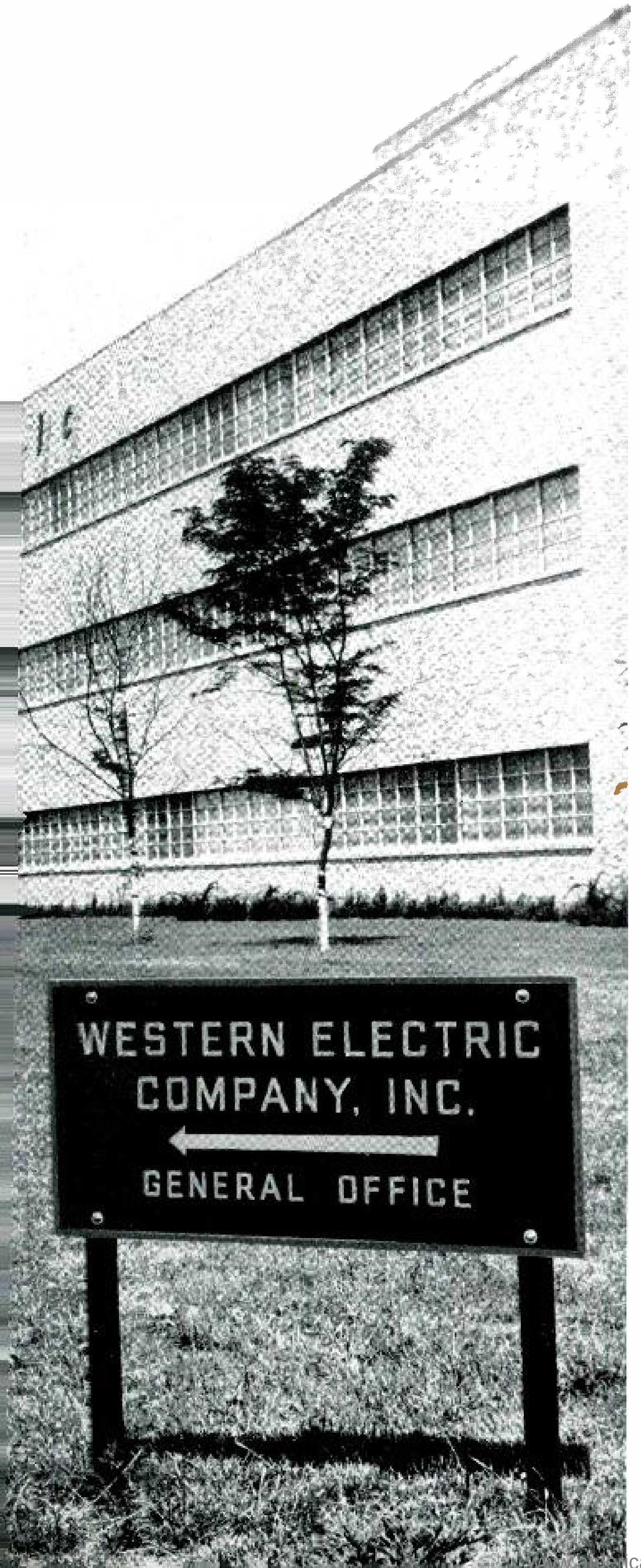
This trend in technology, coupled with the growth of the business, led to the separate incorporation of the Bell Telephone Laboratories in 1925. Initially, the personnel and the methods of operation continued much along the lines of the earlier Western Electric Engineering Department. However, with both corporate and geographical separation, easy and direct communication between the Laboratories in New York and the manufacturing operations in Hawthorne gradually became more difficult. The increasing specialization of technology called for changes which tightened internal organizational lines. Also, both the Laboratories and the Western Electric manufacturing people became more intimately involved with their own immediate problems. Both organizations were growing, and the newly recruited personnel lacked the background which would permit adequate understanding of both the development and the manufacturing aspects of the business.

This situation developed through the 1920's without becoming sufficiently obvious to engage the serious concern of the managements of the two companies. The pressure of costs and competition were relatively light. Communications by correspondence, interlocation visits, telephone and telegraph, although becoming increasingly cumbersome, continued to serve most of the needs.

The formation of the "Engineer of Manufacture" organization in Western Electric in 1926 intensified factors of specialization, putting the need for better communications into somewhat sharper focus. At first, rather elaborate provisions were made to ensure that inter-company contacts and correspondence were given considered attention. However, experience showed that

Signs at the Columbus, Ohio, branch location testify to the close working arrangement between Bell Laboratories and Western Electric.





these formal arrangements only served to widen the gap, introduce delays, obstruct personal contacts and promote misunderstandings. The corporate interface was becoming more of an impediment.

By about 1930, individual supervisors in some areas, in attempts to overcome the impediment, instituted practices whereby interlocation visits, correspondence, and other communications could be made more direct and less formal. Operations noticeably improved.

The Depression of the 1930's was a violent interruption of the established order. In both the Laboratories and Western Electric, existing practives were re-examined to reduce costs and improve operations. The Western Electric Company began to change over from a functional to a product setup in manufacture, first by establishing a complete unit for the manufacture of station apparatus at Hawthorne, and later by the extension of this plan to other products.

For many years the Laboratories had maintained a cable development group at Hawthorne. When the Western Electric plants at Kearny, N. J., and Baltimore, Md., were built, similar groups were established there. Another laboratory was set up at Kearny to work with the Western Electric Specialty Products Department. A group of Laboratories people had been located in the Hudson Street Tube Shop in New York for a few years in the late 1920's and early 1930's. This unit had been discontinued, but was reestablished in 1939. These Laboratories demonstrated the value of having Laboratories people resident in Western Electric manufacturing plants.

Various "ad hoc" arrangements were made from time to time when new equipment and apparatus was introduced into manufacture. These temporary setups also pointed up the advantages of close association of development and design people with manufacturing engineers.

With the advent of the World War II military programs, it became evident that a more efficient working arrangement was needed. Consequently, a number of new Laboratories were established in Western Electric manufacturing locations. These units included a core of Bell Laboratories engineers and supervisors, supplemented by Western Electric engineers and draftsmen. Space and facilities were made available in expedient fashion. Due to the many projects and their rapidly changing character, both Laboratories and Western Electric personnel moved around a great deal on temporary assignments between manufacturing locations and the New York and

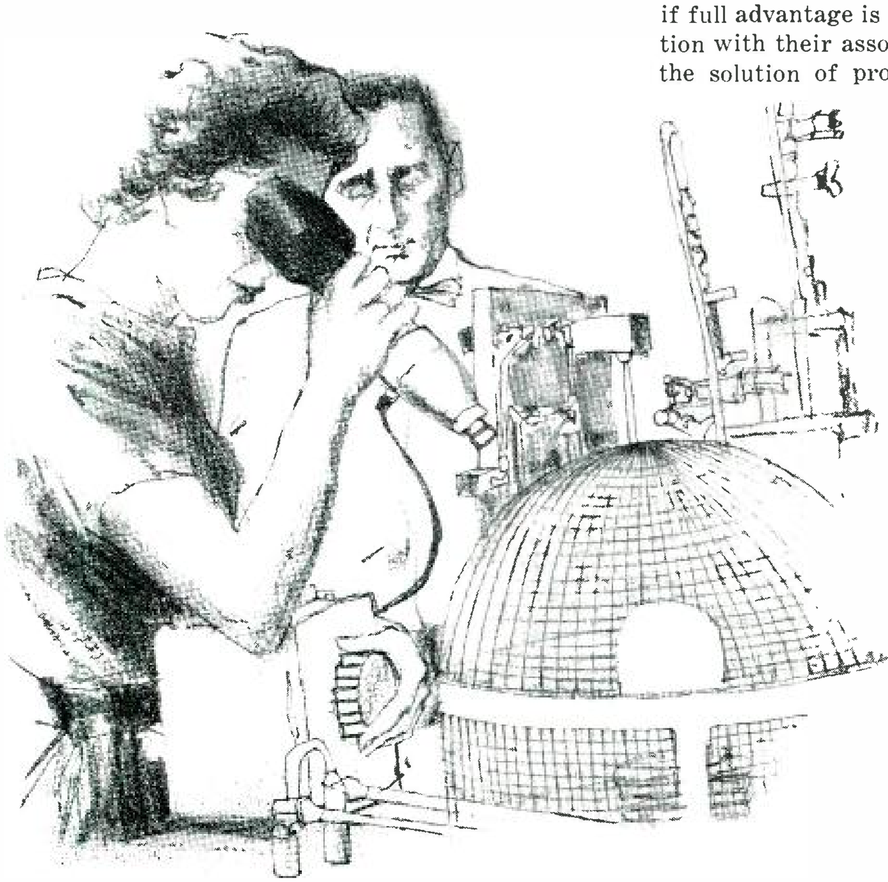
New Jersey Laboratories. Thousands of changes in design and manufacture had to be made quickly, with as little interruption of output as possible.

With the end of the War, the military Branch Laboratories were generally discontinued. Western Electric entered into an era of rapid expansion and decentralization. Large new manufacturing plants were established in North Carolina for military gear and commercial products, and at Allentown, Pa., for electronic devices. In each of these locations, Branch Laboratories were established as permanent units. At first, they served principally as liaison between the development and design groups of the Laboratories and the Western Electric manufacturing engineers. As experience was gained, personnel were added and functions were broadened.

