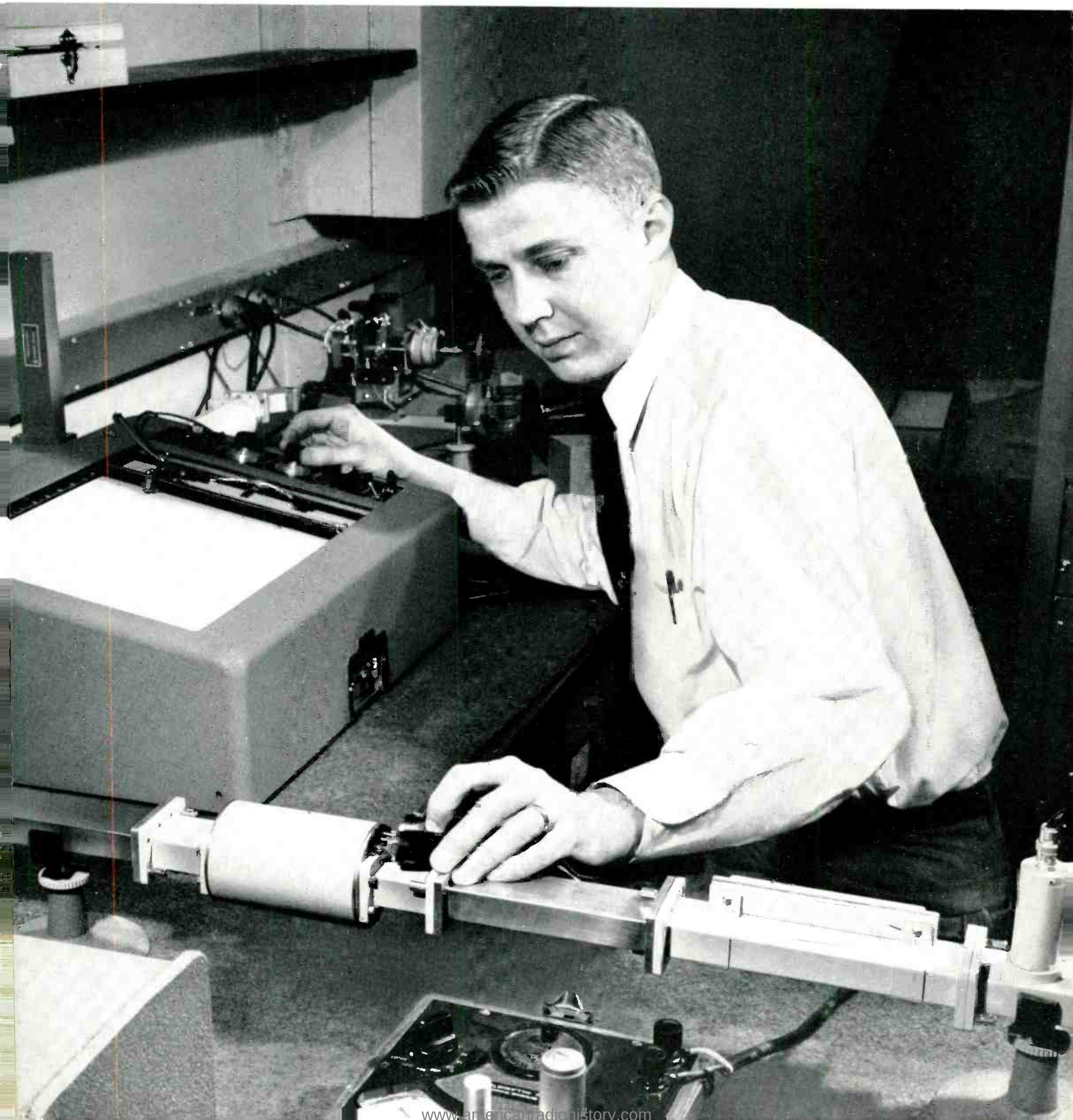
April 1959

Bell Laboratories RECORD



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Bell Laboratories **RECORD**

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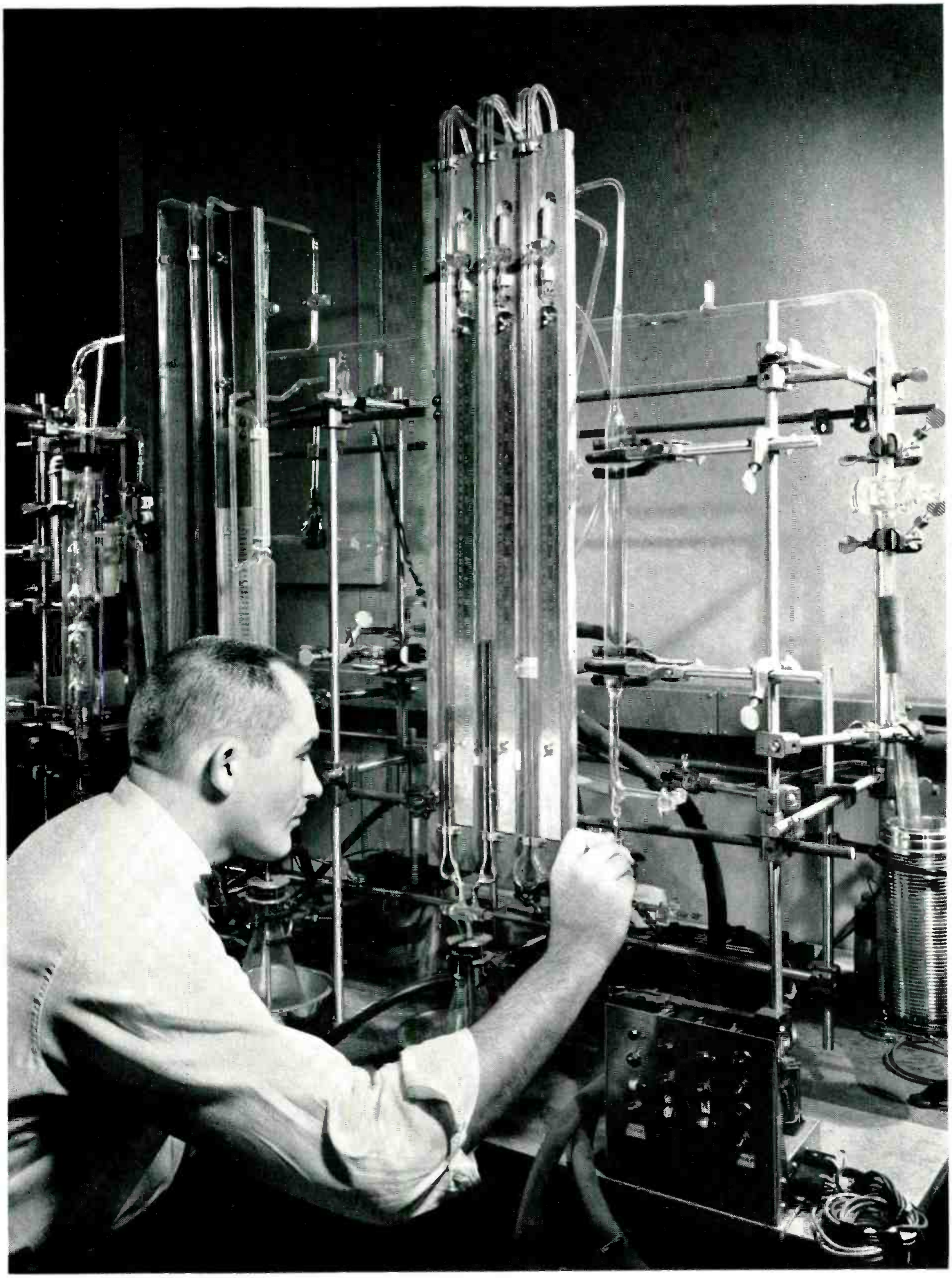
Contents

Cover *R. W. Judkins performing transmission tests on new Faraday rotation switch for the TH microwave system (see p. 139).*



J. Fisher making a gas absorption analysis at the Merrimack Valley Laboratory.

Instead of a sharp dividing line between development and manufacture, there is a phase during which both development and manufacturing concepts modify each other. In North Andover, Massachusetts, Bell Laboratories and Western Electric engineers work together on their mutual problem—to produce high quality transmission systems and related components with the greatest speed, and at the lowest possible cost.

M. B. McDavitt

The Merrimack Valley Laboratory

The Merrimack Valley Laboratory began on a pilot scale in 1955 and came into full bloom a year later. It bears some close resemblances to other branch laboratories, but it differs in one important respect. It is the first Bell Telephone Laboratories establishment on Western Electric Company premises to have major responsibility for development of complete systems for use in the Bell System. At this laboratory, final development for manufacture of most transmission systems and of many of the components used in these and other systems is carried out.

Branch laboratories have a long and important history in the evolution of our development pattern. The first one dates back to 1909 when a small group from the Western Electric Company Engineering Department (the predecessor of Bell Telephone Laboratories, Incorporated) was moved from New York City to the Hawthorne Works to provide a necessary close tie between development and production of toll (quadded) cable. This group has been in existence ever since, and currently resides at both the Kearny and Point Breeze Works. Other early Laboratories groups at Western locations included one at Kearny in 1939 to handle radio broadcast transmitters, and one at the Hudson Street Tube Shop in New York City — in 1939 on electron tubes for commercial sales, and in 1944 on those for Bell System use. The dozen or so groups set up in several Western Electric Co. plants during the war were *ad hoc* branch locations of Bell Laboratories.

Postwar Technology

In 1943, Dr. M. J. Kelly, then Director of Research and recently retired Chairman of the Board of Bell Laboratories, foresaw the spectacular surge in technology that followed the war, and gave his views to top management in Western Electric and the Laboratories on what would be needed to make the most of it in the Bell System. A key item, in his analysis, was an intimate interplay between the final development and the manufacture of telephone plant elements. It was clear to him that both high performance and low cost could be achieved only by having the development engineers in close daily contact with, and benefiting by the feedback from, the engineers who would be responsible for manufacturing methods.

When the Allentown, Pennsylvania, plant for the manufacture of electron tubes and other de-

General view of transmission systems laboratory at Merrimack Valley. On far side of aisle are systems installations of voice-frequency equipment, broadband multiplex terminals, currently manufactured carrier systems, video switching and mobile and microwave radio. On the near side of aisle are bench setups where subsidiary units are constructed, tested and measured.

vices opened in 1948, it was part of the basic plan to have in residence the Laboratories group responsible for the development for manufacture of those devices. When semiconductor devices were introduced, the Allentown Laboratory was augmented correspondingly. Still another branch laboratory, after modest beginnings in 1946, attained major stature in 1950 at the North Carolina Works, where substantially the entire effort is on systems for military use.

Early Planning

In 1953, Western Electric made commitments for consolidation and expansion of its Lawrence and Haverhill Shops at a new plant in North Andover, Massachusetts, which has since become the Merrimack Valley Works. Here, the principal product is transmission systems for Bell System use. Again, the Laboratories was consulted, and it was decided that an organization responsible for final development of transmission systems would be established there. Thus came into being the Merrimack Valley Laboratory.

The Indianapolis Laboratory, with similar responsibilities for telephone sets and other products for use on customers' premises, was established in 1956.

The charter for the Merrimack Valley Laboratory was unique among branch laboratories. Never before, in our system development for Bell use, had there been a separation, organization-wise or geographically, between exploratory and preliminary development, on the one hand, and final development for manufacture on the other, although such division of effort had proved to be highly successful in cable, electronic device and military systems work. If it had worked for military systems, what was different about commercial transmission systems?

The military systems in question are almost exclusively in the weaponry class — fire control or guidance. Weaponry requires discrete systems with finite bounds; their interaction with other systems, if it exists, is usually limited. A telephone transmission system, on the other hand, is intimately linked and must be compatible with the entire, enormously complex, telephone plant — as it exists today and as it is likely to evolve in the future. It is assigned its pro rata share of the total allowable transmission impairment between two customers who, in the past, were considered to be possibly 4000 miles apart; now we must think of them as frequently being separated by 8000 miles.

There are other important distinctions between military and commercial systems. First cost of a weapons system is important to the taxpayer, but this cannot be allowed to compromise its reliable performance under extremely rugged environment of handling and climate. Its operating and maintenance features must recognize the limitations of hastily trained people. The function of a transmission or any other commercial telephone system, on the other hand, is both to give service and to earn money. Economic considerations are, therefore, ever present. A commercial system should not be developed until its earning capacity is clear. While it must be designed for simple operation and low maintenance effort, it is usually fair to assume that it will be cared for by career people with adequate training.

A third characteristic of military systems is that their life before technical obsolescence tends to be relatively short. Most telephone systems, by contrast, are designed for a service life of thirty or forty years, or even longer.

Moving the Laboratories group to Merrimack Valley followed the formulation of a plan to prosecute transmission systems development both there and at Murray Hill. Proximity to the Research, Systems Engineering, and Exploratory Device Development Departments indicated assigning the role of exploratory and preliminary development of new systems to the organization remaining at Murray Hill. This is especially desirable for a system in which radically new concepts are involved, since it entails a transition from research to development with appropriate transfer of information on fundamental concepts; the formulation and evolution of system objectives; and the proof of feasibility using new circuit techniques and electronic devices whose introduction to manufacture might be several years in the future. The daily interplay between the people responsible for development of systems and devices at this stage will shape the basic characteristics of each. The preliminary development phase should ideally end when the "brassboard feasibility model" stage of development has been completed.

Emphasis on Costs

In addition to taking stock on a technical plane at this time, it must be clear before proceeding with final development that the new system has an assured economic future. This does not mean that all details have to be settled, but the course from this point on, into manufacture and service, must not be beset with doubts about eventual costs or usefulness. If serious doubts do exist, a longer period of exploration is indicated; on relatively rare occasions the course of wisdom is to change the objectives radically, to postpone further work until fundamental advances in the art come along, or even to drop the development.

When the conditions of successful exploration have been satisfied, the development then moves into the final phase — the role assigned to the branch laboratory. Superficially, the goal is a finished set of drawings and specifications to deliver to Western Electric from which they can manufacture the system. But between the brassboard model and this goal, much exacting work must be done by skillful people. At times, the preceding development work, in effect, merely points the way to further original circuit design. In most cases, the entire job of devising the physical configuration of the system — the "equipment" design — has yet to be conceived and executed. This work usually has to be done concurrently with the final development — at this or some other branch laboratory — of the active and passive devices to be used. Extensive laboratory testing and measurement is required. As a rule, one or more prototypes are built for evaluation, such evaluation being conducted both in the laboratory and under field operating conditions.

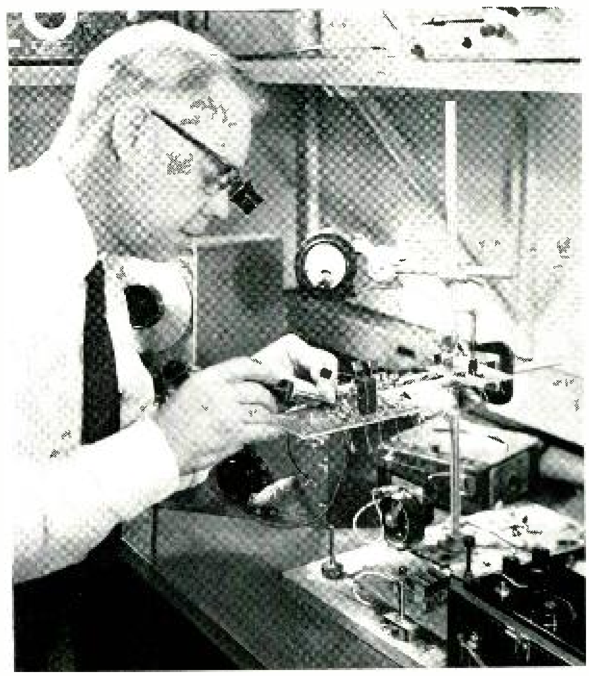
R. Kuntze running a test on equipment for the new TH microwave (6000 megacycles) system.

