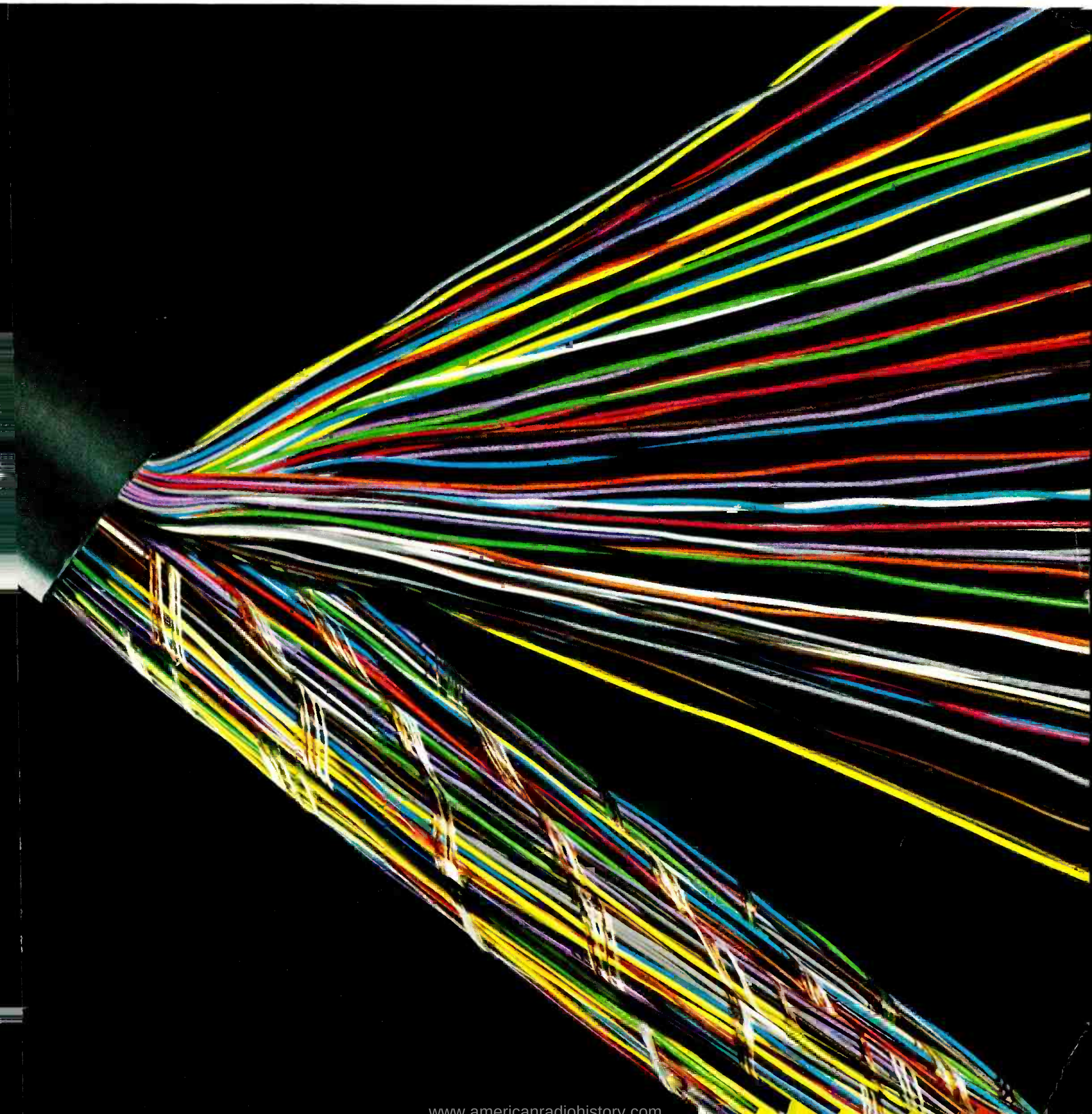
June 1959

Bell Laboratories RECORD



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Cover *"Even-count" cable (see page 208), a major advance in cable development. Pairs are insulated with polyethylene and are completely color coded. View shows only part of sheath construction.*

Thor-Able II at start of flight (Air Force photo).

Military systems specialists at Bell Laboratories have made a significant contribution to the science of missile guidance — a radio-inertial system being tested for use with the Titan ICBM.