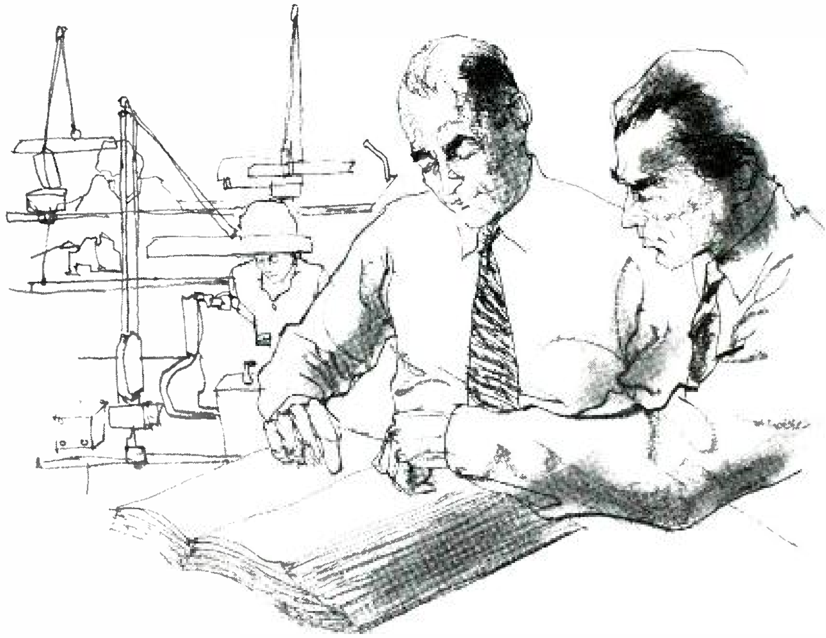
Close contact with manufacturing groups permitted Laboratories engineers to collaborate with the Engineer of Manufacture in the prompt solution of manufacturing problems where design considerations were involved. Current engineering and minor development and design responsibilities were also assumed by the Branch Laboratories. The advantages of completing production designs at the manufacturing locations were demonstrated, and an increasing amount of this work was transferred there. Laboratories facilities were expanded and improved. Additional Laboratories were established at Indianapolis, Ind., and in the Merrimack Valley area near Boston, Mass. (RECORD, *May,* 1960). The Branch Laboratories were increasingly staffed and equipped for autonomous operation.

The growth of both Bell Telephone Laboratories and the Western Electric Company has accented the advantages of decentralized operation. Whereas in years past a wide variety of products were produced in a single factory, today each Western Electric plant specializes primarily in a limited number of product areas. For example, Merrimack Valley is predominantly a manufacturer of transmission systems, Allentown of electronic devices, Indianapolis of station apparatus, and Baltimore of wire and cable. The large quantities of equipment produced justifies this specialization of methods and facilities. The engineering personnel, in turn, concentrate on a narrower field which they can exploit more intensively.

Similarly, these features permit the Laboratories to assign personnel to the groups resident in the Western Electric locations who are substantially self-sufficient in handling the development and design work involved. This is essential if full advantage is to accrue from close collaboration with their associates in Western Electric. In the solution of problems, and in the design of



Bell Laboratories engineer observes production techniques in a vacuum metallizing procedure at manufacturing location.



Western Electric and Bell Laboratories engineers consult on manufacturing problems in plant production area.

products, local Laboratories people have the same responsibilities for making decisions as do their counterparts in the home Laboratories. If the situation warrants, they can contact other Laboratories departments for specific advice and assistance in the various specialties. Facilities, operating methods and practices are confined to those proven most effective for the work at hand. Consequently, duplication of specialized personnel and facilities between the several locations is reduced to a minimum.

In those projects which originate in the home Laboratories, fundamental development usually is done in close contact with research groups and systems engineering personnel. During these early stages, the Branch Laboratories and Western Electric engineers keep informed of progress by correspondence, telephone and exchange of visits. These activities help them contribute to the projects as they develop, and to acquire a background of the engineering and systems considerations involved. Project responsibility is normally transferred to the Western Electric location after the operating and engineering features are proved by experimental models, made in the home Laboratories. Field-trial models of apparatus are usually made in Western Electric model shops, while equipment for systems trials may be made in either the home Laboratories or Western Electric, or in a combination of both. During the "design for manufacture" stage in the Western Electric location, the home Laboratories continue to participate to a degree appropriate to their interest (RECORD, *June*, 1961). In some cases, experience, change of plans, or new information may call for additional development at the home Laboratories.

New projects draw on the most recent technology of the communication art. Similarly, the design for production takes advantage of new developments in manufacturing facilities, processes and methods. In accomplishing these objectives, engineers from both the Laboratories and Western Electric contribute in detail. Their studies determine whether parts are to be metal or plastic, and whether they should be cast or formed. Types of finish and electrical and dimensional tolerances are typical subjects of discussion, investigation and trial. They consider the size and arrangement of modules and subassemblies; provisions for adjustment, test and inspection; methods of packing; and arrangements for handling in shipment and installation, and then apply the combined judgments of both groups.

Frequently, Western Electric engineers are transferred to the Laboratories staff at the Branch, to gain first-hand experience in development and design, and to apply their knowledge of manufacturing. Draftsmen, mechanics, clerks and secretaries are furnished by Western Electric; the Laboratories thus share in the large pool of experienced personnel. Landlord and staff services are furnished by Western Electric and relieve the Laboratories of these responsibilities.

The continuing association of resident Laboratories people with their opposite numbers in Western Electric promotes mutual confidence and understanding, and eliminates the occasion for much formal correspondence. The same drawings and records often serve the needs of both groups, and tons of paper have been eliminated. Where changes in practice offer advantages, they can be put into effect locally, without disturbing other locations where different conditions may prevail.

Hawthorne Laboratories group in 1926. Seated left to right: R. E. Alberts, R. C. Jones, L. S. Ford, five secretaries, F. W. Horn, C. H. Hitchcock, E. I. Bartinek. Standing left to right: E. C. Wegman, C. K. Milnar, R. P. Ashbaugh, C. Kreider, S. C. Cawthon, Griffin, C. J. Solawetz, C. L. Hessler, W. A. Southwick, A. G. Hall, J. P. Fisher, C. B. Robertson, C. E. Wiley, H. R. Rife, C. F. Gross and M. Golay.

Because the primary use of much of the record keeping is local, duplicate reference files are reduced to a minimum. These are potent factors in today's "battle of the paper work," and have been quite effective in de-emphasizing the impediment of the corporate interface.

The pressure of costs, time and competition make it highly desirable that development, design and preparation for manufacture be done in parallel rather than in sequence. Preparation for manufacture can be well along by the time the design information is complete; experience and ideas for cost reduction features can be pooled and incorporated at the beginning of production.

Currently, the eleven Branch Laboratories in Western Electric plants include more than 1700 Bell Laboratories employees, as well as about 1500 contract and Western Electric personnel. Another measure of the magnitude of these operations is the fact that they include almost twenty per cent of the assignable floor space occupied by the Bell Laboratories at all locations.

In addition, Laboratories units at such military bases and field stations as the Army's White Sands, N. M., missile range, the Air Force missile test center at Cape Canaveral, Fla., Kwajalein Island, Vandenberg Air Force Base and Pt. Mugu, Calif., on the Navy's Pacific missile range, and Ascension Island in the South Atlantic provide close and continuous contact with the Armed Services. More than 100 Bell Laboratories people are resident in these Laboratories, which are spread halfway around the world. Obviously, such far-flung units must have a high degree of local autonomy and responsibility if they are to give the prompt and effective service for which they were established.

The present Laboratories decentralization is a result of more than thirty-five years of experience and experiment in Bell Laboratories-Western Electric collaboration. It has been devised as a practical compromise to balance advantages and disadvantages in an enterprise which is far too large and complex for concentration into a single location. Having demonstrated its effectiveness, it can be expected to continue as an important feature of Bell Telephone Laboratories operation in the years ahead.

In the present TD-2 system, the spacing between adjacent channels is 20 megacycles. Recently, Laboratories engineers have found a way to insert interstitial channels in this space, thus doubling TD-2's capacity.

H. E. Curtis

INTERSTITIAL CHANNELS FOR THE TD-2 SYSTEM

In the 10 years since the first TD-2 system was installed, the demand for intercity television and voice circuits has increased tremendously. Although the TH system will handle much of this communication traffic (RECORD, *February*, 1961) when it becomes a transcontinental route, it will not necessarily diminish the amount of communication passing along the TD-2 routes. The TH system is like a communications superhighway, and the TD-2 system like a good access road. The more traffic you get on the highway, the more traffic you get on the access roads. And just as secondary roads have been widened, so can engineers increase the capacity of the TD-2 routes. By adding interstitial—or "in-between"—channels to the existing TD-2 systems, engineers at Bell Laboratories can now squeeze twice as much communication out of the system with relatively minor modifications to the existing equipment at the repeater stations and the terminals.

The TD-2 system operates in the 4 kilomegacycles common-carrier band. The regular channel frequencies are assigned so that the space between the carrier of a transmitter and the carrier of its nearest receiver operating in the same direction is 40 megacycles. In this way, each channel potentially occupies a 20 mc band. This leaves six interstitial bands of 20 mc each which are essentially empty. In the present six-channel system all six transmitters for a given direction use a single antenna, and similarly all six receivers from the same direction use a second antenna. These two antennas are mounted side-by-side on the same microwave tower.

At a microwave repeater station, each of the six carriers from the receiving antenna are separated from the other five incoming carriers by RF waveguide filters. Each carrier is then passed on to its own receiver for amplification. Since the adjacent receiving channels are separated in frequency by 80 mc, RF waveguide filters can effectively block interference otherwise caused by undesired carriers and permit the proper carrier to pass through to its own amplifier.

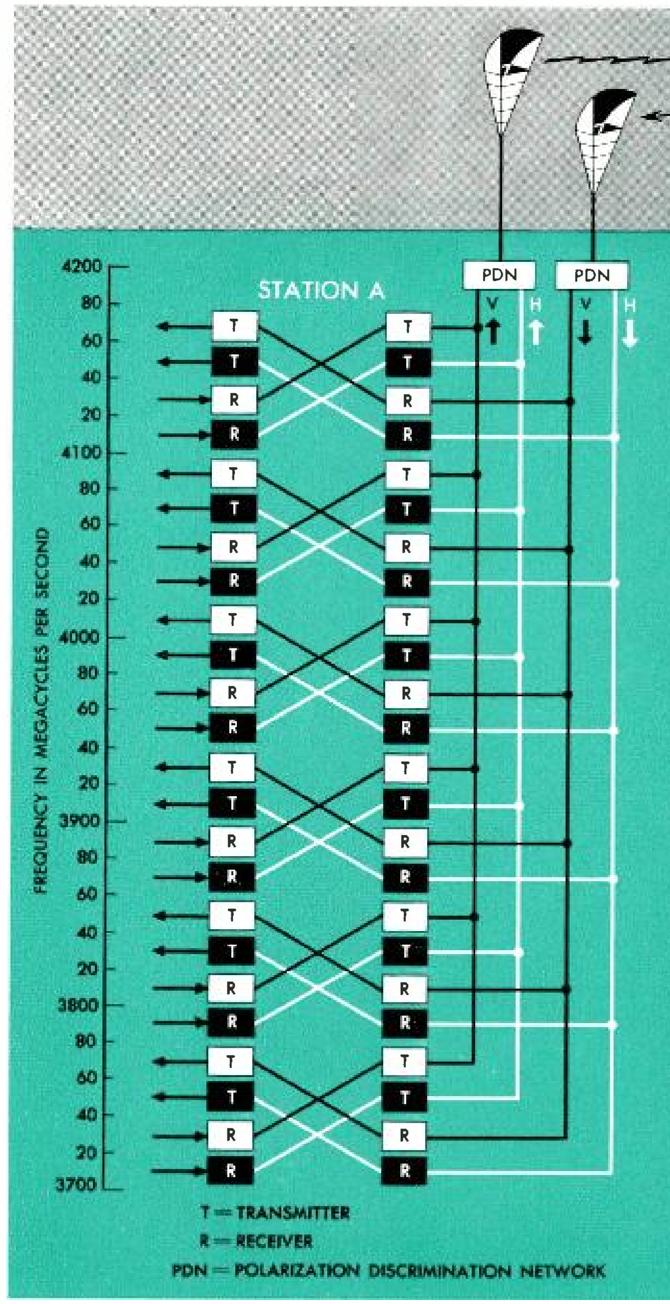
There is also potential interference from mutual coupling—interchange of energy between transmitting and receiving antennas on the same tower. Adjacent transmitting and receiving channels are only 40 mc apart, and these same RF waveguide filters at the receiver also suppress this source of interference. Although these filters operate satisfactorily in the present system, they cannot adequately separate more closely spaced channels.