Ferrite materials are processed in this laboratory. S. Carrubba (left) and W. G. Stieritz are removing a specimen from one of the furnaces.

During this stage of development, there is an added essential ingredient, namely, the closest collaboration between the designers and people in the Western Electric Engineer of Manufacture organization. The latter are skilled in manufacturing processes and limitations; they are the most qualified to predict manufacturing costs; and they know new techniques that might be on the verge of introduction in the factory. They can, therefore, guide the Laboratories engineers to the design choices, among several usually available, that will result in lowest manufacturing costs. At times, the lowest manufacturing cost may not be compatible with other objectives, as, for example, low maintenance over the life of the system. In such instances, the Laboratories designer might decide to forego some first cost advantage. Under basic Bell System philosophy, the Laboratories is responsible for assuring that all systems meet their design intent — a term that embraces a number of objectives, many of them interdependent.

The transfer of development responsibility from the preliminary development group to the people responsible for final development cannot be made abruptly. When the branch laboratory was first established, people who had participated in the early phases of projects were transferred from Murray Hill but, of course, this procedure could not be carried on for long. The usual procedure, working quite successfully, is for the branch group to start picking up the threads of the project a few months to a year and a half before final transfer of responsibility. During this transitional phase, the final development people learn about the new system in great detail and take on responsibility gradually — portion by portion. Thus, at the time the preliminary development people stand aside, the final development group is under a full head of steam.

In addition to a steady stream of new developments, the Laboratories must give a variety of developmental services on older systems that may or may not still be in manufacture. It may be necessary to correct difficulties that do not show up until a system has been in operation for a number of years. Or entirely new features may be required on an older system to accommodate changed conditions in the Operating Telephone Companies. Furthermore, there is a continuous requirement for consultation with Western Electric on all systems in manufacture and a considerable amount of design changes on them, resulting, for example, from proposals by Western for cost reduction, or from changes in sources of supply or unavailability of materials or components. The role of rendering this type of service on most voice frequency, video, carrier and radio transmission systems is assigned to



S. Coleman constructing a miniaturized subassembly for an experimental pocket radio receiver, used in a personal-signaling service.

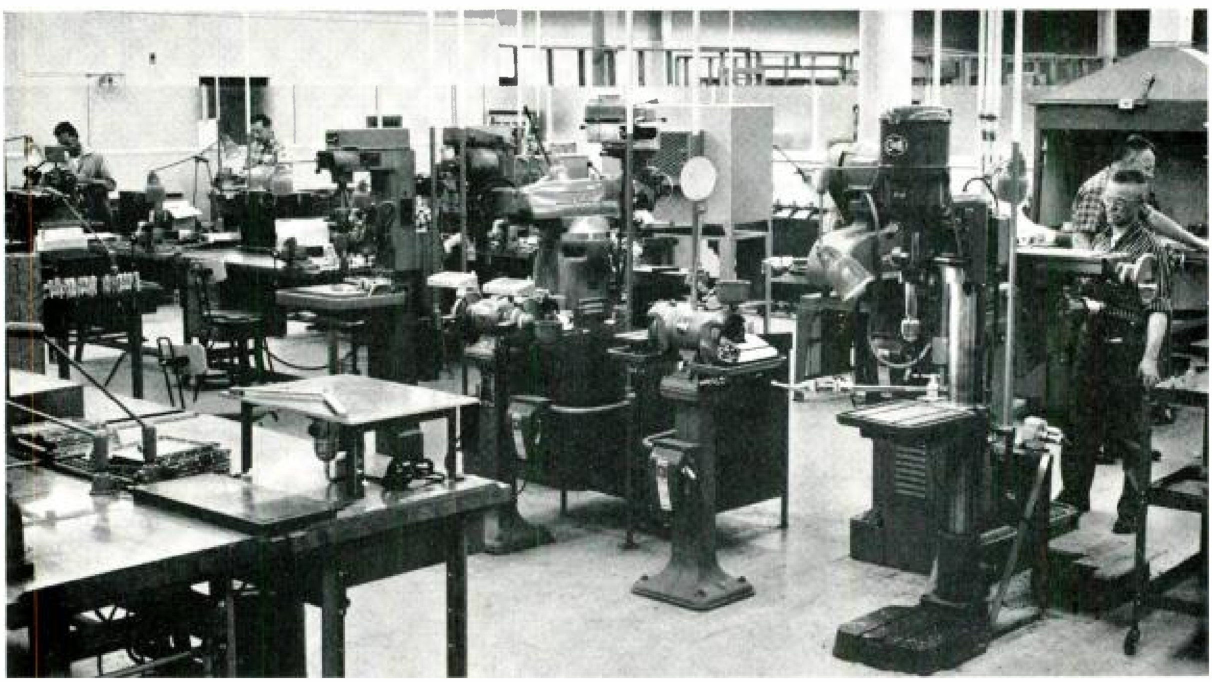
groups at the Merrimack Valley Laboratory.

As previously mentioned, a diverse line of passive components used in the transmission and other systems is manufactured at the Merrimack Valley Works. These include resistors, capacitors, inductors, transformers, microwave ferrite devices and electrical networks. Groups of Laboratories specialists on all of these items are members of the Merrimack Valley Laboratory team. They likewise prosecute final development and collaborate with the systems developers and with their counterparts at Murray Hill concerned with exploratory work on similar items. They also work closely with Western Electric in the manner already described.

Distribution of Projects

As in all well-ordered households, there are exceptions made to the rules of living for practical reasons, without invalidating the broad rules. For example, some systems developments are initiated at Merrimack Valley without benefit of prior exploratory development at Murray Hill. There have been instances where the basic idea has originated at Merrimack and the magnitude or nature of the job did not warrant having the two phases of development carried out by different groups. On the other hand, there have been times when Merrimack was completely loaded with high priority work, requiring the Murray Hill project group to carry the job through some of the final development stages. Other transmission systems development groups deal with products manufactured by Western plants in the New York metropolitan area, in which cases no purpose would be served by moving them to Merrimack Valley.

The establishment of the first systems branch laboratory required a couple of years of intensive planning, some initial experimentation, and learning and evolution from practical experience that will undoubtedly continue as long as the laboratory exists. When the mission was formulated, numbers of people with requisite talents to execute it were estimated. Then, physical facilities were planned. It was promptly agreed that accommodations would duplicate those at Murray Hill as nearly as feasible, and would deviate only when required by the design of Western Electric's office building associated with the factory. While unnecessary duplication of laboratory facilities was to be avoided, the laboratory would be equipped to carry out its mission without the necessity of borrowing from Murray Hill, except in rare instances. The completeness and adequacy of laboratories are



Well equipped model shop is staffed by Western Electric personnel, but serves the Merrimack Valley Laboratory exclusively. Here, many experimental devices and components are fabricated.

attested by the accompanying photographs. Currently, Bell Telephone Laboratories occupies almost 63,000 square feet on the ground and top floors of Western's office building.

In addition to offices and laboratories, there is a model shop with an extensive assortment of light machine tools and facilities for assembly, wiring and the fabrication of experimental quantities of printed wiring boards, ferrite cores and the like. As a matter of principle, whenever feasible, experimental devices and systems assemblies are obtained from Western Electric to give them early experience on things they are likely to manufacture in quantity eventually. In addition to providing supplemental feedback on design for manufacture, Western Electric thereby relieves the Laboratories of peaks in procurement functions and model shop load.

An essential adjunct to a development organization is an adequate technical library. Western Electric has similar needs. At Merrimack Valley, the library is maintained jointly by the Laboratories and Western. It is operated by a professional librarian in an appropriate environment, with quiet reading tables and periodical reference shelves. In addition to some 850 volumes of technical works and 100 periodicals, it has access to all publications held at any of the other locations, and can obtain any of these on short notice.

Western Electric now has large capacity digital computers at all its Works for its varied operational requirements. The one at Merrimack Valley is used extensively by Bell Laboratories on an hourly rental basis — principally for problems in the design of electrical networks and occasionally for systems problems.

Educational Opportunities

Educational opportunities in the vicinity compare favorably with those in the New York Metropolitan area. Harvard, M.I.T., and Northeastern University are accessible to Members of Staff under the Part Time Graduate Study Plan. Newly recruited four-year engineering graduates have attended Northeastern and received Master's degrees under a cooperative plan in which the student attends classes full time for a period and, during alternate periods, works at Merrimack Valley. This plan serves in lieu of the first two years of the Communications Development Training Program at Metropolitan locations; it is supplemented by Bell System Technology courses and by rotational assignments in other Laboratories departments. The University of New Hampshire, about one hour's drive away, offers evening courses counting toward an engineering degree, and a number of Technical Aides are availing themselves of this. Merrimack College, in North Andover, offers a varied selection of liberal arts and some technical courses. In addition to these opportunities in formal education, several out-of-hours courses are given each year by Members of Technical Staff; besides Laboratories people, a number of Western Electric personnel regularly attend these.

The branch laboratory system brings with it manifestations of a problem common in decentralization, namely, communication. For day-to-day communication, mail and parcel service is expedited to the extent feasible. In addition, direct telephone tie lines are provided between the branch and the Metropolitan laboratory having the greatest community of interest, with switched service to other locations. Speakerphone facilities at both Merrimack Valley and Murray Hill facilitate interlocation telephone conferences. Teletypewriter service by way of Western Electric's large switched-message system is also available. Supplementing these methods of communication, travel between locations inevitably increases and is encouraged.

The transfer of the large number of people required to establish the Merrimack Valley Laboratory unavoidably entailed disruption of living arrangements and social and cultural ties for them and their families. It would have been naïve to expect this to occur without complaint. Neither is it surprising that these people have since integrated into the attractive Merrimack Valley community and are taking the active part, characteristic of Laboratories people, in the civic, religious and cultural life of the area.

Some 100 Members of Technical Staff and 100 Technical Aides at Merrimack Valley are employees of Bell Telephone Laboratories. Western Electric employees are made available to the Laboratories on a billing basis for clerical, drafting, model shop and maintenance of laboratory test equipment services. At this writing, these number somewhat more than 100.

While, as observed, the modes of operation and the size of this laboratory will always be in a state of evolution, as is the case for the entire Bell Laboratories, there is no doubt whatever of the value to transmission systems development of the branch laboratory method of operation. In the light of this favorable experience, a new laboratory, with a corresponding mission in switching systems development, will be established at the Columbus, Ohio, Works of the Western Electric Company in mid-1959.

Both telephone and television services show increasing dependence on microwave radio-relay systems. The latest, Bell Telephone Laboratories' TJ Radio System, operates in a frequency band at 11,000 mc to transmit efficiently short-haul telephone, television, SAGE and similar signals.

S. D. Hathaway and H. H. Haas

THE TJ RADIO SYSTEM

Microwave radio-relay systems have assumed an increasingly important role in today's telephone plant. At present, over 15 million (27 per cent) of the long-distance telephone circuit miles and more than 60,000 (78 per cent) of the intercity television circuit miles of the Bell System are provided by microwave radio. Though long-distance circuit mileage as a whole increased 20 per cent from 1955 to 1957, the circuit mileage handled by microwave radio increased 50 per cent. This trend toward relatively greater use of radio is expected to continue.

The greatest use of microwave radio in the Bell System has been in the long-haul plant for large numbers of telephone circuits and for television network service. However, it has also been found economical in many instances for short-haul services and smaller numbers of circuits. It is anticipated that the use of microwave radio in the short-haul field will increase rapidly.

A new microwave radio-relay system has been designed by Bell Telephone Laboratories specifically for short-haul use. This system, now being manufactured by the Western Electric Company, has been designated the TJ Radio System, and it operates in a hitherto unoccupied common-carrier frequency band at about 11,000 mc. Applications of the new system are expected to include telephone message service, SAGE data transmission, and private-line applications—over distances up to 200-300 miles (10 hops) or television transmission up to distances of 100 miles (6 hops). TJ Radio will be used for new routes and to supplement existing open-wire and cable routes to give needed circuit relief and improved reliability by diversification of transmission facilities.

Six Broadband Channels

The TJ Radio System offers a maximum of six two-way broadband channels, each of which is suitable for television or, alternatively, for multichannel telephone transmission. To give a high degree of reliability, only three of these will ordinarily be used as working channels, the remaining three being "protection" channels on a one-for-one basis. These radio signals are transmitted by an RF channelizing and duplexing arrangement with a dual-polarized antenna. It is expected that the majority of the TJ systems will use a "periscope"-type antenna arrangement. For this purpose, a 5-foot paraboloid, a 6 by 8 foot plane reflector, an 8 by 12 foot curved reflector and standard towers have been developed. A 10-foot paraboloid is available as a direct radiator for those applications using natural elevations.

The frequency assignment chart is shown in the first diagram (*next page*). This TJ frequency plan divides the 10,700- to 11,700-mc band into twenty-four channel assignments, each about 40-mc wide. In a given repeater section or "hop," only twelve of these assignments (every other channel) are used to give a spacing of 80 mc between adjacent mid-channel frequencies. These are divided into two groups of six for transmission in the two directions. Also, the polarization of these twelve channels alternates between vertical and horizontal to give a 160-mc separation of the same polarization. Thus, the requirements on the channelizing networks are eased substantially. The remaining twelve channel assignments are used in adjacent repeater sections.

Although there is potential co-channel interference of the "over-reach" type because of repetition of frequency assignments in alternate hops, this possibility is lessened by reversing the polarization in these hops.

Adequate frequency separation between transmitters and receivers at any one repeater station is achieved by "frequency frogging" — that is, the upper half of the band is allocated to transmitters, and the lower half to receivers at a given station, but with allocations inverted at the alternate stations.

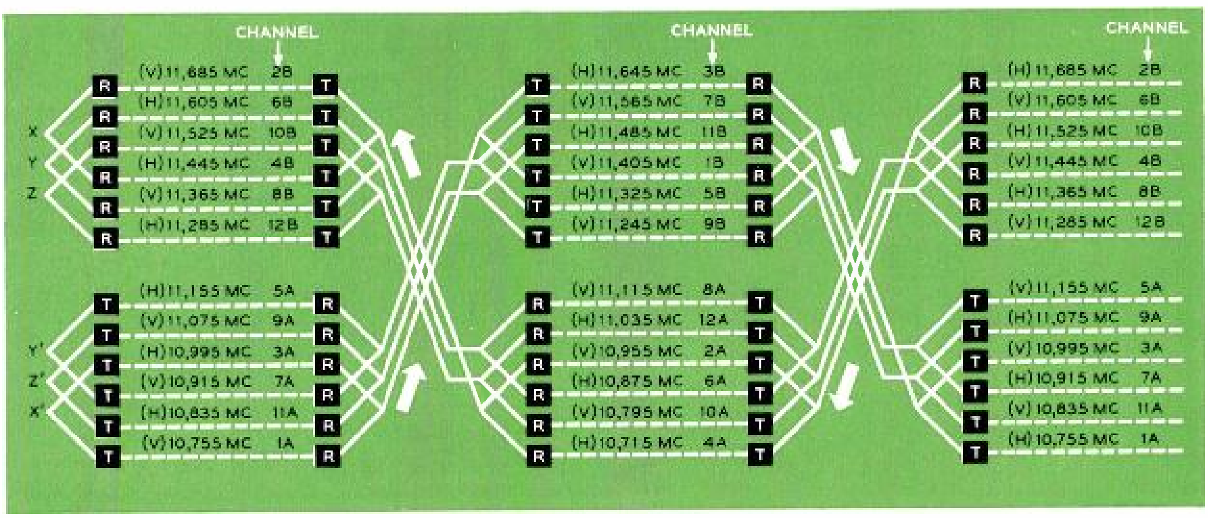
Efficient use of the entire 11,000-mc common-carrier band is permitted by the TJ frequency plan and channelizing arrangement. These features allow for particular applications requiring less than the maximum capabilities of the system by omitting certain channelizing components. An orderly pattern for growth is thus given. Actual route cross sections may range from a single one-way channel carrying a TV signal, without diversity, up to a maximum of three protected two-way channels carrying either TV or telephone circuits. TJ channels will transmit satisfactorily either monochrome or color TV signals.