In 1951, Bell Laboratories engineers designed equipment to provide a second set of broadband channels in the TD-2's interstitial bands. To do this, they reduced the spacing between carriers to only 20 mc as shown in the diagram at right. The RF filters provide almost no discrimination against frequencies only 20 megacycles from their normal operating frequency. Laboratories studies showed that this prevents simultaneous operation of the interstitial channels and the regular channels on the same route.

Special Use of Interstitial Channels

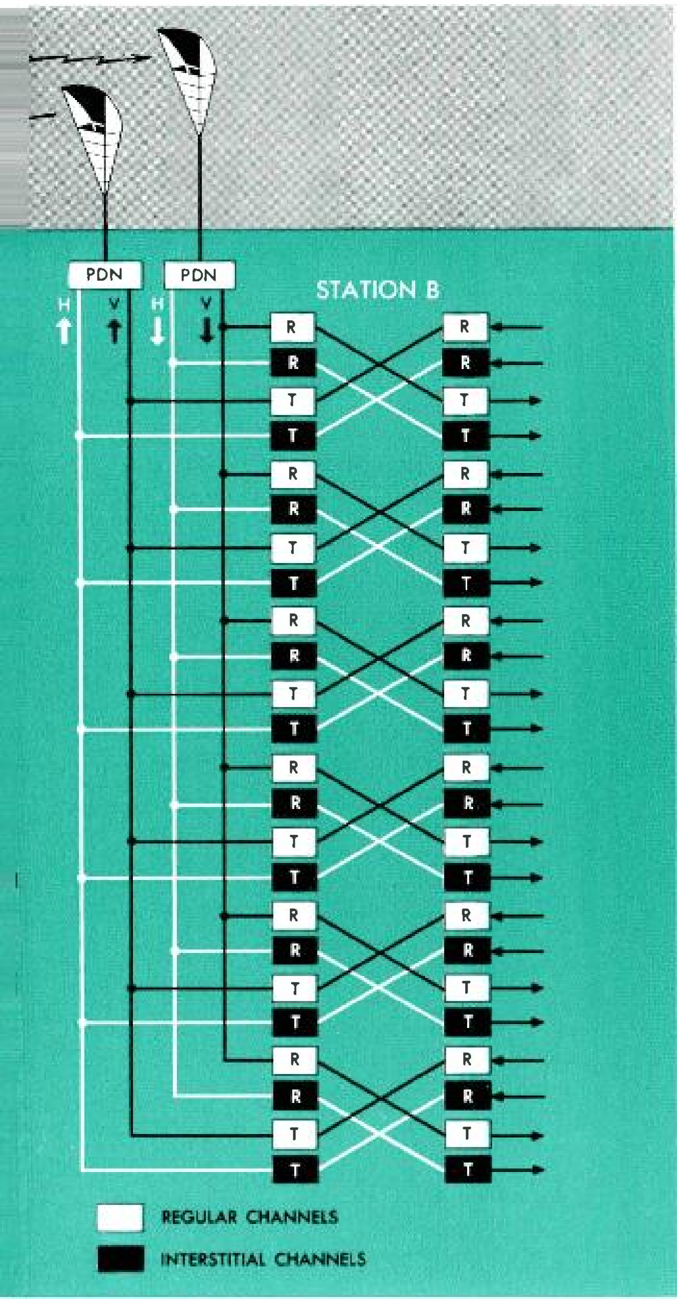
Interstitial channels however, have been very useful in special situations. If, for example, two TD-2 routes cross, and each route uses the normal frequency plan, the angle of crossing must be greater than about 60 degrees, otherwise interference would be intolerable. However, we can reduce the angle of crossing to as little as 9 degrees if we use the regular six-channel system on one route and the six interstitial channels on the other. In the latter case, the inherent sharp discrimination patterns of the antennas provide the extra "filtering" required to prevent interference between channels on the two routes.

The horn-reflector antenna, which came into use in the Bell System in 1955, provided the means whereby regular and interstitial channels can be operated simultaneously on the same route. Before this time, the delay-lens antenna and its rectangular waveguide were used in all long-haul TD-2 systems. The design of this antenna limited transmission between antennas to vertically polarized waves. But the horn-reflector antenna does not have this limitation. Thus, it is possible to transmit simultaneously six channels with vertical polarization and six channels with horizontal polarization from the same antenna. A polarization discrimination network at the receiving antenna separates these two groups of channels. When the polarized waves pass through this network, they emerge from two output ports. Unfortunately, under certain atmospheric conditions, the polarization of the waves may shift as they emerge at this point. Then, some of the energy of the vertically polarized wave may impinge on



TD-2 system with interstitial channels. The use of entire broadband channel between 37 and 42 kmc the horizontally polarized wave, and vice versa. Communications systems designers refer to this shift, or difference in energy level as the cross-polarization discrimination ratio.

Studies indicated that at least 20 db of cross-polarization discrimination was needed to separate adjacent receiving channels adequately. The seriousness of the cross-polarization shift during fading could not be evaluated in the laboratory; therefore, Laboratories engineers made extensive field tests in which a vertically polarized wave was transmitted from Holmdel, N. J. to Murray Hill, N. J. At the receiving end, the wave was passed through a polarization-discrimination network and the difference in level between the vertically and horizontally polarized components was recorded continuously. The results obtained with this arrangement were quite satisfying. This experiment indicates that polarization discriminations poorer than 20 db might be expected less than about 0.002 per cent of the time.



...is made possible by the practical method of cross-polarization and the use of horn-reflector antenna.

With interstitial channels operating in a commercial system, adjacent transmitting and receiving channels may be only 20 mc apart. Then, the effect of mutual coupling between transmitting and receiving antennas on the same tower becomes much more severe (see diagram top of page 406). This happens because the RF waveguide filter is relatively ineffective at frequencies only 20 mc from its operating frequency. Cross polarization of alternate channels is not effective in reducing this source of interference. The coupling loss between transmitting and receiving antennas must be sufficiently great that the power of the interfering carrier (shown in white), is well below that of the normal incoming carrier (shown in black) at the receiver input. The normal transmitted power is +27 dbm (one-half a watt) and the normal received power is about −36 dbm (one quarter of a microwatt). Thus, there is a normal power level difference between the two of 63 db. Field tests have shown that with six-channel operation the mutual coupling between antennas should provide a loss of about 75 to 80 db for satisfactory operation under all conditions.

Coupling Loss on Interstitial Channels

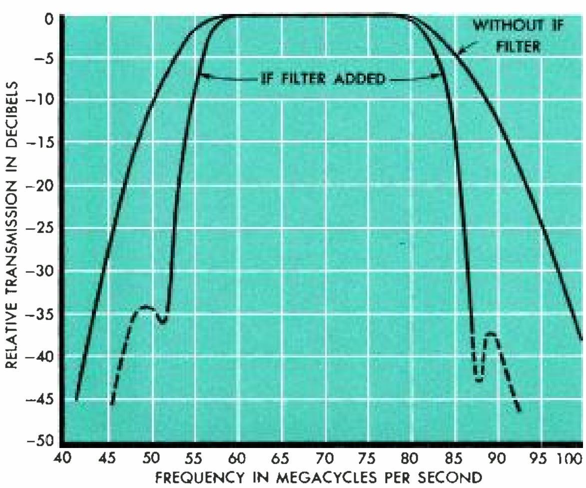
With interstitial, or 12-channel operation, this loss must be even greater since the channels are closer together. In fact, laboratory tests showed that the coupling loss should be 97 db or greater; otherwise there would be danger of cross-talk between adjacent microwave channels under deep fading conditions. Therefore, a survey was made by the Long Lines Department of A.T.&T. to determine the amount of mutual coupling between antennas at various TD-2 locations in the United States. Here a substantial percentage of the observations do not meet the coupling loss objective of 97 db for satisfactory 12-channel operation.

Additional protection was needed to prevent crosstalk between adjacent microwave channels.

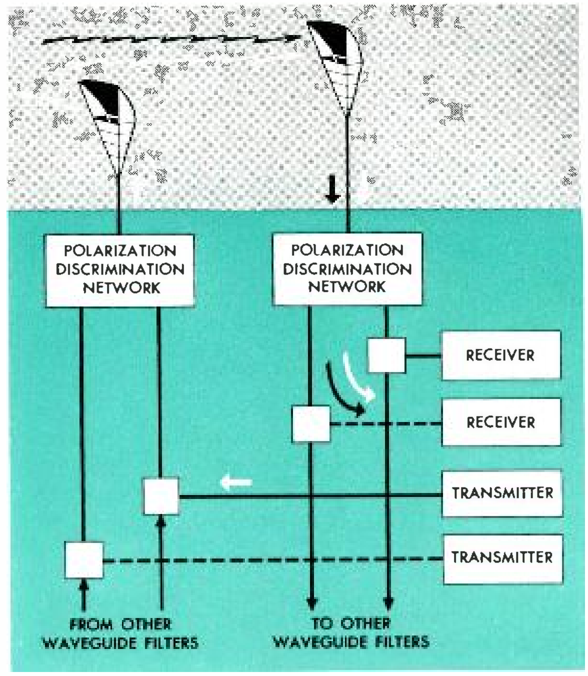
An additional IF filter supplied this protection. Each radio repeater includes an amplifier operating at 70 mc. These amplifiers provide a certain amount of selectivity to interference outside the normal pass band of 60 to 80 mc. The adjacent interstitial channels in each case pass through this amplifier at 50 and 90 mc; therefore by placing the new filter ahead of this amplifier, more than 30 db of loss at these two frequencies was obtained (see diagram below).

Laboratories engineers tested interstitial channel operation on the TD-2 microwave system between West Unity, Ohio and Grant Park, Illinois. On this section of the transcontinental system, they applied telephone, television, sine wave, and special test signals to one channel and observed the effects of crosstalk in a second channel 20 mc away. No crosstalk was observed provided the new filters were included in each radio repeater and the applied test signal did not exceed the capacity of the radio channel.

The six interstitial channels operate as a system separate from the six regular channels. In other words, with the six-channel arrangement, one channel is set aside as a protection channel which takes over immediately if one of the five channels fails. When the six interstitial channels are added, one of these will also be a protection channel. In this arrangement, both the regular and the interstitial channel will have its own automatic-switching system for protection purposes.



Radio receiver gain-frequency characteristics showing loss obtained by placing an additional IF filter ahead of the 70 mc amplifier in each receiver.



The effect of mutual coupling between the transmitting and the receiving antennas on the same tower. Extra IF filter helps reduce coupling loss due to interference between the two antennas.

Various technical and economic factors will determine the use and growth of interstitial channels on TD-2 routes. Routes that have a high rate of circuit growth are normally good candidates for interstitial channels. However, routes that have numerous branches or nearby paralleling routes often are not good candidates since interstitial channels may already be used on one route to prevent interference into the second. The early delay-lens used on some routes must be replaced with horn-reflector antennas before interstitial channels can be placed in operation.

In view of the satisfactory results of the study described above, interstitial channels have been installed on many TD-2 routes and plans are being made for their installation on other routes throughout the United States. The importance of these interstitial channels lies not only in the fact that they are a means of doubling the communication capacity of the TD-2 system, but also in that this increased capacity is achieved within the limits of the existing common-carrier band for TD-2. This represents an advance in the science of communication technology and the conservation of one of our vital national resources—the radio spectrum.

The "new look" in the Bell System's outside plant cannot always be seen. One recent behind-the-scenes improvement is in underground construction, where the long-used clay conduit is being supplemented by new concrete units.

W. T. Jervey

Concrete for Cable Conduit

Keeping telephone wires in an ordered arrangement usually requires that they be contained in cables. In populated areas, these cables go underground to minimize service interruptions and, incidentally, to get them out of sight. Moreover, in densely populated areas telephone cables are not buried directly in the earth but are housed in conduits. Conduits permit installing extra ducts, at the time of original construction, to accommodate additional cables as they are later required for circuit growth. Also, conduits furnish some protection for the cables against heavy traffic loads and inadvertent damage from digging operations of other agencies.

A conduit duct "run" usually extends continuously from one manhole to the next, a distance varying from 200 to 1200 feet. To make it easy to pull cables through them, these ducts must be reasonably smooth and should remain free from obstructions. The most likely causes of duct blockage are misalignment of conduit units and the entry of silt at the joints.

Since the turn of the century, the underground conduit used principally in the Bell System has been made of vitrified clay, mainly in multiduct form. This conduit is low in cost, durable, strong under compressive loading, and does not react chemically with the lead sheaths covering some cables. Clay provides duct surfaces sufficiently smooth to permit lead or plastic-sheathed cables to pass through without cutting, scoring, or excessive friction. However, clay conduit is brittle, with consequent likelihood of breakage in shipping, handling, and installation.

To manufacture vitrified clay conduit requires a large capital outlay for plants which, to minimize hauling costs for raw materials, must be located near suitable clay beds and fuel sources. For many years, the clay conduit factories serving all the United States except the West Coast have been mainly in Ohio and Indiana, although recently an additional Southern plant has become available. The long distances between plant and job site have magnified the costs of delivering the conduit to where it will be used. Furthermore, chances of breakage have been increased by the necessary multiple handling on rail and truck.

But the major objection to the clay conduit has been the lack of a dependable way to close the joints against silt. The standard method is with a mortar "bandage" made of cheesecloth, roofing felt, and cement mortar prepared at the trench where the conduit is to be placed. Properly prepared and applied, this joint closure is silt-tight, durable and mechanically strong. Imperfections do occur, however; moreover, a defective closure is not easy to detect at installation.

There is nothing novel about concrete as a construction material in the underground plant of the Bell System. Manholes are made of concrete, and cable conduits are encased in concrete where the duct structure itself is not strong enough to withstand expected mechanical stresses.

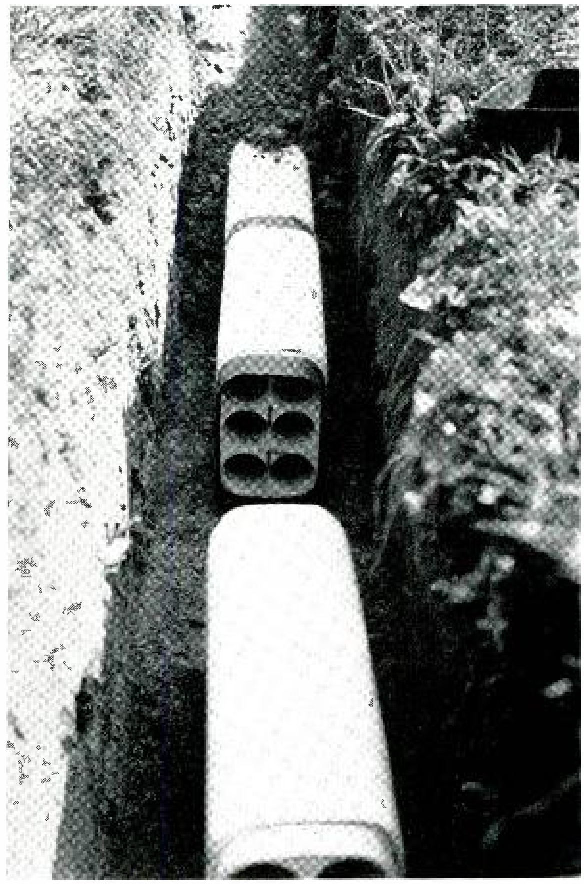
Until a few years ago concrete had not been seriously considered as an underground conduit material. This was because it is heavy and, under certain conditions, can corrode the lead sheaths of the cable. Weight is important because of costs for hauling and installation. Also, until recently, there has been enough vitrified clay conduit to meet Bell System needs. This reduced concrete conduit, in its early versions, to the status of a curiosity.

However, about five years ago a shortage in the supply of clay conduit made it necessary to use various other conduit types, some of which were of doubtful adequacy. To fill the supply gap, two of the Operating Telephone Companies designed, and obtained by local manufacture, multiduct conduits made of concrete.

Plainly, steps had to be taken to preclude repetition of the supply situation. Expanding clay conduit manufacturing facilities to care for increased demand seemed unattractive because of the slow and costly set-up factors. Also, fluctuations in yearly requirements for conduit make continuity of demand uncertain.

Second Look at Concrete

Thus the Bell System took a new look at concrete conduit and found that, with existing technological improvements, a manufacturer of other concrete products could quickly go into conduit production at moderate set-up cost for a price competitive with clay. Depending on the cost of trucking, he could economically deliver the units to trenchside within a radius of 50 to 150 miles. Practically all new cable is plastic sheathed now, and this obviates concern over corrosion in new installations. Also, the general availability of light weight aggregates (inert solid materials) for the concrete mix significantly reduces the weight penalty.



Six-duct conduit sections with double tenon ends are aligned with dowel pins. A polyethylene sleeve provides a silt tight closure pad between each unit.

Like clay conduit, concrete conduit is durable, strong in compressive loading, and low in cost. Both are also heavy and rather brittle. Duct surfaces in concrete are less smooth than in clay conduit but experience so far has indicated this differential to be insignificant in terms of damage to cable sheath or limitation on the length of cable that can be pulled into a duct.

The outstanding advantage of concrete over clay is that dimensions can be closely controlled in the concrete unit, because it is essentially a casting of a well-compacted mix with low water content. The clay unit, produced by extrusion, is subsequently cured and fired, causing relatively large variations in dimensions. The Laboratories approach to concrete conduit has been to exploit this dimensional stability to produce a system at least equivalent to clay, and having in addition a dependable, silt-tight joint.

As a result, Bell Laboratories arrived at two designs of concrete conduit in which end dimensions require close control for a proper joint. In one of these designs—"mortise and tenon" —one end of each conduit unit is finished as a tenon and the other end as a mortise. The tenon end, encircled by a ribbon of mastic or putty-like compound, is pushed into the mortise end of the previously laid unit to form a gasketed flush joint. This construction is designed to give good duct alignment and resistance to lateral shift.

In the other design—the "double tenon"—both ends of the conduit units are tenons. A tenon end registers in a mating expansible plastic sleeve already loosely placed on the adjacent tenon end of the previously laid unit. Applied pressure forces the tenon ends into the plastic sleeve up to the tenon shoulders to form a practically flush joint. As with clay conduit, two steel dowel pins are used to assure initial duct alignment and provide support against subsequent lateral shift of conduit units.

The sleeve forming the joint closure for double-tenon conduit is of a recently developed plastic material—crosslinked polyethylene (RECORD, *September*, 1958). This material was selected for its general durability, slow "creep-and-relaxation" under stress, and high resistance to the environmental stress-cracking that plagued polyethylene cable sheath in its initial history. The compound, consisting of polyethylene together with a large loading of carbon black and a few parts of peroxide, requires a curing interval in the molding operation analogous to that necessary in vulcanizing rubber. The resulting product has good handling characteristics in the working range of temperatures. As a matter of interest, the sleeve for the six-duct size of double-tenon conduit is probably the largest commercially molded piece of chemically crosslinked polyethylene produced to date.

Development of the mortise-and-tenon and double-tenon concrete conduits progressed sufficiently to indicate these designs to be practicable. The next step, then, was a trial in the field to compare them with clay conduit and with a "bell and spigot" design of concrete conduit developed by one of the Operating Telephone Companies.

The first field trial, made at Baton Rouge, Lousiana in the spring of 1959, involved six-duct double-tenon and bell-and-spigot conduits, both made of lightweight aggregate concrete. Three manhole sections (about 2100 trench feet) of each type of conduit were laid. This limited trial indicated that both designs of concrete conduit installed were economically competitive with clay conduit.