Basic Element

The basic elements of the TJ system are a transmitter (RECORD, *April*, 1955) and a receiver. In the simplest one-way system, a terminal consists essentially of a transmitter or a receiver, but a repeater is made up of a receiver in which the signal is demodulated to baseband, followed by a transmitter. Access to the baseband signal makes it convenient to drop and reinsert telephone channels at any repeater. The manner in which the basic elements and other elements go together to make up a system will be evident after we trace a representative signal through the system itself.

At a terminal, the video or message baseband input to a transmitter is frequency modulated on an RF carrier, combined with the microwave output of other transmitters of the same polarization by means of channel-combining networks, and carried to a polarizer in a rectangular waveguide. The channels of both polarizations are combined in the polarizer, then conducted in circular waveguide to the antenna system.

At a repeater, all of the RF channels are received on the same antenna. Channels are first separated according to polarization, then by channel frequency, and distributed to the receivers. In



A TJ frequency assignment chart. Basic letter and its prime (XX'), (YY'), (ZZ') constitute a four-wire circuit; transmitters (T) are paired for protection with a split pad, and receivers (R) are paired for protection by a diversity switch. Horizontal (H), vertical (V) polarization are noted.

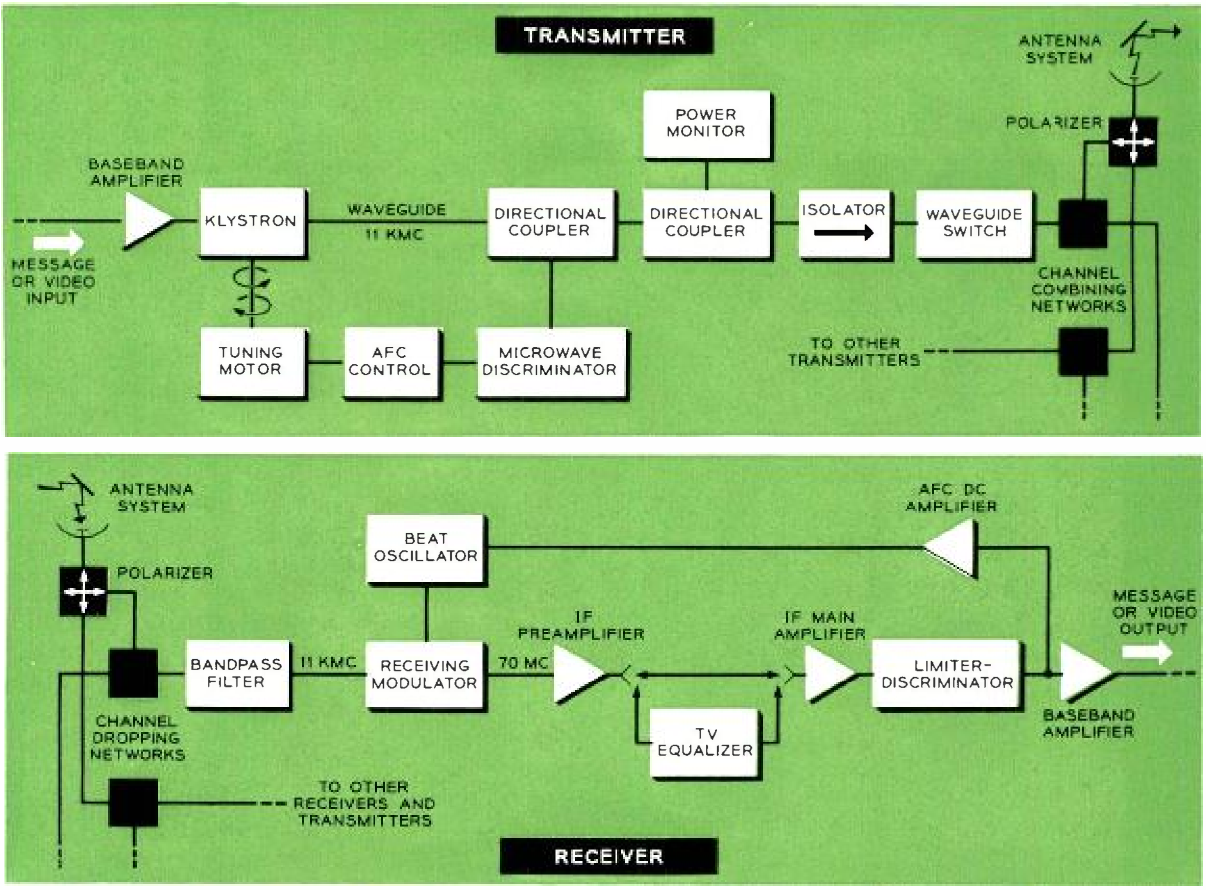


Diagram of the TJ transmitter (top) which accepts baseband signal and supplies a microwave power output of 0.5 watt. For generation and direct frequency modulation of the microwave carrier, a reflex klystron is used. TJ receiver (bottom) shifts microwave signal to 70-mc frequency.

the receiver, we note that the microwave signal is converted to a 70-mc intermediate frequency (IF), amplified, and demodulated to baseband. The baseband signal then passes directly or through intervening diversity switching equipment to the transmitter of the succeeding hop. From this point, the signal paths we have described are repeated until the receiving terminal is reached. Transmission in the opposite direction is identical to that we have traced.

A block diagram of the TJ transmitter and receiver is shown in the second drawing (*above*). The transmitter accepts the baseband signal and gives a microwave power output of nominally 0.5 watt. A reflex klystron is used for the generation and direct frequency modulation of the microwave carrier.

The TJ receiver is a conventional one in which microwave signals from the channel-dropping network are heterodyned, or shifted, to a 70-mc IF signal. Then the IF signal is amplified, passed through a limiter and demodulated to baseband; the modulator employs a balanced converter and a klystron beat-frequency oscillator. An automatic frequency-control loop is then employed to control the oscillator.

For reliability, the TJ Radio System employs dual frequency-diversity transmission. This technique involves transmission of the same intelligence on two channels so separated in frequency that multipath fading on the one channel is essentially independent or uncorrelated with the other. Diversity also insures protection against equipment failures and permits in-service maintenance of equipment without disrupting a working system. For diversity operation, the baseband signal is applied to two transmitters simultaneously; at the receiving end of the link a switching relay selects the better signal from the two channels. Switching is accomplished at baseband frequencies by an inexpensive wire-spring relay (RECORD, *December*, 1958). The configuration of the relay

The guided missile system known as Nike Ajax has been defending our nation for a number of years. Bell Laboratories engineers have played a major role in the development of this significant anti-aircraft weapon.

L. H. Kellogg, *Bell Telephone Laboratories*
P. C. Swan, *Douglas Aircraft Company*

THE NIKE-AJAX MISSILE

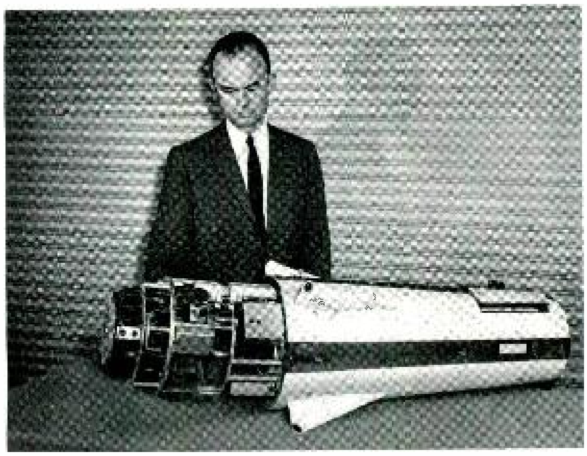
Nike, named after the winged goddess of victory of Greek mythology, is the nation's first air defense guided missile system ready for combat (RECORD, *February*, 1959). The Nike-Ajax system uses a complex of radars and automatic computers to direct a 20-foot supersonic "bullet" to its flying prey. Guidance and control equipment, based on the ground, comprise the center of the intelligence of the system. This intelligence directs the Nike missile to destroy hostile aircraft even though the latter may be at very high altitudes, and may be using evasive tactics.

Before we discuss the missile in detail, it would be well to review the basic operation of the Nike-Ajax system. One of its radars — the acquisition radar — detects the approach of a distant aircraft and furnishes warning and location data on the aircraft to another radar — the target-tracking radar. The latter is a highly precise device that furnishes to a computer a steady flow of accurate data on the position of the hostile aircraft.

The officer in charge of the Nike battery keeps abreast of the course of the engagement by studying automatic plotting boards located inside a radar van. From his analysis of the situation, he chooses the best time to launch the missile. Then a third radar — the missile-tracking radar — begins to track the missile as it proceeds toward the target. This radar also transmits flight instructions to the missile based on predictions by the computer as to where the target will be when the missile arrives. The equipment even recognizes evasive action by the target and changes the course of the missile accordingly. All of these actions occur automatically and, although the hostile target is destroyed well before it can release its bomb, the entire engagement may last less than one minute.

Development of the Nike-Ajax missile is the result of close cooperation among Bell Laboratories, Western Electric, the Douglas Aircraft Company, the Army Ordnance Corps, and many subcontractors. For example, the Laboratories developed system requirements for the missile as well as the electronic equipment required for its brain. The Douglas Aircraft Company designed the missile itself, including the aerodynamic considerations and power-plant requirements. The missile servo system, although conceived by the Laboratories, was developed cooperatively by both the Laboratories and Douglas. The Army Ordnance Corps was responsible for the design of warheads and the booster rocket. Launching and ground handling and support equipment again were the responsibility of Douglas.

Physically, the Nike-Ajax missile is 20 feet long and one foot in diameter, and weighs slightly more than one-half ton. Within its tubular body is the explosive warhead, an electronic brain, an hydraulic servo system, and a rocket engine. Burning liquid fuel, this engine propels the missile with a thrust equivalent to the pulling power of several thousand horses. When a missile takes off, its first few seconds of straight-up flight are powered by a ten-foot booster rocket that burns solid fuel. This booster pushes the missile to supersonic speed. It drops off shortly before the missile turns toward the target and the rocket motor takes over.



L. H. Kellogg with the guidance section of the Nike-Ajax missile. This versatile "brain" of the missile was developed by the Laboratories and was manufactured by Western Electric Company.

Body Construction

The body of the missile is made up of several sections of cylindrical magnesium castings, machined aluminum forgings and fabricated stressed-sheet aluminum that are bolted together. The body obtains its strength from its outer walls; in the aircraft industry this is known as monocoque construction. Two sets of delta-shaped fins — one small set for steering and one large set for stabilizing — are bolted to the body. The arrangement of "small fins forward and large fins aft" on this missile is called a "canard configuration."

Ailerons attached to rear of the large fins control the roll attitude of the missile. Hydraulic "actuators" move the control surfaces for both steering and roll control. As a source of power these actuators use hydraulic oil pressure, which is controlled by valves operated electromagnetically. The valves, in turn, receive their power from electronic servo amplifiers.

The steering servo-loop of the missile is controlled by measuring missile acceleration, and it works in the following manner. A steering order is received from the ground guidance through the missile's receiving and demodulating circuits and appears as an unbalancing voltage to the servo amplifier. When amplified, this unbalance actuates the hydraulic valve, releasing oil to operate the actuators and steering surfaces. As a result of the reaction of the deflected steering surface on the slip stream of air, the missile turns. Devices called accelerometers sense the lateral forces set up by the missile flying in a turn and furnish a balancing voltage to the servo amplifiers. The missile then maintains its turn as long as the ground control system orders it to accelerate.

Restrained gyros feed back a signal, both to prevent the missile from turning too far and to keep the feedback loop of the servo-missile from oscillating. Considerably less than a second after the receipt of a ground command the half-ton, 20-foot long missile is in a turn with its servo system balanced. Less than two watts of servo electrical power are required to control about two horsepower of hydraulic force to accomplish this feat.

A similar electrical-hydraulic servo system controls surfaces on the trailing edge of the large rear fins to stabilize the roll of the missile. The controlling feedback in this servo is a voltage proportional to roll position generated by a gyro having freedom of motion in two directions. Rate-of-roll feedback here also stabilizes the servo. Before the missile is fired, the outer gimbal of the roll-position gyro is rotated by signals from the guidance computer. This pre-sets the missile flight path in the direction of the target.

The flight path of the missile may require it to be steered through air that varies in density from the comparatively dense air at sea level to the very thin air at extreme altitudes. Therefore, the missile may encounter great variations in air pressure of approximately 30 to one. In addition, the missile may be steered at speeds that vary as much as three to one. This means that the amount of "bite" that the control surfaces of the missile obtain on the air, to turn or roll the missile, varies greatly. To compensate for this variation, the gain of the missile servos is adjusted as a function of the ram pressure as sensed by a pressure instrument. Without such compensation, the missile at one extreme would be "lazy" and at the other extreme would be "over active" or oscillate.