In the fall of 1959, a broader trial installation was made at Peoria, Illinois. Here the terrain was more irregular and trench obstructions more frequent than at Baton Rouge. In this trial, six-duct clay conduit was compared directly with six-duct double-tenon, three-duct and six-duct mortise and tenon, and six-duct bell-and-spigot concrete conduits made with lightweight aggregate. Three manhole sections of each design and size of concrete conduit were laid. This resulted in approximately 2500 trench feet of each six-duct size of concrete conduit, and about 2200 trench feet of the three-duct mortise and tenon conduit. For comparison, installation data were taken on 3200 trench feet of six-duct lightweight clay conduit.

The Peoria trial results confirmed the tentative conclusions reached at Baton Rouge. Analysis of in-place costs indicated a saving with both the double-tenon and the bell-and-spigot concrete conduits, the latter design having the greater advantage. On the other hand, the mortise and tenon concrete conduit showed an installed cost increase over clay. This is attributed to the mortise-and-tenon design requiring an unusually thick wall which increases unit weight and results in higher materials and labor costs.

Non-Cost Factors Important

Of course, if in-place cost were the sole determining factor, the trial results would indicate the bell-and-spigot concrete conduit to be the preferred design. But uniform duct alignment and silt-tight joints are also to be considered. Both these factors put the bell-and-spigot design into the category of marginal performance. In the double-tenon design, however, dowel pins, assisted by a degree of automatic alignment contributed by the plastic sleeve, assure good duct alignment. For silt-tightness, the sleeve appears to be the best multi-duct joint closure yet tried in the Bell System plant.

For these reasons, the double-tenon design of concrete conduit has been selected for standardization in the Bell System. As an alternative to clay, it offers the convenience and economic advantage of quick, flexible supply through local production. It also has the functional advantage of a simple joint closure of consistent silt-tightness, whose proper installation can be readily checked by inspection from the trench side.

At a recent Japanese Conference on Magnetism and Crystallography, Bell Laboratories scientists presented several papers on research in solid-state physics.

Laboratories Scientists, In Japan, Report On Solid-State Research

Several Bell Laboratories scientists participated in the International Conference on Magnetism and Crystallography recently held in Kyoto, Japan. The Laboratories papers presented included one on the improved properties of yttrium iron garnet and one on a new low-energy diffraction technique.

A significant advance in the understanding of yttrium iron garnet (YIG), a material that provides a substantial improvement over ferrites in many electronic applications, was described by R. C. LeCraw and E. G. Spencer of the Solid State Development Laboratory. YIG is similar to the ferrites in that it is both ferrimagnetic and an electrical insulator, but it has a different crystal structure from ferrites and is a much better insulator.

News of the Solid-State

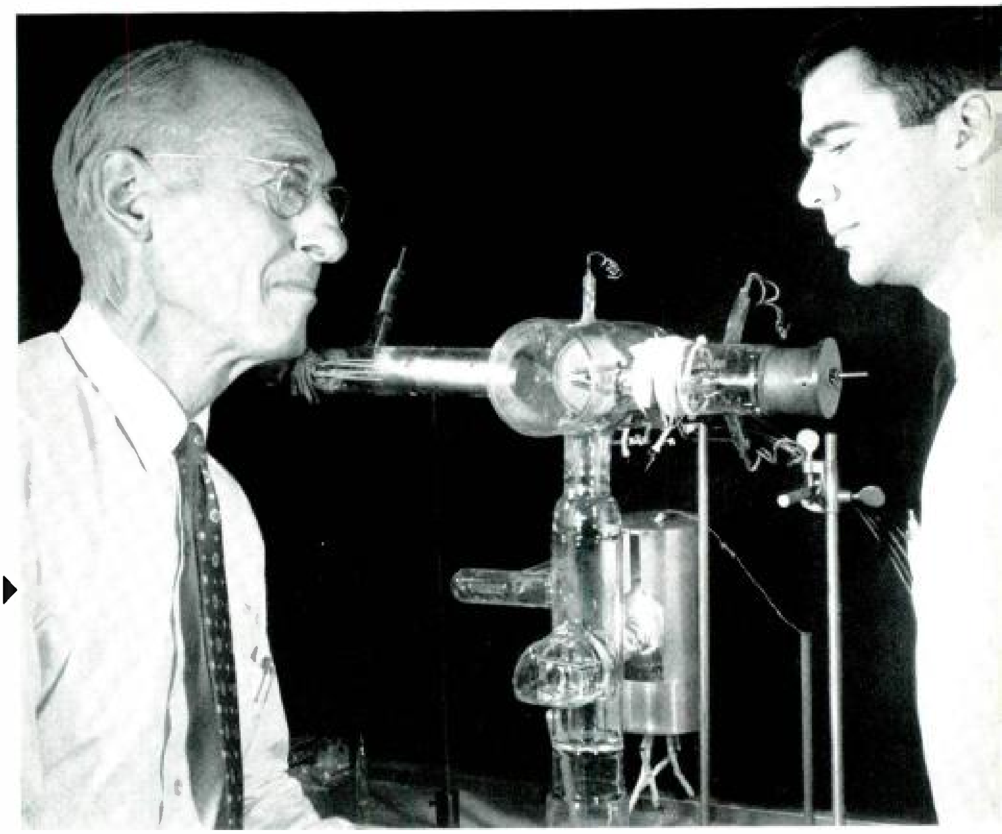
Both types of material transmit microwave radiation with very little loss. Equally important, when a strong dc magnetic field is applied to them, they can be made to transmit microwave radiation in one direction with little loss, but absorb radiation strongly in the reverse direction. This makes them useful as "isolators," or one-way transmission lines, and as power limiters for microwave systems.

One of the primary techniques used in studies of these ferrimagnetic insulators is measurement of the "ferromagnetic resonance linewidth." When a dc magnetic field and a small magnetic field at a radio frequency are applied to a specimen, a resonance peak occurs where the rf energy is strongly absorbed. The "width" of this resonance peak for a constant applied rf magnetic field is a measure of the efficiency of the material.

Messrs. LeCraw and Spencer reported ferromagnetic resonance linewidths in YIG at room temperature and 6,000 mc of only 0.14 oersteds—the narrowest linewidth ever obtained for a ferrimagnetic material. This is many times narrower than that reported for the best ferrites, which have linewidths of about 5 oersteds.

Pioneering work on the resonance properties of YIG were first begun at the Bell Laboratories by J. F. Dillon, Jr., of the Solid State Electronics Research Laboratory, who showed that very narrow linewidths were obtainable. Since that time, Laboratories scientists have devoted a sustained effort toward reducing the effects of impurities and other factors to establish the inherent linewidth of "perfect" YIG.

E. G. Spencer, left, and R. C. LeCraw adjust apparatus with which they measured what appears to be the inherent resonant linewidth of perfect yttrium iron garnet.



L. H. Germer, left, and A. U. MacRae are shown with the apparatus used in a new technique for studying the adsorption of monolayers of gas on the surface of a crystal.

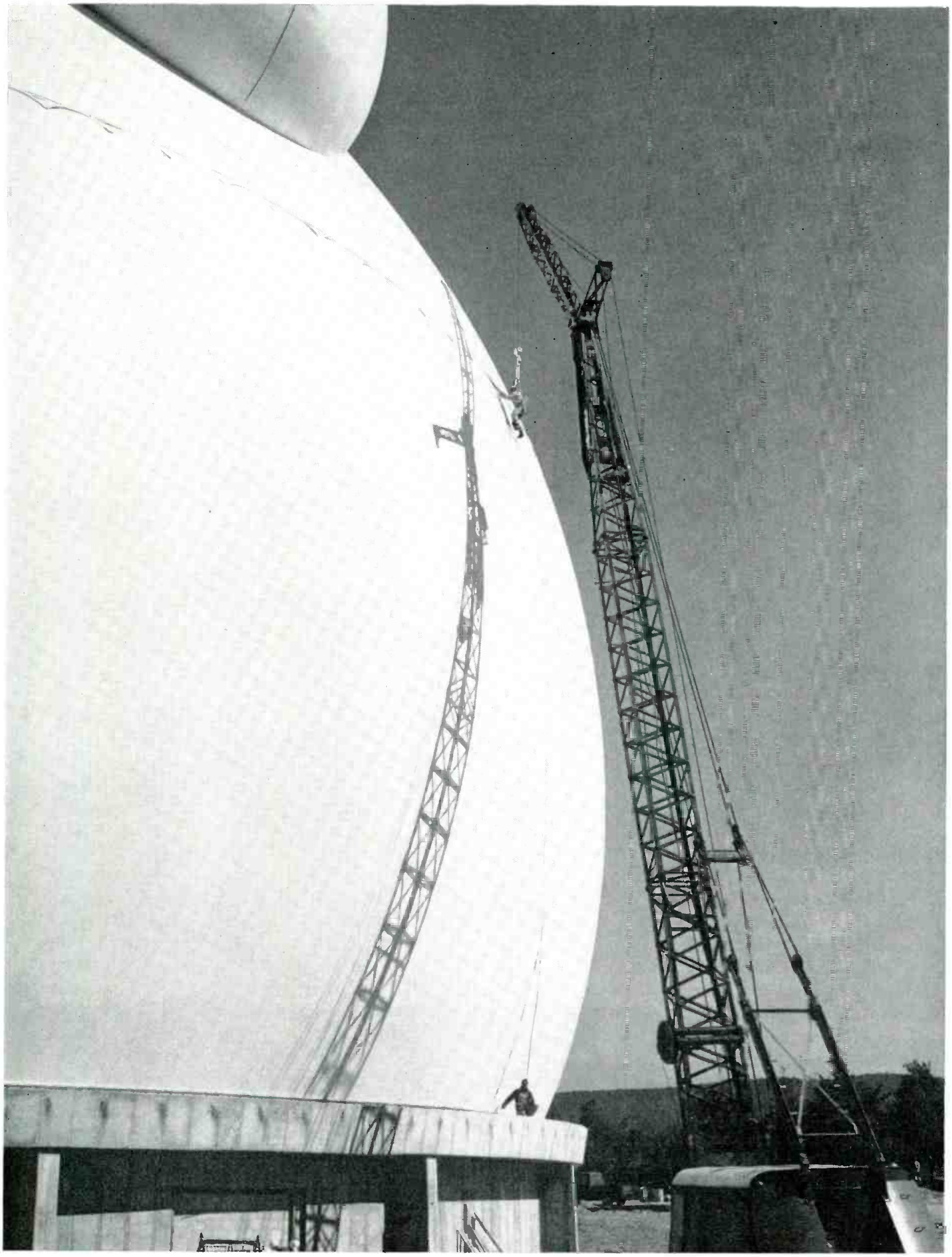
Messrs. LeCraw and Spencer found that surface roughness of YIG crystals had a large effect, and that the residual linewidth at low temperatures is caused by ferrous ions. By polishing the crystals to an extremely smooth finish and developing methods of removing impurities, the Bell Laboratories scientists succeeded in lowering the linewidth to its 0.14 oe. The measured linewidth now agrees closely with a recently developed theory, except at very low temperatures, and they believe this figure is the intrinsic linewidth of perfect YIG.

The low-energy diffraction technique was presented by L. H. Germer and A. U. MacRae of the Physical Research Laboratory. They reported on studies of adsorption of monolayers of gases on a crystal surface using a new experimental method perfected by Mr. Germer. In this technique, low energy electrons are diffracted from a surface and accelerated to a fluorescent screen by a strong electric field. The diffraction pattern produced on the screen shows how the first monolayer of atoms is arranged on the surface.

The technique is providing a powerful new tool for the study of surface reactions, since it gives a detailed picture of the arrangement of atoms entering into such reactions. It is opening the way to a far more detailed understanding of such surface phenomena as catalysis and corrosion.

In their paper, Messrs. Germer and MacRae reported on studies of oxygen and hydrogen adsorption on a nickel crystal. They found that after a monolayer of oxygen had been adsorbed, nickel atoms diffused to the surface, producing an orderly arrangement containing either one or two oxygen atoms for each nickel atom. The arrangement containing equal numbers of oxygen and nickel atoms proves to be remarkably stable, up to temperatures at which nickel evaporates rapidly. The scientists found, however, that the oxygen can be easily removed by hydrogen at moderate temperatures, and that the hydrogen in turn is removed by slight heating, leaving a perfectly clean surface.

Other Bell Laboratories papers at the Kyoto Conference were also devoted primarily to the fundamental nature of magnetism and included a report by Mr. Dillon on the effect of rare earth impurities in YIG. Also reported were studies on the rare earth metals and the magnetic behavior of individual atoms of iron, cobalt, and nickel dissolved in non-magnetic materials.



This radome, 160 feet high and 210 feet across, is the largest inflated earthbound structure in the world.

Recently, the world's largest nylon dome was inflated on "Space Hill" near the town of Rumford, Maine. It will soon house the antenna of Project Telstar, the Bell System's voice to outer space.

Radome Takes Shape At Space Center

News of Satellite Communications

A nylon dome—210 feet across, 160 feet high—the largest inflated earthbound structure in the world, has been erected at Long Lines' space communications center near Rumford, Me. The chemically-treated dome, which was designed at Bell Laboratories, was inflated late in the evening of September 29. It serves as a temporary cover within which technicians will assemble a giant 300-ton steel and aluminum antenna—the Bell System's voice and ear to outer space. Although the dome is only one-twentieth of an inch thick, it weighs almost 12 tons.

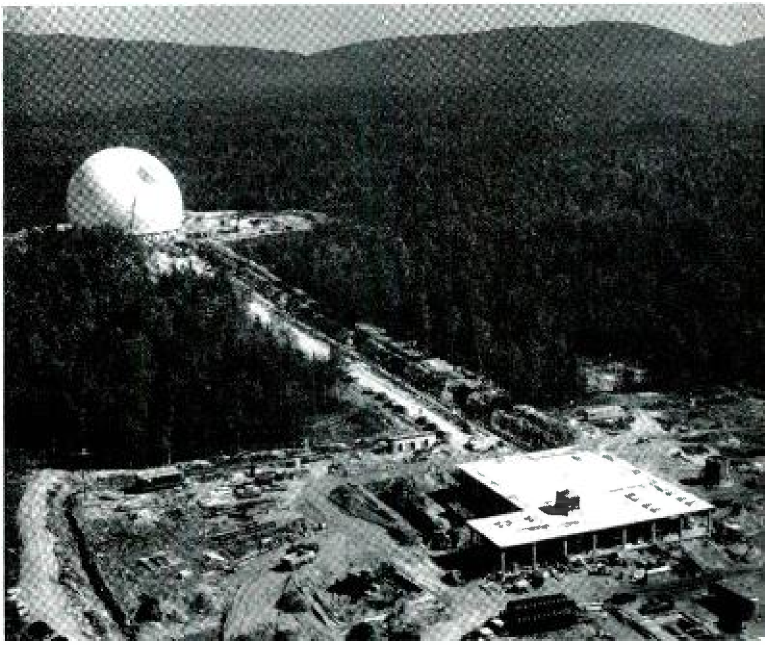
To inflate the dome, five blowers placed about the concrete rim of the radome started pumped air beneath the nylon cover at the rate of 50,000 cubic feet a minute. The dome was inflated in slightly under two hours. It is supported by air pressure about one-tenth of a pound per square inch greater than the outside atmospheric pressure. People and vehicles enter the huge dome through air locks.

By the end of December, a permanent radome, practically "transparent" to radio waves, will replace the present temporary cover. A bubble on this temporary cover (see the accompanying photograph) provides for raising the permanent radome over the house on the horn antenna while the temporary cover is partially deflated. Thus the radome will slide over the dome without danger of ripping.

The antenna, another Laboratories design, will play a vital role in Project Telstar, the Bell System's space communications experiments. This project calls for launching two active communications satellites next year—the first in April, the second later in the year. The project will investigate the technological and operational problems of wideband communications via satellites. In addition to testing transmission characteristics of satellites in an eliptical orbit ranging from approximately 1,000 to 3,000 miles high, Project Telstar will check performance of facilities being developed for pointing ground antennas and for tracking the satellites. The satellites themselves will supply information needed to build satellites which should be designed to last ten or more years.

All costs of Project Telstar are being paid by the Bell System; the satellites and the ground facilities are being furnished by the Bell System. To carry out the experiments, A.T.&T. will reimburse the National Aeronautics and Space Administration for the rockets, as well as for the launching and other expenses.

Antenna and dome under construction in hills of Maine. Central control building being erected in foreground.



DATA TERMINAL EQUIPMENT DESCRIBED AT A.I.E.E. MEETING

News of Transmission Systems Development

The latest in a varied line of data communication equipment to come out of Bell Laboratories is an experimental transmitting and receiving set using amplitude modulation and vestigial sideband operation in a voice channel. This device was revealed last month at the Fall General Meeting of the American Institute of Electrical Engineers held in Detroit, Michigan. It is one of a number of data sets, designed for use over voice circuits, that were discussed at the meeting by Bell Laboratories engineers in the Data Communications Laboratory.

A paper prepared by F. K. Becker, J. R. Davey, and B. R. Saltzberg, and delivered by Mr. Saltzberg, described the AM vestigial sideband set as a versatile and economical terminal equipment for high-speed transmission of digital data over voice circuits. Depending on the capability of the transmission channel, it can transmit data at rates of 2000 to 3000 bits per second, using synchronous detection and "suppressed" carrier.

In ordinary AM transmission, the carrier signal goes along with the information-carrying sidebands. This carrier uses energy, however, which might better be used for the transmission of information. "Suppressing" the carrier leaves the transmission energy for use by the information-carrying sideband. At the receiver the carrier must be reconstituted before the signal can be demodulated.

For voice transmission, the carrier can be supplied by a local oscillator whose frequency is within a few cps of the original. But for data, the reconstituted carrier signal must be exactly the same frequency as the original. In the new AM arrangement, a low-level reference signal at the carrier frequency travels with the sideband at "quadrature." This means the reference signal is 90 degrees out of phase with the suppressed carrier. The data receiver restores a full strength, in phase, carrier signal for use by the synchronous detector.

The advantages of using synchronous detection and suppressed carrier in this accurate data system are good signal-to-noise ratio and a minimum of distortion. A further advantage lies in the efficient use of the frequency spectrum through the vestigial sideband transmission. This is a sort of "single side-band" arrangement that uses only about half the normal frequency space.

The Bell System provides a wide variety of speed ranges in data transmission terminals to serve the many different needs of customers. There are, for example, slow-speed sets such as the multi-frequency parallel device operating at 120 bits (20 characters) per second described in a paper by Mr. Saltzberg and R. Sokoler. This is a low-cost equipment, designed for systems where data is gathered from users at outlying points for processing in a centrally located computer. For example, these points might be "branch offices" of a business where the amount of work would not warrant individual, expensive computing equipment.

A number of data sets operate serially at faster speeds and can transmit or receive data from a variety of business machines. One such set is a frequency modulation device described by S. T. Meyers. This versatile set can handle any binary type code—any pulse "width." As a result, customers can use any code and any speed of transmission up to the maximum. The FM set operates at speeds up to 1200 bits per second on the switched telephone network and up to 1600 bits per second on equalized (distortion compensated) private lines.

P. A. Baker reported on another serial data set that uses phase modulation. Although this set accepts and delivers serial data, its "quarternary" or four-phase nature permits sending two bits at a time. The two versions described at the meeting operate at 2000 and 2400 bits per second. Unlike many data sets, the PM set has internal features for synchronous operation. The transmitter portion has a self-contained clock and the receiver portion maintains continuous bit synchronization for all data-signal sequences.

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

Abrahams, S. C., *PEXRAD: Programmed Electronic X-Ray Automatic Diffractometer*, Am. Crystallographic Assoc., Boulder, Colo.

Allen, F. G., see Becker, J. A.

Ballman, A. A., *A New Series of Piezoelectric and Fluorescent Crystals*, Am. Chem. Soc., Chicago, Ill.

Barstow, J. M., *The Measurement of Random Video Interference to Monochrome and Color TV Pictures*, A.I.E.E. Pacific General Meeting, Salt Lake City, Utah.

Beach, A. L.. see Guldner, W. G.

Becker, J. A., presented by Allen, F. G., *Some Observations on Tungsten Oxide Structures in the Electron Field Emission Microscope*, Eighth Field Emission Symposium, Williams College, Mass.

Black, H. S., *Global Communications via Artificial Earth Satellites*, Western Electric Tech. Publ. Symposium, Winston-Salem, N. C.

Black, H. S., *World-Wide Communications via Satellites*, N. J. Section of A.I.Ch.E., Am. Smelting & Refining Co., South Plainfield, N. J.