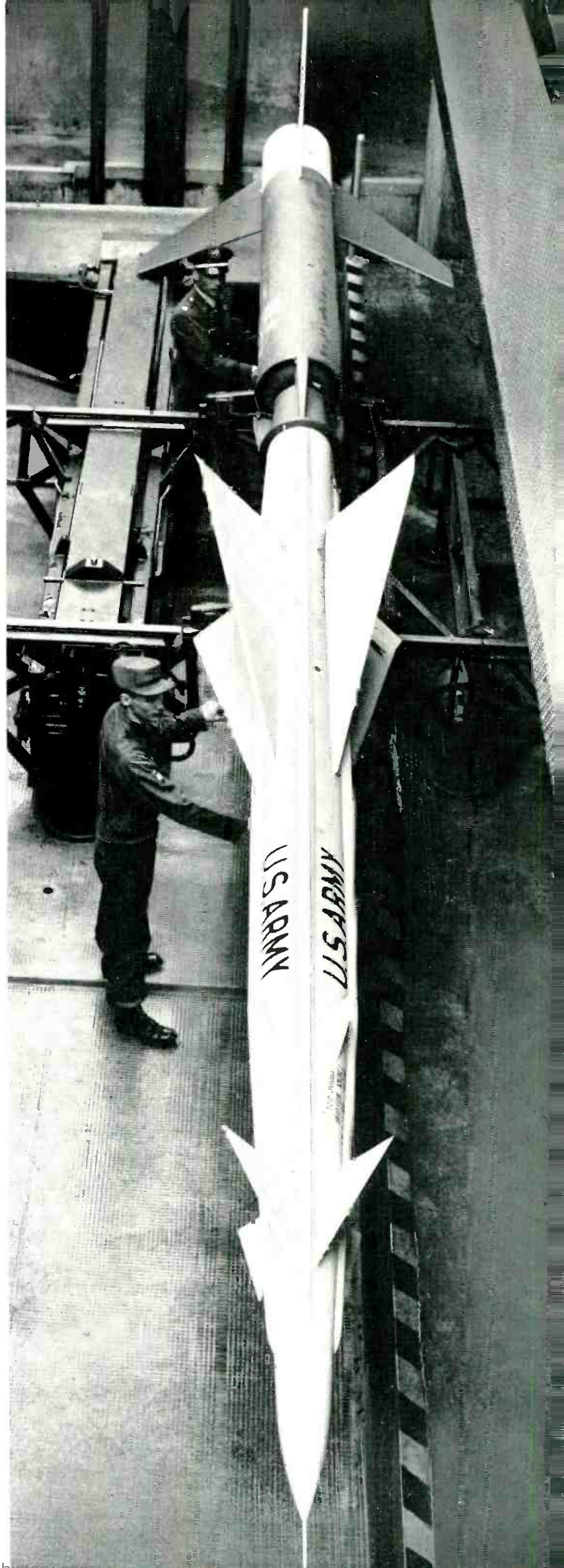
Guidance Transmission

The electronic units of the missile — called the guidance set — is housed in one cylindrical casting to provide a pressure-tight container. Four antennas for communication with ground guidance are located in small, streamlined assemblies attached to the outside of the missile section. These are placed in line with the fins. Two opposing antennas receive; the other two transmit. A hemispherical pattern of coverage ensures adequate contact with the ground regardless of the attitude of the missile at any time during its flight.

The missile-guidance set was developed by the Laboratories and was manufactured by Western Electric. It consists of a pulse receiver, order-command demodulation circuits, a pulsed RF transmitter, servo amplifiers, and associated gyros, accelerometers, and other flight control instruments. The basic power comes from a nickel-cadmium storage battery; subminiature vacuum tubes are used throughout. The rather severe environment of shock and acceleration of missile flight and the very limited space and weight permissible required meticulous mechanical design and simplicity in electrical design to insure high reliability.

The killing power of the missile comes from three warheads located in its fore, middle, and aft sections. These warheads were developed by the Army Ordnance Corps for a high lethality compatible with the accuracy of Nike-Ajax. An efficient high-explosive scatters steel at a very high velocity in a nearly hemispherical pattern to intercept and penetrate a target. The lethality of these warheads has been dramatically demon-

Completely assembled missiles are usually stored in concrete underground cellars. Here, Army personnel are preparing a missile on one of the elevators. Within a few seconds the weapon will be at ground level, elevated and ready for firing.



strated many times in firings against drone aircraft at the White Sands Missile Range in New Mexico.

The engine of the missile consists of a thrust chamber, fed through many small orifices a jet-engine fuel and an oxidizer — red fuming nitric acid. The fuel and oxidizer are under pressure from air accumulators (bottles which contain air under pressure). Combustion is started by the reaction of the oxidizer and a "starting" fluid (Unsymmetrical Dimethyl Hydrazine) which is stored in the fuel line and which precedes the fuel into the combustion chamber. Burning of the jet fuel with nitric acid produces a large volume of gases which escape from the thrust nozzle (a venturi section) of the engine. Well over a ton of thrust is imparted to the missile by this engine although it is so light that it can be lifted easily with one hand.

Designers chose a power plant that uses liquid fuel and has its own oxidizer because of its high efficiency in terms of ratio of its thrust to its total weight. The solid-propellant motors available at that time were much lower in efficiency. A ram-jet engine, which uses the oxygen of the air to burn the fuel, was not chosen because of the lack of oxygen at the extremely high altitude to which Nike may go for its targets.

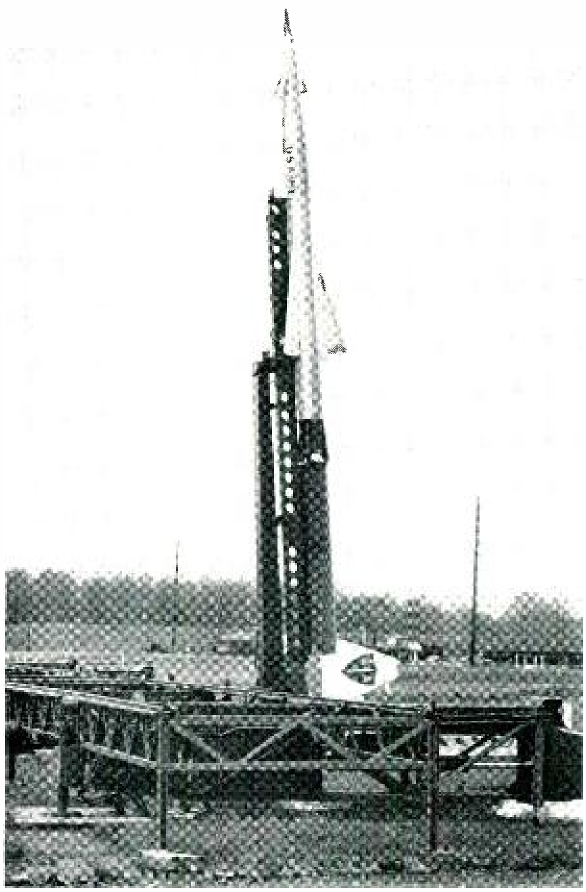
Missile Trajectory

A study was made of the most efficient flight path or trajectory for a missile launched from the ground to reach a remote target aircraft. This study indicated that the missile should accelerate quickly to supersonic speeds into the rarified atmosphere (where air drag is low) and then dive upon the target. This flight path results in the maximum range and payload for a minimum weight of fuel. It differs only slightly from a true ballistic free-fall path flown by an artillery shell. In Nike, the "gun barrel" is the guidance computed from radar information. The impact point is target position, predicted by the computer, at the time the missile will arrive. This predicted point of intercept is continually corrected, of course, as the target deviates from its original course, and the path of the missile is corrected accordingly.

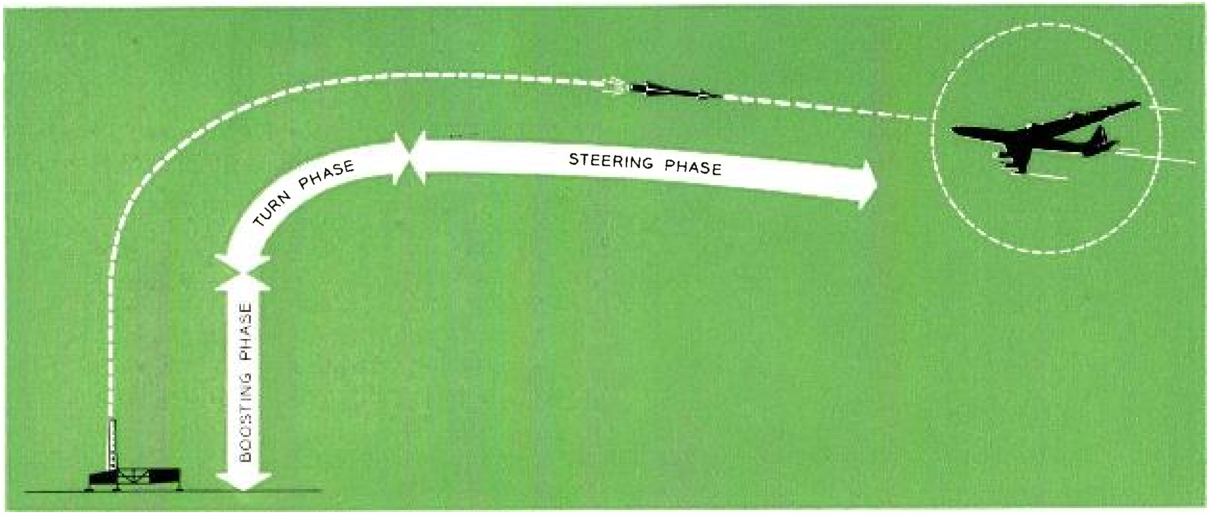
The fast acceleration required to push Nike to supersonic speeds within a very few seconds comes from a booster rocket weighing a little more than the missile itself. This rocket falls free of the missile when its solid fuel is expended. Engineers decided to use solid fuel for the booster because it is easy to handle. The lower efficiency could be tolerated because the booster is dropped from the missile when it has done its job, and does not contribute to the weight and mass of the missile during the major part of the flight.

The missile-booster combination is launched in a near vertical direction to start its "up and over" flight. The relatively large fins on the booster make the combination extremely stable aerodynamically. This ensures a straight flight while the vehicle accelerates, and also ensures a straight "gun barrel" until ground guidance can take over to steer the missile the rest of the way. By itself, the missile is nearly neutral in aerodynamic stability — a condition that makes it easy to steer.

These two conditions of aerodynamic stability might be compared to two categories of aircraft. The booster-missile assembly is highly stable, like a commercial airliner or bomber aircraft. After the booster drops off, however, the missile becomes extremely maneuverable — more so even



Aimed toward the sky, this Nike missile awaits a signal from guidance area to send it on its mission.



The flight path of the Nike missile is in many ways similar to the ballistic trajectory of an artillery shell. The missile is quickly accelerated to supersonic speeds into the rarified atmosphere and then dives on the target. Flight path gives maximum range, payload for minimum weight of fuel.

than the most agile of attacking fighter aircraft.

The hydraulically operated launchers and associated electrical-control equipment serve as berths for the missile held in readiness at the launching site. Electronic and hydraulic test equipment furnish the routine maintenance testing to continuously ensure this readiness.

Missile Logistics

Supporting the Nike missile "farm" is assembly, fueling, and arming equipment. This part of the system is necessary because missiles cannot be shipped about the country or across the oceans with warheads attached and fuel inside. For convenience and safety in shipping, the missile body without its fins is placed and sealed in a shock-proof container at the factory. A Nike base receives its missiles, warheads, fuel, and booster rockets at an assembly area. Here Army personnel assemble the fins and test the missile in an operation called flight simulation. In addition, they "exercise" the electronic brain and hydraulic servo system with a radar and intelligence transmitter simulator. Also, the power-plant's system of pipes and tanks for the fuel and the oxidizer are tested for leakage at this time.

After the missile has passed the assembly area test and inspection, the warheads are installed in the missile and fuel and oxidizer are loaded into its tanks. The air accumulators are then charged with air under high pressure to force these propellants into the missile's motor. The booster rocket is joined to the missile on a rail and the whole assembly travels on a "soft ride" trailer to either a launcher or to a "ready storage" area.

Nike-Hercules, a new big brother to the Nike-Ajax missile, has been designed with the background of Ajax for longer range and high altitude and with an atomic-warhead punch. Hercules systems are now being produced and deployed to furnish an improved level of defense against the ever-increasing capabilities of modern aircraft.

The "one-way" property of certain ferrite structures has been found to be very useful in communications, but to design an actual operating device, considerable attention must be given to the many variables affecting performance. By exploiting an "interference" phenomenon, a Bell Laboratories group has developed an efficient, fast-acting microwave switch.

Jerald A. Weiss

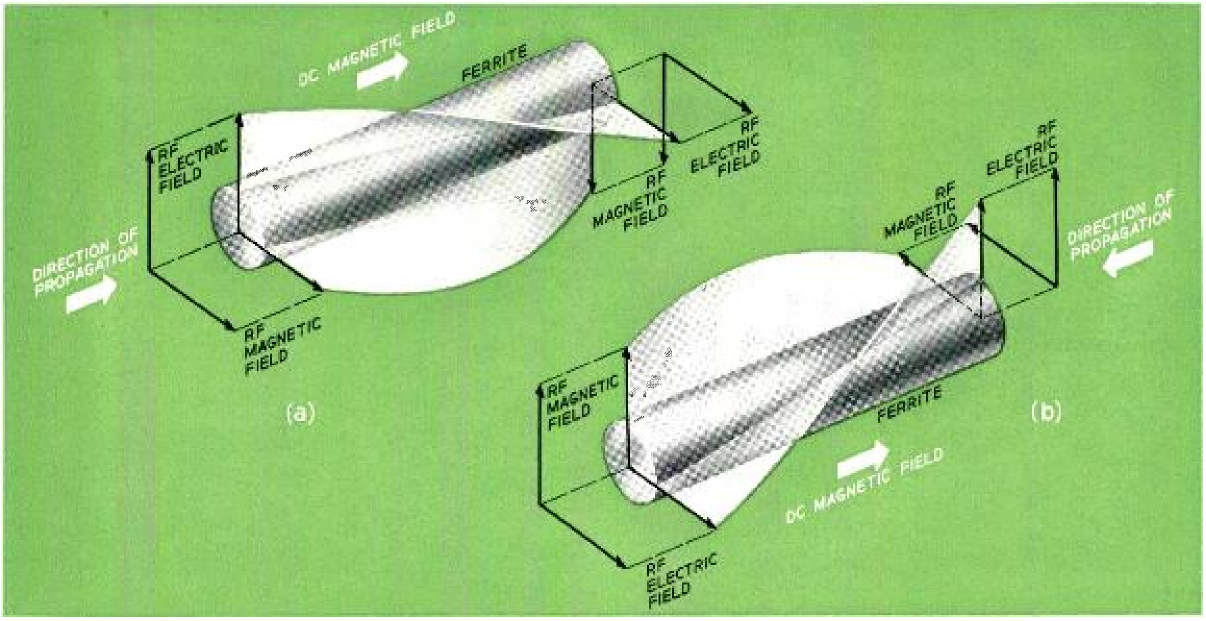
A Faraday Rotation Switch For the TH System

In the past decade, progress in microwave technique has included a number of important advances in the use of nonconducting ferromagnetic substances (ferrites and their chemical relatives) in waveguide structures. As fast as these new devices are promoted from the status of laboratory curiosities and become part of the resources of the microwave engineer, they are being incorporated in the newest commercial and military microwave systems.

One such system, recently developed at Bell Laboratories, is the TH Radio-Relay System (RECORD, *July*, 1957). This system is designed for transcontinental communication service, and it operates in the 5925-6425 mc band. It can provide up to eight broadband (10 mc) and two narrow-band (0.5 mc) channels in each direction of transmission. Among the many innovations incorporated in the TH System is a ferrite-actuated switch, based on the Faraday rotation principle, used in its protection circuits.

The enormous information-handling capacity of this system calls for elaborate protection facilities, since failure of a single component might affect many telephone and television circuits. Among the units which are crucial to the operation of the system are two local oscillators located in each relay station. These generate carrier signals at 6049 and 6301 mc respectively, and failure of either one, if unprotected, would result in a complete failure of all the broadband and auxiliary channels in one direction. Protecting them, therefore, is many times more important than protecting any single microwave channel of the system. For this purpose, a duplicate standby oscillator is installed with each operating oscillator. The standbys are in operation at all times, ready to be switched into the system if an operating oscillator shows evidence of malfunction.

This array of signal generators is joined to the microwave circuit through a switching network, which must have the following characteristics.



The Faraday rotation principle: direction of rotation for an advancing portion of the wave is clockwise, viewed in the direction of the dc field, irrespective of the direction of wave propagation. This nonreciprocal effect has been used for isolators and for circulators, as well as for switches.

Under normal operating conditions, the output of the standby oscillator must pass into a termination and be fully absorbed, while that of the operating unit must proceed through the circuit and into the system with minimum absorption.

The system is equipped with special circuits for detecting loss of power or other difficulties. If these circuits indicate a failure, the switching circuit must interchange the transmission paths of the two oscillators with sufficient speed to cause no interruption of service. The switches themselves must be much less subject to failure than the system they are designed to protect, and they must be capable of operating under a wide range of conditions such as might arise from troubles in the associated equipment.

The circuit which performs this function includes a pair of Faraday rotation switches developed to conform to the special requirements of the system. The optical phenomenon of Faraday rotation has been known for some time (Michael Faraday, 1791-1876). Its association with microwave technology, however, dates from the period about ten years ago with the use of ferrites in microwave devices (RECORD, *October*, 1955).

Since the ferrites interact strongly with microwaves, it is possible to produce large rotation effects using small amounts of materials in practical waveguide structures. To produce a device to fulfill the rather stringent requirements of the TH System, however, it was necessary to solve a number of design problems and to improve our understanding of the consequences of Faraday rotation under the relevant conditions.

To demonstrate the Faraday effect, a linearly polarized wave is made to interact with a specimen of ferrite. The ferrite is magnetized longitudinally — that is, in the direction of the axis along which the wave is traveling. As the wave passes through the ferrite, its direction of polarization is rotated as indicated in the first of the accompanying drawings (*see above*). The total angle of rotation is determined by what fraction of the wave penetrates the ferrite, by the length of the interaction region, and by the magnetic state of the ferrite. The ferrite need only be partially magnetized, in which case the amount of rotation is approximately proportional to the net component of magnetic strength of the material in the direction of propagation. This component can be easily varied by changing the strength of the dc field.

Nonreciprocal Rotation

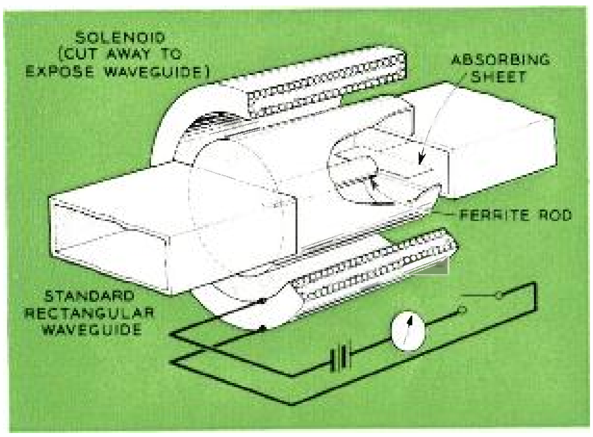
The sense of rotation in the drawing is clockwise as viewed in the direction of the dc field; this sense originates in an intrinsic "gyroscopic" property of the electrons whose spin is responsible for the magnetism of the ferrite. Note that this rule makes no reference to the direction of propagation of the wave. That is, looking in the direction of the dc magnetizing field, we see the polarization turning in the clockwise sense irrespective of whether the wave is traveling away from us or toward us. We describe the consequences of this phenomenon by saying that the Faraday effect is *nonreciprocal.*

We shall see later how the nonreciprocal character of Faraday rotation can be exploited to enhance the effectiveness of the switch. Let us consider first, however, a simple type of switch whose operation does not depend on nonreciprocity, but only on the fact that the presence of the ferrite in the device allows the amount of rotation to be varied magnetically.

Structure of Switch

A section of circular waveguide containing a ferrite rod is connected between sections of a transmission line composed of rectangular guide. Then a longitudinal dc magnetic field is supplied by an external solenoid. This type of structure is shown in the second drawing (*see below*). We adjust the current in the solenoid to produce exactly 90 degrees of Faraday rotation. This switch is in the "on" or transmitting state when the dc field is off and there is no rotation. When the field is applied, the incident radiation is rotated and arrives at the output end oriented at 90 degrees with respect to the polarization for which propagation can take place in the rectangular guide. In this polarization, the radiation interacts with the two broad faces of the guide whose spacing is only half that of the narrow faces. Since this spacing is less than the "cutoff" half-wavelength, the radiation is fully reflected. On the return trip the wave undergoes a further 90 degrees rotation, so that it arrives at the input end so polarized as to be freely transmitted into the input guide. Thus, in the "off" or non-transmitting state, the switch reflects.

R. W. Judkins inspecting a rotation switch in the laboratory. The Faraday "one-way" transmission property of ferrites in a dc magnetic field permits the desired type of on-off operation.



A simplified representation of a Faraday-rotation switch. Solenoid supplies the dc magnetic field to produce 90 degrees of rotation; a sheet of absorbing material suppresses the reflections.

For many applications the presence of this reflected radiation is objectionable. It can be suppressed by inserting a properly oriented sheet of absorbing material, as shown in the right-hand part of the drawing on this page.

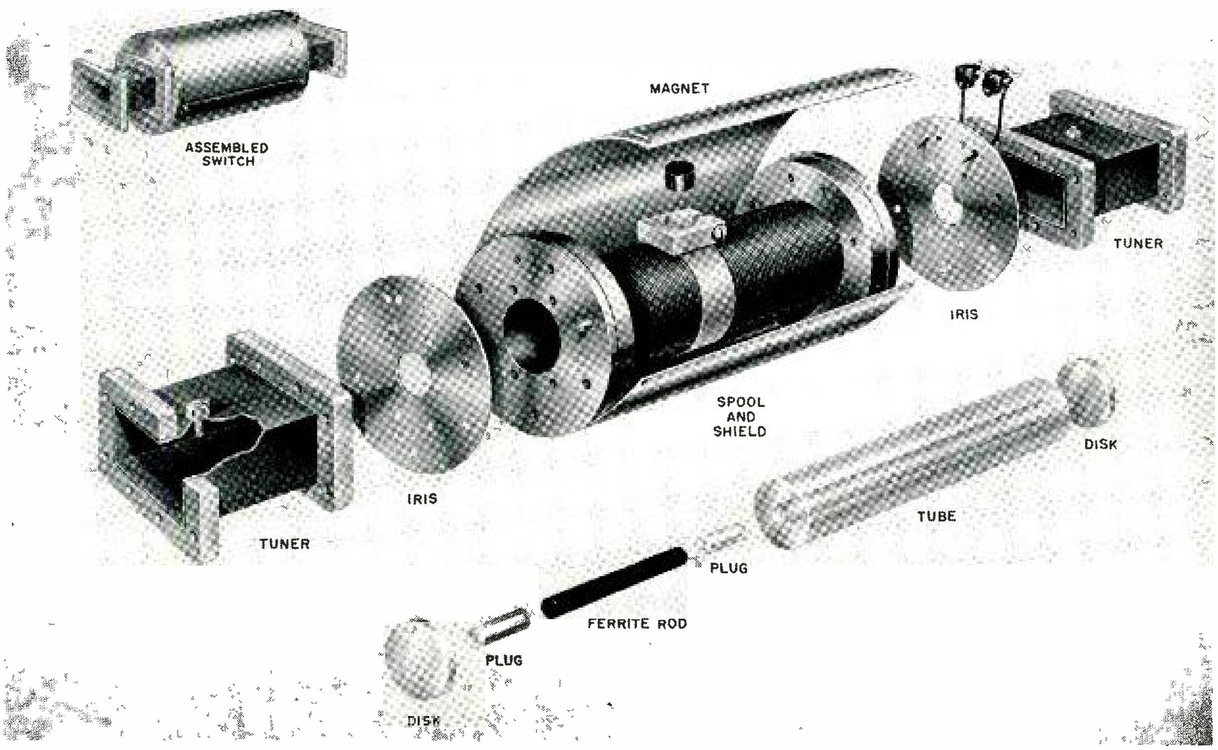
The device in this drawing clearly demonstrates the principle of the Faraday rotation switch, but it has several weaknesses which limit its usefulness as a practical circuit component. Two of the most serious limitations are the following. First, the angle of rotation is required to be extremely close to 90 degrees for the "off" state, which means that the current supply to the solenoid must be very accurately controlled. Even if the structure were perfect in every other respect, a departure of only 4 degrees would destroy the "off" state. Second, the circular waveguide and ferrite assembly must be cylindrically symmetrical to within very close tolerances. Even a small degree of ellipticity seriously degrades the maximum obtainable reduction in transmission by causing an elliptically-polarized component of radiation to be excited. This symmetry requirement imposes severe restrictions on the mechanical design, especially if an unsymmetrical absorbing sheet is included in the structure.

Interference Effect

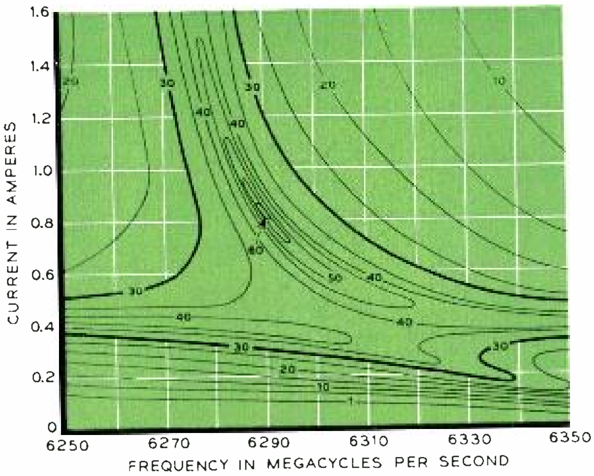
On looking more closely into the details of the Faraday effect as it is manifested in this structure, we find that the nonreciprocal rotation of reflected waves produces an added effect which enables us to cure these and other ills. The additional effect in question is an interference phenomenon present whenever there is *any* amount of rotation, not just 90 degrees. It occurs only in a structure which is essentially free of dissipative materials. For this reason, the element that absorbs the radiation reflected from the switch in the "off" state must not be located inside the rotator structure.

The interference effect alters the behavior of the switch in the following ways: first, in a range of frequencies determined by certain mechanical features of the device, chiefly its length, the switch goes abruptly into the "off" state at values of rotation much smaller than 90 degrees (20 degrees is typical). Also, it remains "off" over a wide range of rotations, thus relieving the stringent requirement on the strength of the dc field. Furthermore, the phenomenon makes the effectiveness of the switch depend essentially on the dissipative properties of the ferrite and not on the mechanical precision of the circular structure.

To see why the interference effect occurs, we may compare the nonreciprocal Faraday rotator with a simple *reciprocal* device which produces rotation of the polarization of the wave. Radiation entering a reciprocal structure and arriving, rotated, at the output end, is resolved into two components. One of these is so polarized as to continue freely into the rectangular guide at that end, but the remainder of the radiation is reflected and rotates *back again* to its original orientation. It arrives at the input end in exactly



Component parts of the actual Faraday-rotation switch designed for the new TH microwave radio system. Unit switches rapidly between operating and standby oscillators to prevent loss of service.



"Map" showing contour lines of insertion loss in db. The line for 30db—transmission of 0.1 per cent of incident power—represents "off" boundary.

the same polarization with which it started. Such a device cannot cause full reflection of the incident wave unless it rotates the wave exactly 90 degrees in a single traversal.

Repeated Reflections

Rotation caused by the Faraday effect, on the other hand, is controlled by the "gyroscopic" property of the ferrite and is independent of the direction of propagation. The radiation reflected on arrival at the output end undergoes *further* rotation on its return trip, so that it returns to the input end oriented at a new angle with respect to the input waveguide. Thus, it is again resolved into two portions, of which one undergoes a second forward traversal of the structure. This process is repeated endlessly, with the wave contributing part of its energy to the over-all transmission or to the over-all reflection at the end of each traversal.

How these contributions combine at each end depends on their relative phases, which in turn are determined by the length of the cylindrical section, measured in units of wavelength. Over certain ranges of frequencies, they superpose in such a way as to produce destructive interference at the output end. That is, the algebraic sum of amplitudes of all the contributing waves is exactly zero, or nearly so; there is no net transmission and the switch is "off."

In this circumstance, the interference at the input end must be constructive; thus, aside from the small amount of energy absorbed by the ferrite, all radiation not transmitted appears as a reflection. Except for certain differences in details, the effect takes place equally well in waveguide of elliptical (or rectangular) cross-section as in circular, provided the ellipticity does not exceed certain very broad limits.

Completed Switch

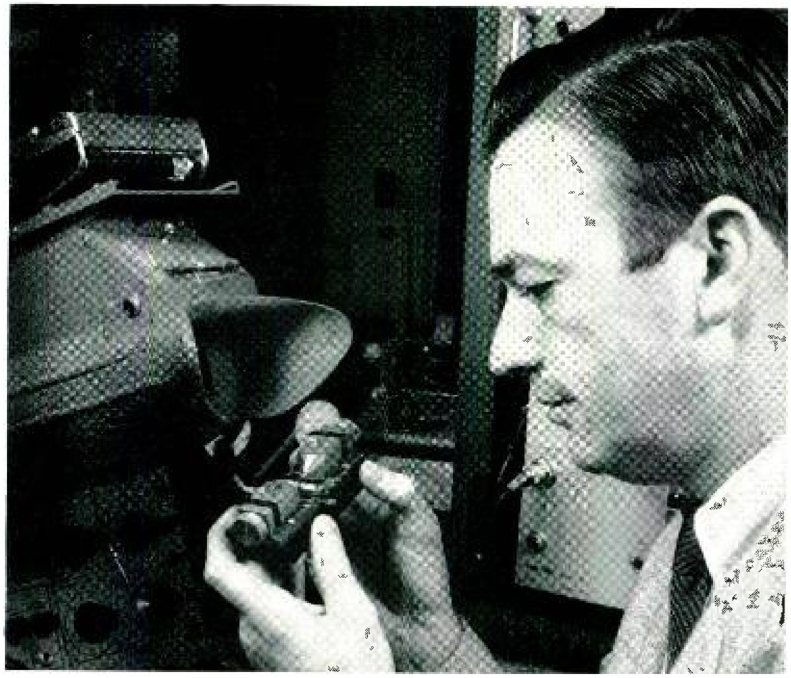
The switch was designed so as to exploit this interference effect and to compensate for a number of lesser phenomena relating to the details of the radiation field configuration and of the magnetic characteristics of the ferrite. Such a model is shown in the exploded view seen on the previous page. In addition to the basic components, it is adorned with irises, tuning screws, a small permanent magnet, shield, and dielectric tubes, each of which plays a contributing role.

There is a convenient way to display the transmission of the switch over a range of frequencies and of applied dc field values. This method takes the form of a map constructed by joining all the points for which the insertion loss (defined as the fraction of incident power transmitted expressed in decibels) has a specified value. The result is an array of contour lines.

The final illustration with this article (*on this page*) is an example of such a map, on which the region of highest insertion loss represents the "off" state. The contour line for an insertion loss of 30 db is accentuated because this value, representing the transmission of 0.1 per cent of the incident power, is our criterion for the "off" state of the switch. The narrow region of high insertion loss — extending horizontally to the edges of the map — occurs where the Faraday rotation passes through 90 degrees, while the extensions of this region to lower and higher values of current (that is, of dc field) are produced by the interference effect.

The development of the Faraday rotation switch has led to a device which fulfills a specific need in the TH System. Beyond this, it illustrates again the axiom that a fresh approach to an old and venerable physical phenomenon, supported by new technology and new application requirements, can often reveal novel and unexpected properties.

Polarization Reversal in Barium Titanate



Robert C. Miller views barium titanate in liquid electrode holder.