Buchsbaum, S. J., *Coupling Between Electromagnetic and Plasma Waves*, Plasma Phys. & Nuclear Fusion Res. Conf., Salzburg, Austria.

Buchsbaum, S. J., *Resonant Interaction of an Extraordinary Wave with a Plasma Column*, Nuclear Fusion Res. Conf., Salzburg, Austria.

Cave, J. H., *Echo I—First Birthday Review of Satellite Communication Program*, Congdon Lodge #201 F. & A. M., Bernardsville, N. J.

Danielson, W. E., see Jacobs, I.

Davis, C. G., *Satellite Communications*, Md.-D. C. Utilities Assoc., Virginia Beach, Va.

DeBenedictis, T., see Hansen, R. H.

DeMonte, R. W., *Synthesis of Two-Terminal Networks Simulating Impedance of Loaded Cable Facilities*, A.I.E.E. Conv., Salt Lake City, Utah.

Deutsch, M., *Psychological Alternatives to War*, Am. Psychological Assoc., N. Y. C.

Drenick, R. F., *On the Wold Decomposition of Non-Gaussian Random Processes*, Am. Math. Soc., Seattle, Wash.

Ferrell, E. B., *Fundamental Concepts of Statistical Analysis*, 1961 Rutgers Conf., Metropolitan Section of Am. Soc. for Quality Control, New Brunswick, N. J.

Fuller, C. S., and Wolfstirn, Miss K. B., *Kinetics and Equilibrium Involving Copper and Oxygen*, Conf. Chem. Phys. of Non-Metallic Crystals, Chicago, Ill.

Garn, P. D., and Kessler, J. E., *Thermal Analysis of Small Samples*, International Symposium on Microchem. Techniques, University Park, Pa.

Garn, P. D., and Kessler, J. E., *Thermal Analysis Using Sealed-Tube Sample Holder*, Am. Chem. Soc., Chicago, Ill.

Gerard, H. B., *Inconsistency of Beliefs and Their Implications*, Am. Psychological Assoc., N. Y. C.

Gerard, H. B., *Reciprocal Effects of the Influenced Upon the Influencing Agent*, International Cong. Appl. Psychology, Copenhagen, Denmark.

Geschwind, S., *Spin Resonance of Transition Metal Ions in Corundum*, Conf. Chem. Phys. of Non-Metallic Crystals, Northwestern University, Evanston, Ill.

Giffels, C. A., see Jacobs, I.

Ginsberg, A. P., *Application of Proton Magnetic Resonance to the Study of Transition Metal-Hydrogen Compounds*, Am. Chem. Soc., Magnetic Phenomena in Inorganic Chem. Symposium, Chicago, Ill.

Guldner, W. G., and Beach, A. L., *The Application of a Conductometric Method for the Determination of Oxygen in Organic Materials*, International Symposium on Microchem. Techniques, University Park, Pa.

Haase, O., *Transmission Electron Microscopy of Evaporated Germanium Films*, Tech. Conf. on Metallurgy of Semiconductor Materials, Los Angeles, Calif.

Hammock, J., *Teaching Machines, The Consumer and The Data: Some Suggestions*, Am. Psychological Assoc., N. Y. C.

Hansen, R. H., and DeBenedictis, T., *Study of the Decomposition of Blowing Agents. I: A Method for Predicting Performance*, Am. Chem. Soc., Chicago, Ill.

Herber, R. H.. see Wertheim, G. K.

Hershey, J. H., *Attainment of Reliable Design*, 1961 Rutgers Conf., Metropolitan Section of Am. Soc. for Quality Control, New Brunswick, N. J.

Hight, S. C., *Satellite and Space Communications*, Western Electric Tech. Publ. Symposium, Winston-Salem, N. C.

Jacobs, I., Danielson, W. E., and Giffels, C. A., *Simple Satellite Concepts to Meet Relatively Unsophisticated Communication Needs*, 1961 National Symposium on Space Electronics & Telemetry, Albuquerque, N. M.

Jenkins, H. M., *Resistance to Extinction When Partial Reinforcement is Followed by Vari-*

ous Amounts of Regular Reinforcement, Psychonomic Soc., N. Y. C.

Karnaugh, M., and Kuo, F. F., *A Visual Aid to Filter Approximation*, WESCON Conv., San Francisco, Calif.

Keith, H. D., *The Study of Polymer Spherulities by Optical Microscopy*, Electron Microscope Soc. Am., Pittsburgh, Pa.

Kennedy, R. A., *Library Shibboleths, Sophistries and Systems*, Tenth Annual Conf. Assoc. of Special Libraries & Deformation Bureaux, Aeronautical Gp., Cranfield, England.

Kessler, J. E., see Garn, P. D.

Kessler, J. E., see Garn, P. D.

Kinsburg, B. J., *Sixteen Oceans at Chester, N. J.*, Rotary Club, Chester, N. J.

Kisliuk, P., *Optical Masers*, I.R.E., Binghamton, N. Y.

Knox, K., *Structures and Properties of Some Complex Fluorides*, Gordon Res. Conf. in Inorganic Chem., New Hampton, N. H.

Knox, K., *The Structure of* $YAl_3(BO_3)_4$, *One of a New Series of Synthetic Borates*, Am. Crystallographic Assoc., Boulder, Colo.

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

Kunzler, J. E., *High Field Superconductors*, MIT Summer Course on Superconductivity. Cambridge, Mass.

Kuo, F. F., see Karnaugh, M.

Liehr, A. D., *Molecular Orbital Theory, Valence Bond Theory, and Ligand Field Theory: A Comparison*, Am. Chem. Soc., Chicago, Ill.

Liehr, A. D., *Optical Activity in Rare Earth and Transition Metal Complexes*, Sixth International Conf. Coordination Chem., Wayne State University, Detroit, Mich.

Lloyd, S. P., *Extreme Means Are Homorphisms*, Am. Math. Soc., Seattle, Wash.

Loomis, T. C., *Miniature Probe Techniques*, Workshop on X-Ray Emission Spectrochem. Analysis, Stevens Institute of Technology, Hoboken, N. J.

Mason, W. P., *Low Frequency Component of the Internal Friction of Single Crystal Copper and Its Relation to the Bordoni Peak*, Cornell University, Ithaca, N. Y.

Mason, W. P., *Use of Semiconductor Transducers and Esaki Diodes in Measuring Strains and Pressures*, Instr. Soc. Am., Los Angeles, Calif.

McCall, D. W., *Nuclear Magnetic Resonance in Polymer Liquids*, Am. Chem. Soc., Chicago, Ill.

Melroy, D. O., *A 50 Milliwatt BWO and a 0.5 Watt TWT for CW Operation Over the 50 to 60 KMC Band*, WESCON Conv., San Francisco, Calif.

Miller, R. C., see Wood, E. A.

Murray, R. W., and Trozzolo, A. M., *Photochemical Decomposition of Dichroic Diazo Compounds, Microscopic Studies*, International Symposium on Microchem. Techniques, University Park, Pa.

Nelson, L. S., and Kuebler, N. A., *Reaction of Sulfur Hexafluoride and Flash-Heated Carbon Studies by Kinetic Spectroscopy*, Am. Chem. Soc., Chicago, Ill.

Pollak, H. O., *Content and Philosophy of the Ninth Grade SMSG Course*, Bowling Green State University, Bowling Green, Ohio.

Pollak, H. O., *On the Nature of Applied Mathematics*, Bowling Green State University, Bowling Green, Ohio; Annual Meeting of National Council of Teachers of Math., University of Toronto, Toronto, Canada.

Pollak, H. O., *Status Report on the Work of the Panel on Mathematics for the Physical Sciences and Engineering of the Committee on the Undergraduate Program in Mathematics of the MAA*, Annual Meeting of Am. Soc. Engg. Ed., University of Kentucky, Lexington, Ky.

Rosenberg, S., *Some Basic Dimensions of Interdependent Feedback in Teams*, XIV International Cong. Appl. Psychology, Copenhagen, Denmark.

Ryder, E. J., *Heat Capacity of Some Superconductors Using a Semi-Adiabatic Colorimeter*, International Colorimetry Conf., Ottawa, Canada.

Schawlow, A. L., *Sharp-Line Optical Spectra of Chromium in Nearly Cubic Crystal Fields*, 1961 International Conf. Chem. Phys. of Non-Metallic Crystals, Northwestern University, Evanston, Ill.

Schreiber, H., Jr., *Some Considerations on the Excitation Efficiency in X-ray Spectrochemical Analysis*, Tenth Annual Conf. on Applications of X-Ray Analysis, Denver, Colo.

Sharpe, L. H., *Surface Analysis by Infrared—New Techniques*, Gordon Res. Conf. on Adhesion, New Hampton, N. H.

Smolinsky, G., *Heterocyclic Organoboron Compounds, Some Derivatives of 1,3,2-Dioxaborole*, Am. Chem. Soc., Chicago, Ill.

Soden, R. R., see Van Uitert, L. G.

Stockler, H. A., see Wertheim, G. K.

Stone, H. A., Jr., *A System of Tantalum Film Microcircuitry*, Avionics Panel Meeting on Microcircuitry, AGARD Microminiaturization Conf., Oslo, Norway.

Sugano, S., *Recent Progress of Crystal Field Theory*, 1961 International Conf. Chem. Phys. on Non-Metallic Crystals, Northwestern University, Evanston, Ill.

Swenson, J., *Mechanism of Flicker Fusion*, International Congress on Biophysics, Stockholm, Sweden.

Thurmond, C. D., *Solid Solubilities of Impurities Near the Melting Point of a Semiconductor*, University of California, Berkeley, Calif.

Traub, J. F., *Functional Iteration and the Calculation of Roots*, Sixteenth National Conf. Assoc. for Computing Machinery, Los Angeles, Calif.; Am. Chem. Soc., Los Angeles, Calif.

Trozzolo, A. M., see Murray, R. W.

Trumbore, F. A., *Problems in Semiconductor Crystal Growth*, Phys. Chem. Sem., Chem. Depart., University of Pittsburgh, Pittsburgh, Pa.

Van Uitert, L. G., *Factors Influencing the Fluorescence of Rare Earth Ions*, Am. Chem. Soc., Chicago, Ill.

Van Uitert, L. G., and Soden, R. R., *Energy Transfer Between Cation-Antipyrene Aggregates in Their Rare Earth Hexa-Antipyrene Salts*, Sixth International Conf. on Coordination Chem., Detroit, Mich.