Research physicists at Bell Laboratories have recently found a new way for ferroelectric polarization to reverse in a single crystal of barium titanate. The reversal takes place through extensive sidewise motion of "domain" walls. This research has been described in a paper prepared by Robert C. Miller of the Solid-State Electronics Research Department and read by P. W. Anderson of the Physical Research Department to the Conference on the Physics of Dielectrics held in Moscow. The paper was one of the first of foreign origin to be delivered to this body.

Ferroelectric Crystal

Barium titanate is one of a number of crystals whose electrical properties are described as "ferroelectric." These crystals possess regions of uniform electric polarization called "domains," resulting from the alignment of electric dipoles. Their properties are somewhat analogous to ferromagnetic crystals in which magnetic domains arise from the alignment of magnetic dipoles. Ferroelectric and ferromagnetic materials can be used in switching systems as storage or memory devices.

Mr. Miller's experiments showed for the first time that domain expansion takes place by the extensive sidewise motion of the domain boundaries occurring between adjacent domains of opposite polarization. These boundaries, called 180 degree domain walls, move perpendicular to the direction of polarization in the ferroelectric domains.

To carry out the experiment, physicists applied liquid electrodes to the crystal. The electrodes consist of a saturated aqueous solution of lithium chloride held against opposite sides of the crystal by two silver rods. Each rod has a small hole drilled in one end to contain the liquid.

To ascertain the structure of the domain, the researchers removed partially reversed or "switched" crystals from the apparatus and etched them for a short time in weak hydrofluoric acid. Positive dipole ends of the domains etch more rapidly than the negative dipole ends, so it is possible to observe the domain structure visually after the etch. The physicists noted with special interest the size and number of reversed domains. They had expected a large number of reversed domains. Instead, they observed, in numerous cases, a single reversed domain comparable in size to the total area of the electrode.

Many of the reversed domains appeared to "nucleate," or originate, at relatively large imperfections in the crystal. Mr. Miller took advantage of this phenomenon and succeeded in "manufacturing" nucleation sites. The technique consists in sandblasting a "dimple" to a depth of about one-third the thickness of the crystal and to a diameter about one-fourth that of the electroded area.

Controlled Nucleation

A crystal so treated will generally nucleate preferentially in the dimpled area. This is because the dimpled area is a region of high field compared to the surrounding area. In other words, the lines of force tend to bunch up where the crystal is thinnest. Once a nucleation has occurred, the domain grows out from the dimple through the sidewise motion of the 180 degree walls until the entire electroded area is switched.

Successive etching of partially switched crystals prepared in this fashion has shown that the growing single domain is roughly square in shape, and under the conditions described, expands in increasing concentric squares.

A major responsibility of the Bell System is the safeguarding of telephone customers from electric shock and fire hazards. This is achieved by the use of protective devices throughout the telephone plant. Recently, Bell Laboratories has developed, for open-wire lines, an improved protector to limit voltages that may arise from accidental contact with electric power wires.

A. E. Dietz and J. B. Hays

A New Protector for Telephone Lines

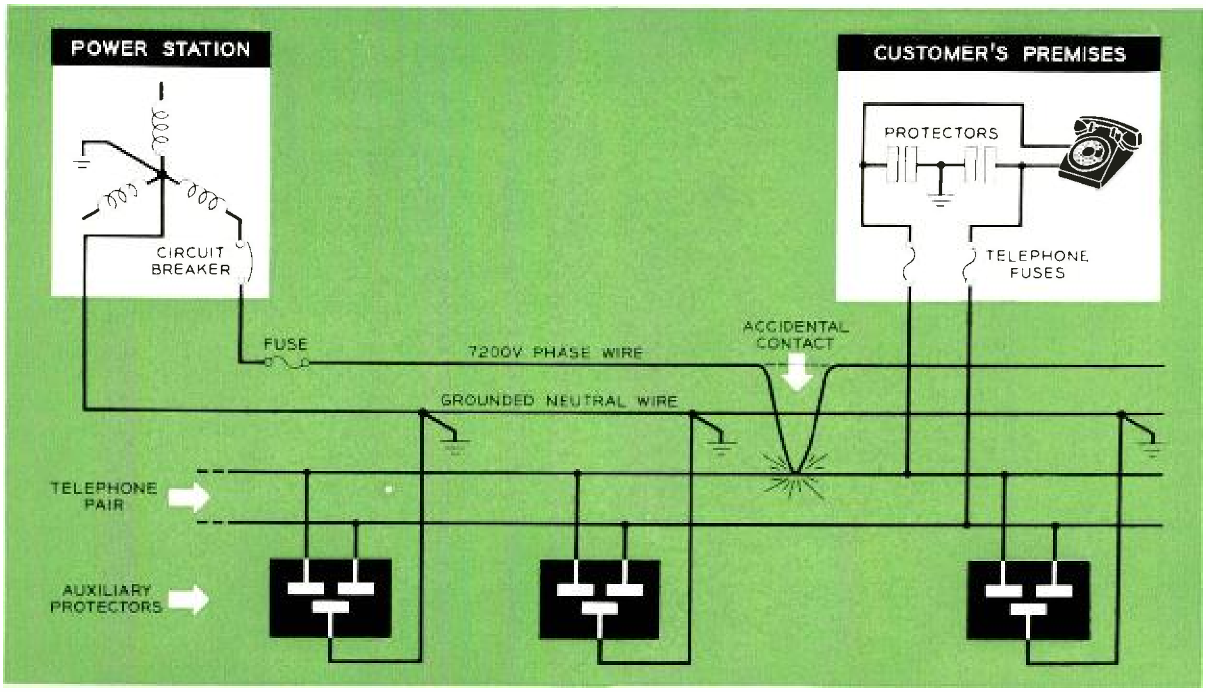
In areas where the number of telephone customers is relatively small, service is often carried to them on open-wire lines. Furthermore, for reasons both economical and practical, these wires are often carried by the same poles used to support electric power lines. This situation illustrates an important concept in safety — the need to keep the telephone and power wires from touching each other.

The likelihood of any contact between these lines has been reduced by high standards of construction, which have done much to provide a good safety record. There are other hazards, however, that are not so readily controlled. These include lightning storms and hurricanes and automobiles in collision with poles. Such situations call for additional safety devices as a necessary safeguard, even though they may rarely, if ever, be called upon to function.

The most recent of these safety devices is an improved version of an existing protector that operates on the telephone line. But before we can appreciate the significance of this development, it would be well to review the basic problem of electrical protection for customers' equipment.

The station protector at the entrance to a customer's premises acts as a final barrier against the build-up of voltage on the telephone set and its wiring. The principal element of this unit is a 0.003-inch air gap between two carbon electrodes (RECORD, *August*, 1956). A pair of electrodes is connected between each of the two line wires and ground at the telephone station. Excessive voltage between either line and ground causes an arc to form across the gap, furnishing a path to ground for excessive currents. This protector takes care of the majority of abnormal conditions — discharges which are either short in duration or relatively low in current magnitude.

There are cases, however, where a long-sustained fault current results from contact between an open-wire telephone line and a power line. In these cases, the station protector has a fuse that opens the circuit before the protector can become overheated. It would be impractical, however, to design a fuse to function properly at all conceivable voltages to which the telephone line might be exposed, and still keep its size and cost within



Protection measures on telephone and power lines. Accidental contact between power line and one of the open-wire lines causes current to travel along the latter. By conducting current to ground, the protector reduces voltage at the customer's premises, permitting the fuse to open the line circuit.

reasonable limits. Thus, this fuse has a maximum rating of 3000 volts. Other protection measures are therefore necessary to take care of situations where this rating is exceeded.

One of these measures is the use of auxiliary, or "back-up" protectors. These are located on the telephone poles at one-half mile intervals along the open-wire line. They are designed to by-pass the station protector entirely when an accidental voltage exceeds the fuse rating at the station protector. In so doing, they furnish a low-impedance path to ground for the fault current of the power system, and thus reduce to a safe value the voltage impressed on the telephone line. Furthermore, this protector ensures a circuit to ground for the operating current of the circuit breakers in the power system.

The high-voltage protector on the telephone line, like that at the station, consists of an air gap between carbon electrodes. This unit, however, has a spacing such that it will arc below 3000 volts, which is within the voltage rating of the fuse. Furthermore, it has heavier electrodes and connecting wires to permit it to carry more current.

The auxiliary protector operates in the following manner. If a high voltage from a power line should appear on the telephone line, the station protector will begin conducting current to ground. If this current is large enough, the fuse will attempt to open the circuit. It will not be able to do this, however, if the open-circuit power voltage exceeds the fuse rating. In that case, as the fuse attempts to open the circuit, enough voltage will appear on the telephone line to cause the auxiliary protector to start conducting current. This will reduce the voltage on the telephone circuit to a value within the rating of the fuse, permitting it to open the telephone circuit to the station.

Re-Evaluation Program

In recent years, the growth in capacity of electric power circuits created situations where the standard auxiliary protector was not adequate. For this reason, an extensive program was undertaken to re-evaluate the requirements of the protector and to design and test a new protector for higher current-carrying capacity.

Specific objectives of the test program included re-evaluation of the older protector over an extended current stage, and evaluation of the effect of the increase in resistance of the line wire due to heating under conditions of heavy fault current. This latter evaluation brought forth a new concept of coordinated protection of power and telephone lines.

As load currents in power lines grow, and as the rating of the high-voltage protector is correspondingly increased, there is one element in the circuit whose parameters remain fixed — namely, the telephone-line wire. While power wires can handle larger fault currents with negligible change in resistance due to heating, this is not necessarily true of the telephone wire in the fault circuit. Furthermore, the effect is aggravated because power systems designed for heavy loads necessarily have a lower impedance. This means that the telephone wire becomes a larger percentage of the total impedance that determines fault currents. And any progressive change in the resistance of the wire will cause the fault current to vary with time.

Because the fault current varies with time, we do not have a simple procedure for calculating the magnitude of the fault current and determining the proper location of protectors. Additional calculation difficulties arise because the heating characteristics of wire depend on the history of the changing current, as do the operating characteristics of the circuit breaker and fuse on the power line with respect to time. In other words, they depend on the cumulative energy delivered to the wire and the power-interrupting device. Unfortunately, present data on these characteristics are for constant, not changing currents.

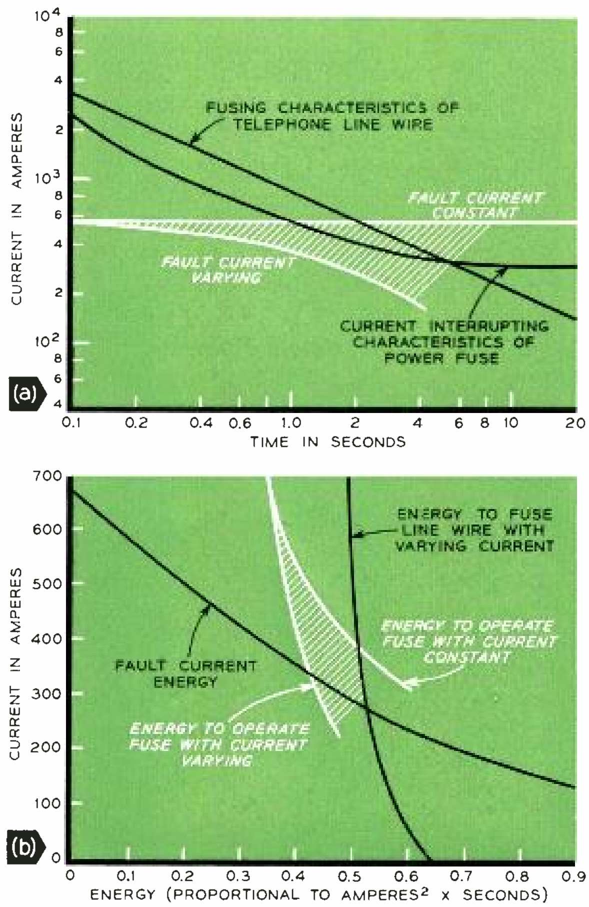
Graphic Data

These difficulties can be appreciated by examining the curve of changing current for a specific situation shown as the dashed line in part (a) of the illustration at the right. Here, the initial current is nearly 700 amperes. After 0.16 second, the wire has heated; this changes the resistance by 25 per cent. Recalculation at this time thus yields a new value for the current, and successive calculations result in the curve of dynamic current. Basically, these plots are made to see whether the current will operate the power-interrupting device and if so, whether the current will operate the device before it reaches a value that can fuse the wires or damage the protector. In this particular curve the power-interruption device would not be operated. In addition, tests were made to determine that the protector would not be damaged before the wire fuses.

In a sense, a contest exists between the fusing of the wire and the operation of the power interrupting device. The curves in part (a) of the figure showing these characteristics are correct, however, only for constant fault current since constant-current tests determine the fuse and line-wire characteristics.

By another graphical maneuver, we can convert the time scale to an energy scale and replot the curves to show cumulative energy. When this is done, as in part (b) of the illustration, we see that the dynamic curve of energy delivered (the black diagonal line) by the varying fault correct intersects the power-fuse boundary before it reaches the wire-fusing boundary; thus, the fuse will operate first. If this were not the case, it would be necessary to reduce the spacing of the protectors along the telephone line so that there would be a smaller length of telephone line in the fault-current path, and thus less change in the current with time.

These graphical calculations were extremely helpful in developing a new device for auxiliary protection on telephone lines. The new device, called the 118A Protector, differs mainly from



Typical graphic methods that determine what value of fault current will operate power-interrupting device. Fuse and line-wire characteristics are related to (a) fault current, and (b) energy.

the former device in the shape of its electrodes. The new electrodes, spaced 0.02 inch apart, have flat, rather than cylindrical arcing surfaces. This allows the arc to take place over a very large area. An increase in arcing area results in less erosion of the electrode material, and consequently in a smaller increase in the breakdown voltage on sustained faults.

Another major improvement appearing in the 118A is the method by which the electrodes are fastened. One-piece terminals connect the electrodes to their lead-out wires in the protector and also clamp the electrodes in place. The lead-out wires are crimped in the terminal, and the electrodes are fastened with a nut. These features eliminate the points of greatest heating in previously available protectors. In fact, the current-carrying capacity of the new protector is greater than the capacity of the commonly used steel or copper-steel telephone line wires.

During tests on the new protector, observations indicated that the arc would remain between the electrodes for appreciable lengths of time before jumping to the metal fastenings. Excessive currents will damage the protector, which will then require replacement to restore telephone service. Until then, however, it will provide protection from subsequent voltages appearing on the line. Currents at or below the critical damage point — where arcing occurs between the metal parts — have only a small effect on the life of the protector. Therefore it will withstand a larger number of such operations before it must be replaced.

J. B. Hays checks spacing of carbon blocks on the 118A protector. Gap of 0.02 inch arcs at 2000 volts.

Bell System earnings were $14.01 a share of American Telephone and Telegraph Company stock in 1958, A.T.&T. President Frederick R. Kappel said in the annual report, released February 17. The earnings were on 67,982,000 average shares outstanding, an increase of 4,171,000 from the average in the previous year.

"Earnings improved last year for a number of reasons," Mr. Kappel said. "We were able to increase the efficiency of operations. The services and instruments we provide are increasingly attractive and they have been vigorously sold. Some of the telephone companies obtained much needed increases in rates. The sustained and broadening sales effort of thousands of Bell System employees was a key factor in enabling us to meet the problems of recession," he continued. "We had many improvements to offer. We sold them hard.

The Bell System spent $2.2 billion for construction in 1958. Expenditures of this magnitude are expected to continue, Mr. Kappel said. "Relating all the equipment to all the service," he went on, "our capital investment is about two and one-half times our annual revenue. As we continue to grow, we shall need more and more physical plant and large additional amounts of capital."

To widen the market for

H. G. O'Kean, J. R. Logie, Jr., and J. L. Murray of the Laboratories Missile Systems Development Department examine new electronics setup for the Nike Hercules in missile-system laboratory.

A.T.&T. REPORTS 1958 PROGRESS

A.T.&T. stock, he noted, the Board of Directors announced in December that it would propose a three-for-one stock split at the annual meeting of share owners in April.

Mr. Kappel said that the improvement in earnings accomplished in recent years has been necessary to keep facilities and service growing and to support the research that is vital to the future. In some areas, however, he said, low earnings still hamper the companies' ability to serve. The companies concerned are therefore continuing every effort to improve the earnings.

Taxes equal to $3.18 per telephone per month (on the average) were paid on Bell System service last year, the report said. The total was $2,033,000,000, including $550,000,000 in federal excise taxes paid directly by telephone users.

The A.T.&T. report pointed out these gains in service:

- The Bell System added nearly 2,500,000 telephones in 1958, to bring the total in service to some 54,700,000.
- Long distance conversations rose about five per cent.
- Long distance dialing has increased, and telephone users now dial one out of five calls straight through to the distant telephone.
- Overseas conversations increased 11 per cent last year. Service is now available to 125 countries and territories.

The market for world-wide telephone communication is growing, Mr. Kappel said. A second transatlantic cable will be laid this summer. A cable to Puerto Rico will go into service early next year.

Research and Development

Bell System research and development work last year was on a larger scale than ever before, Mr. Kappel said. The work included improved radio-relay systems, cables, switching equipment for telephone central offices, and other changes unseen by the public.

The report describes several instances of current progress. "The telephone system uses hundreds of thousands of amplifiers on so-called 'exchange trunks' between central offices. It also maintains any number of automatic power plants to assure dependable service in emergencies. We are now introducing new transistorized amplifiers to further improve transmission on the exchange trunks, and other new 'solid state' devices to improve the power plants. These are indicative of the kind of change that goes on all the time.

"Western Electric has started to build equipment for the first public trial of a fully electronic telephone switching system now under development at Bell Laboratories. The trial is planned for 1960 at Morris, Illinois. It will offer a glimpse of the future and we believe will profoundly influence the whole course of communications."

Mr. Kappel also stated that "Today our long distance lines carry many kinds of communications, voice, pictures, data, TV, control and metering signals, and so on. Moreover, millions of people can dial long distance calls without operator assistance. These things mean that, more than ever, our circuits must *always* be first-rate. We are therefore studying our network with great care to make sure that every part is in top condition. Bell Laboratories is developing automatic test gear and additional regulating devices for this purpose. . . .

TASI System

"Western Electric has begun manufacture of the first TASI (Time Assignment Speech Interpolation) system developed at Bell Laboratories (RECORD, *March*, 1959). This will be ready for service between the United States and England next year. TASI increases the capacity of ocean cables by automatically assigning voice channels to talkers in the intervals when other people are listening or pausing; at the same time each conversation remains completely private."

Last year the Bell System made the first installations of a microwave relay system designed especially for short routes (see p. 129).

Telephone research and technology are also at work for the country's defense in many ways, the A.T.&T. report emphasized. The Bell System has built a new network of telephone routes that bypass critical areas to insure that essential communications will be maintained in case of disaster.

Bell Laboratories has over-all responsibility for the design of Nike missile systems and is now designing a new anti-missile missile, Nike Zeus. As explained by the report, "the task of Nike Zeus is to discover, track, intercept, and destroy — all in a few minutes' time — oncoming ballistic missiles traveling at more than 15,000 miles an hour.

"A Laboratories-developed guidance system for the Titan ICBM is under test at Cape Canaveral."

Western Electric and Bell Laboratories are also working on communications for a new Ballistic Missile Early Warning System now under construction in the far north.

W.E. Co. Report Cites Cost-Reduction Effort

The Western Electric Company reported sales in 1958 of $2,173,827,000, down $306,787,000 or 12.4 per cent from the previous year. Seventy per cent or $1,527,912,000 of 1958 sales were to Bell System companies. Sales to the Government, consisting principally of products and services associated with national defense projects, were $578,961,000 — slightly higher than in 1957.

In the annual report to stockholders issued February 24, Arthur B. Goetze, President of the company until his recent death, declared the vigorous expense control and intensification of cost-reduction efforts during the year enabled the company to minimize the effects on operating profits of the downturn in business volume. He cited as an example annual savings of more than $10,000,000 at current production levels through manufacturing cost-reduction projects completed during the year.

Earnings in 1958 were $85,936,000 or $5.17 a share compared with 1957 earnings of $84,608,000 or $5.66 on a smaller average number of shares then outstanding. Plant investment increased by $124,241,000 over 1957 to a total of $860,581,000 at year's end after write-off of facilities retired from service.

Noting that 1958 earnings represented a lower return on investment, Mr. Goetze said, "This points up one of the major problems facing most businesses today. When we have occasion to replace a machine or plant facility that has worn out, we generally wind up with more dollars invested in the business, even though our productive capacity remains relatively unchanged. This comes about, of course, because the machine we buy today costs so much more than the one it replaced that we bought years ago." He cited recent figures showing that current replacement costs are running three times the original cost for machinery.

Purchases from other firms of manufactured goods, raw materials and services totaled more than a billion dollars in 1958, equal to about 46 cents of every dollar Western Electric received. Payments went to over 30,000 companies, in all the states and several foreign countries. Nine out of ten supplier firms were small businesses with fewer than 500 employees.

In 1958, Western Electric continued its work on major projects for national defense. In June, the Nike Hercules missile became operational in three important defense areas. Additional funds were authorized by the Army for the development of Nike Zeus.

The company continued to coordinate the work of many contractors in the development and construction of the SAGE system of continental air defense which is now operational for the northeastern United States. The "White Alice" communications network in Alaska was completed in March, and substantial progress was made on a westward extension of the DEW line. An undersea cable was laid in Arctic waters for the Ballistic Missile Early Warning System (BMEWS), for which the company was engaged to design, install and test communications equipment. In its Government work, as in its Bell System business, the company is assisted by many other companies, most of them small businesses.

Last December, the Government renewed for the third five-year period the non-profit contract under which Western Electric — through its subsidiary company, the Sandia Corporation — manages the Atomic Energy Commission's Sandia Laboratory based at Albuquerque, N. M. Sandia's work is concerned with the military application of atomic energy.

news notes

E. I. Green Director of Bell Laboratories

E. I. Green, Executive Vice President, was elected a Director of Bell Laboratories on February 24.

Mr. Green has a long record of distinguished engineering experience and achievement, including more than 70 patents for his inventions. He began his Bell System career in 1921 with the A.T.&T. Co.'s Development and Research department, and with that department transferred to the Laboratories in 1934.

For many years he specialized in the development of transmission systems and transmission apparatus, and later was in charge of military communications systems.

He was elected Vice President in charge of Systems Engineering in 1955, and became Executive Vice President in January 1959.

A. B. Goetze, W.E. Co. President, Dies

Arthur B. Goetze, President of Western Electric and a Director of the Laboratories since 1956, died unexpectedly on March 9. He was 57 years old.

Mr. Goetze entered Western Electric immediately after graduating from high school in 1917. Starting as a draftsman at the Hawthorne Works in Chicago, he continued his studies in electrical engineering through evening classes at Armour Institutes (now Illinois Institute of Technology).

He rose through various company organizations to the post of Personnel Director in 1942 and later headed several manufacturing plants of the company. In 1949 he was elected Vice President of the Chesapeake & Potomac Telephone Companies and the following year Vice President and a Director of the Ohio Bell Telephone Company. He returned to Western Electric as Vice President in 1952 and was elected President in September, 1956.

Mr. Goetze had been a Director of the Laboratories since June, 1956, and of the Western Electric Company since April, 1953.

Designers Honor 500-Type Set

The 500-type telephone has been selected as one of the ten "best designed products of modern times" in a recent poll of 100 leading industrial designers.

The Institute of Design of the Illinois Institute of Technology polled designers, architects and design department heads of manufacturing firms and universities around the world.

The 500 set — the 10th most frequently listed product among 1,000 nominations — was developed by the Laboratories. Its appearance was designed by the Laboratories and Henry Dreyfuss in 1949, using a styling by Mr. Dreyfuss.

Other products in the top ten were Olivetti's Lettera 22 typewriter; a plywood-and-steel side chair designed by Charles Eames; a Barcelona chair designed in 1929 by Ludwig Van Der Rohe; Studebaker's 1953 hardtop coupe; the Parker "51" fountain pen; the Lincoln continental automobile (1939-41); the Edison Voicewriter, VP model; Frigidaire's "Sheer Look" 1957 appliances; and a Hallicrafters radio designed by Raymond Loewy in 1946.

Dr. M. J. Kelly Receives Stevens Institute Award; Keynotes Conference On Solid-State Circuits

Dr. M. J. Kelly, former president and chairman of the board of Bell Laboratories, was recently honored by Stevens Institute of Technology with a Stevens Honor Award for "notable achievement in his field."

Dr. Kelly, a member of the Board of Trustees of Stevens, received the award at the annual dinner of the Stevens Alumni Association held in New York City on February 27.

On February 12, Dr. Kelly delivered the keynote address at the 1959 Solid-State Circuits Conference held at the University of Pennsylvania. His subject was "A Look at the Nation's Future — The Part that We of Science and Technology Will Play." J. A. Morton, Vice President in charge of Device Development at Bell Laboratories, served as Chairman of the Conference.

Bell Laboratories Men Help Restore Service On Transatlantic Cable

On March 1, just eight days after the transatlantic telephone cable service was interrupted, all circuits were back in operation. During the period, Bell System engineers had to determine the point of the break, get to the area, grapple for the cable and make repairs aboard the repair ship, the Lord Kelvin. These jobs were almost continuously hampered by adverse weather conditions.

Two Laboratories men, W. A. Klute and T. F. Gleichmann of the Transmission Systems Development Department, were among the Bell System people who aided in the repair operations.

Grappling was started at 7:30 a.m. on February 28 and the cable was quickly picked up. The final splice was completed by 5:45 a.m. Sunday, March 1, and the final circuit went into operation at 10:28 a.m.

H. I. Romnes Elected President of W.E. Co.

On March 17 the Board of Directors of the Western Electric Company elected H. I. Romnes President and a Director of the Company to succeed Arthur B. Goetze who died suddenly on March 9.

Mr. Romnes has been Vice President of A.T.&T. in charge of the Operating and Engineering Department since 1955. He started in the Bell System in 1927 by installing telephones during the college summer vacation of his senior year. Upon graduation from the University of Wisconsin in 1928 with an electrical engineering degree, Mr. Romnes joined Bell Laboratories, performing circuit design work.

In 1935 he joined the Engineering Division of A.T.&T. and had risen to the position of Plant Extension Engineer when, in 1950, he transferred to the Illinois Bell Telephone Company. Later that year he was appointed General Manager of the Long Lines Department of A.T.&T. He was named Chief Engineer of A.T.&T. in 1952 and was elected Vice President in 1955.

As President of Western Electric, Mr. Romnes heads a nationwide organization of more than 122,000 people, including the principal subsidiaries, Teletype Corporation and Nassau Smelting and Refining Co.

The Acoustoelectric Effect in Germanium

A direct current can be induced in a semiconductor under certain conditions by passing sound waves through it. This "acoustoelectric effect" has been studied extensively by Gabriel Weinreich of the Solid-State Electronics Research Department.

An acoustic wave traveling through a semiconductor tends to produce a net force acting on the charge carriers — the electrons or the holes — in the direction of propagation of the wave. To offset this force, the semiconductor material induces in itself an electric field. Experimenters can measure this field by attaching contacts along the length of the sample.

This effect depends on some "bunching" of the carriers, and it is normally reduced greatly since like carriers repel each other electrostatically. There are some situations, however, in which more than one type of carrier is present, and it is possible to bunch each type separately without developing a net space charge — the bunches "cancel" each other. Such is the case with n-type germanium, in which the electrons belong to a band that has a number of distinct areas of minimum energy or "valleys." Electrons in the vicinity of these various valleys react differently to an acoustic wave, causing the acoustoelectric effect. The magnitude of the effect gives a measure of the intervalley scattering time—the mean time which an electron spends in states near any one of the valleys.

Physicists experimentally verified the acoustoelectric effect by passing acoustic waves through a bar of n-type germanium at frequencies of 20 mc and 60 mc, and by measuring the voltage induced along the bar. To minimize stray effects, the acoustic waves are modulated with an audio frequency to produce an induced voltage at audio frequencies rather than one of direct current.

A study of intervalley scattering time has led researchers to a better understanding of semiconductor materials. For example, they have found that this scattering is due partly to scattering of phonons and partly to scattering of impurities. These two effects may be separated because the phonon effect becomes greater at high temperatures (above 100°K) while the impurity effect is predominant at temperatures below about 60°K. Between 60°K and 100°K, the two effects are mixed.

Gabriel Weinreich inspecting device used for acoustoelectric studies.

Bell System Announces Organization Changes

The Directors of the A.T.&T. Co. on March 18 elected Paul A. Gorman an Executive Vice President, John J. Scanlon and Roy C. Echols Vice Presidents and L. Chester May Treasurer, all effective April 1. Mr. Gorman, President of New Jersey Bell Telephone Company, will replace Clifton W. Phalen, who recently was elected President of New York Telephone Co.

Mr. Scanlon, Treasurer, will be Vice President, Revenue Requirements, replacing E. Hornsby Wasson, who on March 18 was elected President of New Jersey Bell Telephone Co. Mr. Echols will be in charge of the commercial, plant, traffic and sales operations of A.T.&T. He replaces H. I. Romnes, who was elected President of Western Electric on March 17.

Mr. Gorman began his Bell System career as a clerk for Western Electric in 1929. He became Western Electric Vice President in charge of defense projects in 1954 and served as Vice President, Finance, and as Vice President, Manufacturing, before going to New Jersey Bell early in 1958 as Vice President, Operations.

Mr. Scanlon began his career in the general accounting offices of the Pennsylvania Company in 1925. He rose to Chief Accountant and Assistant Comptroller in Pennsylvania before joining A.T.&T. as Assistant Treasurer in 1952. He has been Treasurer since 1953. Mr. Echols started as a clerk in the Southwestern Bell Company and later became General Manager of Oklahoma. He was Vice President and General Manager of the Indiana Company from 1954 until 1958, when he joined A.T.&T. He has been Assistant Vice President in charge of plant operations at A.T.&T.

Mr. May began as a student engineer in Washington for the Chesapeake & Potomac Telephone Cos. in 1930. He has since been an Assistant Vice President of the New England Company, Assistant Comptroller at A.T.&T., and Vice President and Comptroller of the Michigan Company.

Mr. Wasson began as a salesman for the Southern Bell Company at Chattanooga. He became Public Relations Vice President for Northwestern Bell at Omaha in 1950. He joined A.T.&T. as a Vice President in 1952.

Compatible System for Stereophonic Sound Demonstrated Over Television and Radio

Commercial television and radio stations can now present "full-effect" stereophonic sound programs that will remain enjoyable to the many one-receiver listeners in the audience. This is a result of a new "compatibility" circuit developed by F. K. Becker of the Systems Research Department at Bell Laboratories and recently demonstrated to the press and to the National Stereophonic Radio Committee.