Walker, L. R., *The Isomer Shift in* Sn^{119}, Mossbauer Conf., Saclay, France.

Wasserman, E., *Linear Polyene Radicals*, International Cong. of Pure & Appl. Chem., Montreal, Canada.

Wertheim, G. K., Herber, R. H., and Stockler, H. A., *Recoilless Gamma Ray Absorption (Mossbauer Effect) in Ferrocene*, Am. Chem. Soc., Chicago, Ill.

Wolfstirn, Miss K. B., see Fuller, C. S.

Wood, E. A., and Miller, R. C., *Field-Induced Changes in* $hahbO_3$ and $ha(hb_{1-x}V_x)O_3$, Am. Crystallographic Assoc., Boulder, Colo.

PATENTS

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

Anderson, J. R.—*Ferroelectric Storage Circuits and Methods*—3,002,182.

Armstrong, J. M. and Goddard, M. C.—*Private Line Transfer Switching Circuit*—3,001,027.

Baldwin, J. A., Jr. and Feiner, A.—*Magnetically Biased Switch*—3,002,067.

Baird, J. A.—*Amplifying Trigger Circuit*—3,002,109.

Boyle, W. S. and Smith, G. E.—*D. C. Pumped Solid State Maser*—3,002,167.

Burrus, C. A.—*Electric Switch*—3, 002,069.

Doyle, E. F.—*Fastening Device*—3,001,755.

Dreyfuss, H., Genaro, D. and King, D. H.—*Telephone Booth*—D-191,392.

Feiner, A.—*Non-Saturating Transistor Pulse Amplifier*—2,999,169.

Feiner, A., see Baldwin, J. A., Jr.

Fletcher, R. C., Scovil, H. E. D., and Seidel, H.—*Solid State Maser Amplifier*—3,001,141.

Genaro, D., see Dreyfuss, H.

Goddard, M. C., see Armstrong, J. M.

Hilsinger, H. A., Jr.—*Step Twist Waveguide Rotary Joint*—3,001,159.

Houghton, E. W.—*Electromagnetic Wave Tuner*—3,002,167.

Ketchledge, R. W. and Lovell, C. A.—*Magnetically Controlled Switching Device*—3,002,066.

Kinariwala, B. K.—*Active Impedance Branch*—3,001,156.

King, D. H., see Dreyfuss, H.

Kluver, J. W.—*Traveling Wave Tube*—2,999,959.

Krom, M. E.—*Truck Concentrator for Telephone Answering Service*—3,002.054.

Lawrence, W. A., Jr.—*Transistor Trigger Circuit*—2,999,172.

Lovell, C. A., see Ketchledge, R. W.

Mahony, J. P., Ostendorf, B., Jr., Parker, G., and Vanderlippe, R. A.—*Station Control Circuit for Multistation Line*—3,001,010.

Mims, W. B.—*Solid-State Maser*—3,001,142.

Ostendorf, B., Jr., see Mahony, J. P.

Parker, G., see Mahony, J. P.

Scovil, H. E. D., see Fletcher, R. C.

Seidel, H., see Fletcher, R. C.

Sipress, J. M.—*Active One-Port Network*—3,001,155.

Sipress, J. M. and Witt, F. J.—*Nonreciprocal Wave Translating Network*—3,001,157.

Smith, G. E., see Boyle, W. S.

Vanderlippe, R. A., see Mahony, J. P.

Weller, D. C.—*Magnetic Memory Array*—3,000,004.

Witt, F. J., see Sipress, J. M.

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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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Anderson, P. W., *Localized Magnetic States in Metals*, Phys. Rev., Vol. 124, pp. 41-53, Oct. 1, 1961.

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Becker, J. A., *Introduction to Volume 3*, Langmuir Memorial Volumes, 3, pp. XVII-XXVIII, 1961.

Bederson, B., see Salop, A.

Bowers, R., and Yafet, Y., *The Magnetic Susceptibility of p-Ge*, Proc. International Conf. on Semiconductor Phys., Prague, 1960, pp. 802-804, Aug., 1961.

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Clogston, A. M., see Matthias, B. T.

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

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David, E. E., Jr., *The Reproduction of Sound*, Sci. Am., 205, pp. 72-85, Aug., 1961.

Deutsch, M., *The Interpretation of Praise and Criticism as a Function of their Social Context*, J. Abnormal and Social Psych., Vol. 62, pp. 391-400, March, 1961.

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Dewald, J. F., *Experimental Techniques for the Study of Semiconductor Electrodes*, Symposium on Surface Chem. of Metals and Semiconductors, pp. 205-224, 1960.

Dietz, R. E., see Pappalardo, R.

Ditzenberger, J. A., see Whelan, J. M.

Douglass, D. C., *Self-Diffusion and Velocity Correlation*, J. Chem. Phys., 35, pp. 81-90, July, 1961.

Eisinger, J., see Salop, A.

Feher, G., *Paramagnetic Resonance Experiments on Shallow Impurities in Silicon and Germanium*, Proc. International Conf. on Semiconductor Phys., Prague, 1960, pp. 579-586, Aug., 1961.

Flood, W. F., see Haynes, J. R.

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Garrett, C. G. B., Kaiser, W., and Wood, D. L., *Fluorescent and Optical Maser Effects in CaF_2:Sm++*, Phys, Rev., 123, pp. 766-776, Aug. 1, 1961.

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Geller, S., *Parameter Interaction in Least Squares Structure Refinement*, Acta. Cryst., Vol. 14, pp. 1026-1035, Oct. 10, 1961.

Gordon, E. I., *Noise in Beam-Type Parametric Amplifiers*, Proc. I.R.E., 49, p. 1208, July, 1961.

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Gresh, M., see Schwartz, N.

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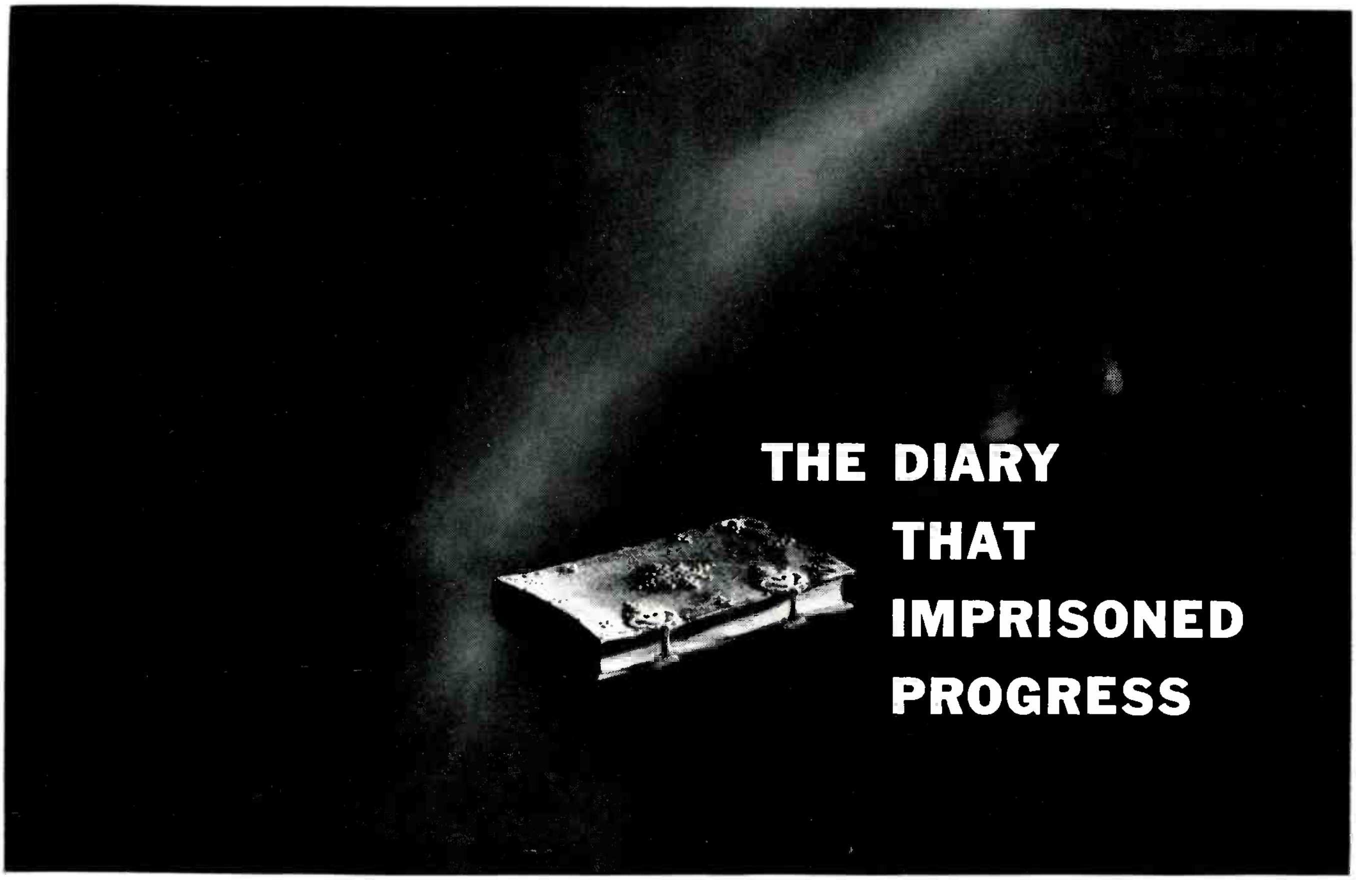

Nearly two centuries ago, Karl Gauss, "Prince of Mathematicians," kept a diary which was destined to become one of the most significant documents in the history of mathematics.

In his diary Gauss jotted down the results of elaborate calculations that had led him to fundamental discoveries in mathematics. But he never published these discoveries, and many of them remained undisclosed during his lifetime.

It wasn't until almost 50 years after Gauss's death that his diary was found and published. Much time and talent, meanwhile, had been spent in duplicating Gauss's efforts. Mathematical progress had been needlessly slowed.

In contrast, today's scientists and engineers are alert to the importance of sharing their findings through publication. In fact, the number of definitive papers published in a scientific or technological field has become a sure sign of the creative effort in that field.

Bell Laboratories scientists and engineers publish more than 800 papers a year, reporting new observations and new thinking in the arts and sciences that serve communications. They have also authored more than 50 technical books, many of which have become standard works of reference. The steady stream of new information that comes out of Bell Laboratories again reflects the scope and depth of the creativity that works to improve Bell System communications.

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