For some time radio and television stations have been offering stereophonic sound programs by broadcasting over two separate sound channels. In various experimental arrangements, the two channels have been selected from different combinations of AM, FM, and TV channels. The listener then spaces his appropriate receivers properly in his home. Results of this technique have been so favorable that more and more broadcasters are now considering stereo programming.

But there has been a major obstacle to increased use of this type of stereo broadcasting — the person who listens with only one receiver. If the broadcaster tries for the full stereo effect, the single channel listener hears the sound from only one of the two widely-spaced microphones, and thus misses a portion of the program. Furthermore, what he does receive is poorly balanced, because of the placement of the microphones in relation to the sound sources. For this reason, the broadcaster has had to dilute the stereo effect to preserve satisfactory reception for the single-channel listener.

This single-channel problem may now be eliminated without affecting the stereo listener, through use of the compatibility circuit. The circuit depends for success on a psycho-acoustic phenomenon known as the "precedence effect." This effect operates in such a manner that when a single sound is reproduced through two separate loudspeakers, but is delayed several milliseconds in one, the listener will "hear" the sound as if it came only from the speaker from which he heard it first. He will judge the second loudspeaker to be silent.

The amount of the precedence effect depends somewhat on the length of built-in delay. For example, with a delay of 10 milliseconds, the sense of direction for an average observer is as if the echo were 8 to 10 decibels softer than the sound that precedes it.

In the new development, the circuits between the microphones and their corresponding radio or TV transmitters are cross-connected through two delay lines, each with its own buffer amplifier. Because of these cross connections, music or voice signals from the left microphone are transmitted directly to the left loudspeaker in the listener's home, while the same signal is slightly delayed before reaching the speaker to his right.

The stereo listener will hear the sound as if it came only from the left loudspeaker. Conversely, the sound from the right microphone goes directly to the right speaker, but is delayed before reaching the left speaker, and is therefore unheard. Thus, the stereo listener localizes the sound he hears as coming properly from each of his two speakers, to maintain the full stereophonic effect.

Monophonic reception is completely compatible, however, since a listener to each single channel hears the total sound from both microphones in a balanced reproduction. According to subjective tests performed at the Laboratories, the slight built-in delay does not effect the reception of the single-receiver listener at all.

Company Engineers Complete Laboratories Training Program

Forty-seven young engineers from eighteen Bell System Operating Companies and Long Lines have completed the Operating Engineers Training Program (O.E.T.P.) at Bell Laboratories.

The graduation program was held Thursday, March 19, at the Murray Hill, N. J., location of Bell Laboratories. Executives of the Laboratories, A.T.&T. Co. and Western Electric Co. attended the ceremonies.

The purpose of the O.E.T.P., started in September, 1956, is to introduce Operating Company engineers to the new electronic devices and systems typical of those expected to revolutionize the Bell System telephone plant in the years ahead. The Laboratories thus hopes to help Operating Companies develop engineers who will be able to assume technical leadership in introducing the new devices and systems into the telephone plant.

The Companies select the trainees on the basis of Company and college records. Since many of the men come from a considerable distance, they usually bring their families and establish new homes in Northern New Jersey for the duration of the Training Program.

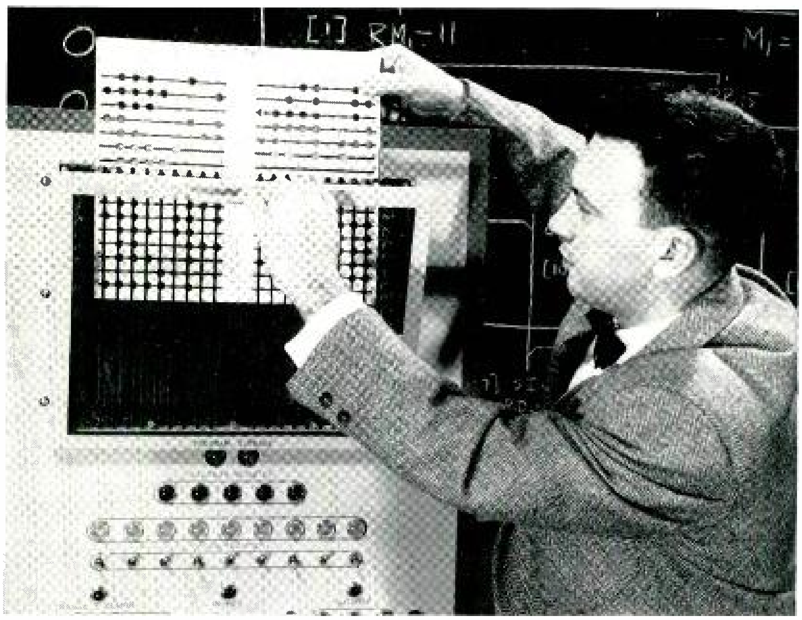
The 47 graduating Seniors were the second class to complete the Program. Forty-eight men from 18 Operating Companies and Long Lines entered in September, 1956, and were graduated last June. Forty-three men from 16 Companies and Long Lines entered as Juniors last August and will be graduated in March, 1960. A new class — the fourth — will enter next August.

During the Program, Seniors spend one day a week in class at the Murray Hill Laboratory, where the O.E.T.P. classrooms and offices are located. The remaining four days are devoted to rotational work assignments in the various technical departments at Murray Hill, N. J., Whippany, N. J., and New York City. All trainees take part in actual projects on their assignments, which run for three months each.

"SPUD" is O.E.T.P. Aid

For O.E.T.P., a unique new "teacher" has joined the instructors' ranks. But this particular instructor — known as SPUD — is not a live lecturer, although it does appear to "think" as it simulates a telephone call or solves math problems to the accompaniment of flashing lights and a busy hum. Actually, this is a miniature information-processing machine created especially by the Laboratories to help students understand the workings of electronic telephone switching systems and digital computers.

Its name is an abbreviation for "Stored Program Universal Demonstrator." Matthew Raspanti, an instructor in the switching training program, conceived the idea for the machine and designed its circuits. Although small, SPUD has complicated circuits that include 29 relays with 500 contacts and about 1,500 wires. There also are 288 "reading fingers" for recognizing different sets of instructions fed into the machine in the form of punched cards. Changing the punched card, as shown by Mr. Raspanti in the photograph, enables SPUD to perform different tasks.



TECHNICAL DRAWING ASSOCIATES ANNUAL Meeting, Chicago, Ill.

Gallagher, W. J., *Drafting Standards for Microfilmed Engineering Drawings.*

Locke, W. J., *How to Prepare for and Operate a Microfilm System.*

Nelson, C. E., *New Developments in Microfilm Equipment and Techniques.*

A.I.E.E. WINTER GENERAL MEETING, New York City

Elliott, S. J., *Evaluation of Solderless Wrapped Connections for Central Office Use.*

Goldey, J. M., *P-N-P-N Switches.*

Goldstein, H. L., *Observation of Transients in the Series Connected Saturable Reactor with High Impedance Control Source.*

Hays, J. B., *Some Aspects of Grounding, Insulating and Bonding in the Problem of Shock Hazard.*

Howard, B. T., *Transistors and Tubes in Telecommunications.*

Massey, R. P., *The Effects of Transformer Parameters on Commutation Transients in Rectifier Circuits.*

Sevick, J., *A 5-Watt 14-mc Transistor Transmitter.*

Shair, R. C., *Recharge Behavior of Lead-Acid Batteries.*

Suozzi, J. J., *On Feedback in Magnetic Amplifiers — Part II —Combined Magnetic and Electric Feedbacks.*

SOLID-STATE CIRCUITS CONFERENCE, Philadelphia, Pa.

Abbott, G. F., Jr., *High-Current, High-Speed, Nonsaturating Transistor Drivers.*

Ballentine, W. E., see Blecher, F. H.

Blecher, F. H., and Ballentine, W. E., *Broadband Transistor Video Amplifiers.*

DeGrasse, R. W., Schulz-Du Bois, E. O., and Scovil, H. E. D., *A Unilateral Three-Level Maser Employing Ruby-Loaded Comb-Type Structure.*

Doucette, E. I., *Some Circuit Applications of the Field Effect Current Limiter.*

Engelbrecht, R. S., *Nonlinear Reactance (Parametric) Traveling-Wave Amplifiers for UHF.*

Giguere, W. J., Jamison, J. H., and Noll, J. C., *Transistor Pulse Circuits for 160-mc Clock Rates.*

Grubbs, W. J., *Hall Effect Devices—A Survey.*

Jamison, J. H., see Giguere, W. J.

Kovanic, E. F., *Circuit Applications of Stepping Transistors.*

Miller, P., see Rupprecht, E. G.

Noll, J. C., *High-Speed Parallel-to-Serial Pulse Multiplexing for 160-mc Clock Rates.*

Noll, J. C., see Giguere, W. J.

Patterson, H. J., see Rupprecht, E. G.

Preston, K., Jr., and Simkins, Q. W., *Twistor Buffer Store.*

Rupprecht, E. G., Miller, P., and Patterson, H. J., *Hyperfast Diffused-Silicon Diode and Transistor for Logic Circuits.*

Schulz-Du Bois, E. O., see DeGrasse, R. W.

Scovil, H. E. D., see DeGrasse, R. W.

Simkins, Q. W., see Preston, K., Jr.

Villars, C. P., *Design of a Transistorized 1.5-Megabit Analog-to-Digital Encoder.*

OTHER TALKS

Baker, P. A., *Bias Considerations for Low-Level Transistor Amplifiers*, Polytechnic Institute of Brooklyn, N. Y.

Bangert, J. T. *Network Synthesis and Practicality*, Chicago Section, I.R.E., Chicago, Ill.

Barnes, E. G., *Maintenance of Grounds*, North Arlington, N. J.

Becker, J. A., *Some Adsorption Characteristics of H_2 and C_2H_6 on Single Crystals of W*, Seton Hall University, South Orange, N. J.

Bennett, W. R., *Nonlinear and Variable Parameter Networks*, Chicago Section, I.R.E., Chicago, Ill.

Blecher, F. H. *Recent Advances in High Frequency Circuit Design Through the Use of Diffused Types of Transistors*, North Carolina Section, I.R.E., Greensboro, N. C.

Brown, L. C., *The Tradic Airborne Navigational Computer*, Naval Reserve Composite Co. 3-6, Madison, N. J.

Chynoweth, A. G., *Domain Dynamics in Ferroelectrics*, National Research Council, Ottawa, Canada.

Crowley, T. H., see Gianola, U. F.

Deutsch, Morton, *Some Studies of Social Perception*, Psychology Department Graduate Colloquium, University of Pennsylvania Philadelphia, Pa.

Dimond, T. L., *Automatic Reading of Machine Written and Hand Written Characters*, Electrical Club of Ottawa; Electrical Club of Montreal; and Bell Telephone of Canada.

Elmendorf, C. H., *Submarine Cable System*, Merrimack Valley Subsection, A.I.E.E., Western Electric Auditorium, Merrimack Valley, North Andover, Mass.

TALKS (CONTINUED)

Ferrell, E. B., *Statistical Methods in Engineering Design*, Philadelphia Section, American Society for Quality Control, Philadelphia, Pa.

Fordam, C. E., *Nike Ajax*, Father-Son Dinner Troop 9, South Orange, N. J.

Frisch, H. L., *Electron Levels in Random One-Dimensional Arrays*, Institute for Study of Metals, University of Chicago, Ill.

Geschwind, S., *Exchange Resonances in Magnetic Materials in the Microwave Region*, St. Johns University, N.Y.C.

Geusic, J. E., *The Three-Level Solid-State Maser*, Cincinnati Section, I.R.E., Cincinnati, Ohio.

Gianola, U. F., and Crowley, T. H., *Magnetic Networks for Performing Logic*, Special Technical Conference, Nonlinear Magnetics and Magnetic Amplifiers, Los Angeles, Calif.

Gibbs, D. F., *The Variation of Permittivity with Pressure*, and *The Electromechanical Properties of Ferroelectrics*, Mineral Products Division, National Bureau of Standards, Washington, D.C.

Glaser, J. L., *Pulse Techniques in Communications*, A.I.E.E. Section Meeting, Buffalo, N. Y.

Goldstein, E., *Data Processing*, H/H Co., 803d Signal Depot (USAR) New York City.

Goldstein, H. L., *Modern Magnetic Amplifiers — Basic Principles and Applications*, East Tennessee Section, A.I.E.E., Knoxville, Tenn.

Gordon, J. P., *Masers*, Stevens Institute of Technology, Hoboken, N. J.

Guttman, N., *Review of Recent Visits to Speech and Hearing Laboratories in Italy, U.S.S.R., Holland and England*, Audiology Study Group, Hunter College, N. Y. C.

Hamming, R. W., *Frontiers of Computer Technology*, Mid-continent Computer Club, Chicago, Ill.

Hamming, R. W., *Where Is the Computer Heading?*, Engineer's Club, Philadelphia, Pa.

Hogg, D. C., *Millimeter Waves— The Transmission Problem*, New York Chapter, P.G.M.T.T., I.R.E., New York City.

Jaccarino, V., *Hyperfine Structure Studies in Antiferromagnetics*, Columbia University, N.Y.C.

Johannesen, J. D., *A Two-Transistor Gate for Time Division Switching*, Electrical Engineering Department Colloquium, Case Institute of Technology, Cleveland, Ohio.

Kennedy, R. A., *Developments in Handling Scientific Information*, Alfred University, Alfred, N. Y.

Keister, W., *New Developments in Electronic Switching*, Boston Section, A.I.E.E., New England Telephone and Telegraph Company, Boston, Mass.

Long, T. R., *New Memory Devices*, Student Section, I.R.E./A.I.E.E., Polytechnic Institute of Brooklyn, N. Y.

McKay, K. G., *New Developments in Solid-State Devices*, Detroit Section, I.R.E., Detroit, Mich.

McVey, J. H., *Nike Ajax*, Morris County Chapter, Alumnae Association, College of St. Elizabeth, Convent Station, N. J.

PATENTS

Anderson, J. R. — *Magnetic Recording System for Storing and Reproducing Television Signals* — 2,874,214.

Belek, E., Miloche, H. A. and Reimels, H. G. — *Mounting and Connecting Apparatus* — 2,872-624.

Biondi, F. J., Cleveland, H. M. and Sullivan, Miles V. — *Ohmic Contacts to Silicon Bodies* — 2,874,341.

Cagle, W. B. and Ulrich, W. — *Logic Circuit* — 2,873,389.

Chase, F. H. — *Electric Circuit Interrupters* — 2,873,372.

Cleveland, H. M., see Biondi, F. J.

Cox, L. R. — *Carrier Distribution Circuit* — 2,874,220.

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M. B. McDavitt ("The Merrimack Valley Laboratory"), a native of Texas, holds an E.E. degree from the University of Virginia and an M.S. in E.E. degree from Massachusetts Institute of Technology. He joined the Development and Research Department of A.T.&T. in 1925, where he worked on dial systems, and continued in this field after transferring to the Laboratories in 1934. During World War II he was associated with various military projects, and later served as Director of the Bell Laboratories School for War Training. He was named Radio Transmission Engineer in 1945, Assistant Director of Switching Engineering in 1948, and in 1949 became Director of Switching Development. He has been Director of Transmission Development since 1952. Mr. McDavitt is currently responsible for the development of all transmission systems for Bell System use. He is a Fellow of the A.I.E.E. and a Senior Member of the I.R.E.

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