E. P. Felch

MISSILE GUIDANCE

In recent years, a steadily increasing portion of the military effort at Bell Laboratories has been devoted to the study, development and design of missile systems. Shortly after World War II, the first guided-missile work began in our research departments with an investigation of methods to counter the threat of manned bombers. The resulting recommendation for a defensive ground-to-air guided missile system prompted Army Ordnance to authorize the development of an experimental system by the Laboratories in collaboration with the Douglas Aircraft Company.

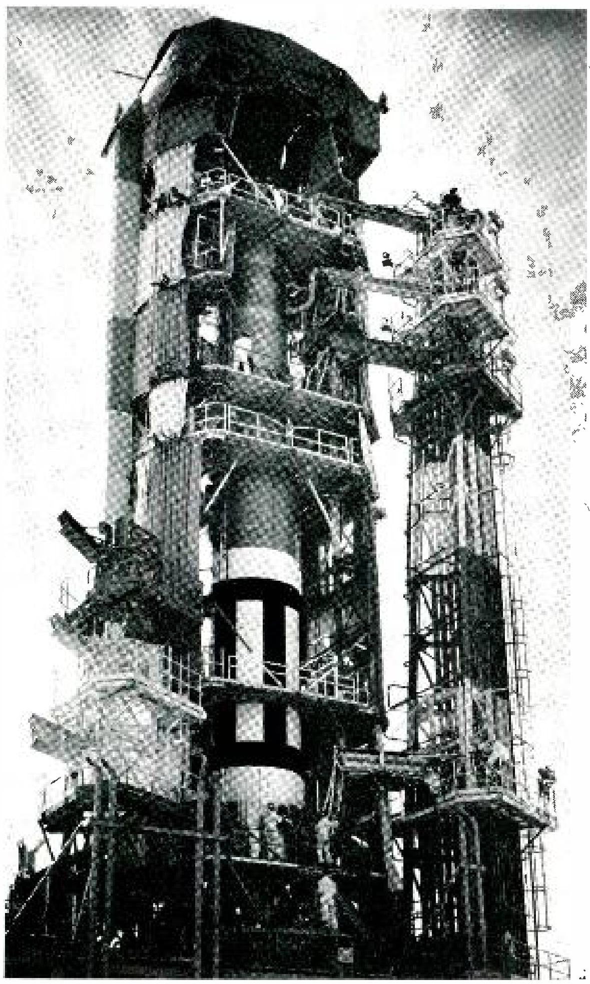
In December, 1951, highly successful demonstrations were staged at White Sands Proving Ground in New Mexico. This system, now known as Nike-Ajax (RECORD, *February*, 1959), was speeded into production under the impetus of the Korean crisis. A high level of manufacturing effort by Western Electric Company and Douglas over a period of several years has provided most American cities with the protection of a ring of Nike-Ajax systems and, more recently, with the longer-range Nike-Hercules systems. Nike-Zeus, for protection against ballistic missiles, is well along in development.

Based upon this Nike background, the Laboratories undertook a study several years ago of the guidance problems for long-range ballistic missiles. This was carried out by the Military Systems Studies Department, supported by fundamental contributions from the Mathematical Research Department. The basic principles underlying the Laboratories guidance system stemmed from this study.

Ballistic missiles fly hundreds of miles above the atmosphere at speeds of several thousand miles per hour. Thus, as compared to manned aircraft or missiles of the air-breathing type, they offer retaliatory capabilities of an entirely new order. Powered by rocket engines, they carry their own oxidizer as well as fuel—liquid oxygen and kerosene, for example. With flight times measured in minutes rather than hours, and with ranges of several thousand miles, such weapons present any enemy with an extremely difficult defensive problem. As applied to these missiles, the term "ballistic" stems from the fact that the engines propel the missile for only a fraction of the total distance, and guidance is applied only during this powered phase. For the remainder of the mission, the missile flies like a projectile that has left a gun barrel.

In 1955 the U. S. Air Force decided to exploit advances in ballistic-missile technology through an intercontinental ballistic missile named Titan. The Western Development Division of the Air Research and Development Command, now the Air Force Ballistic Missile Division, was assigned over-all responsibility for the project. They enlisted the aid of the Guided Missile Research Division of Ramo-Woolridge Corporation, now Space Technology Laboratories, for systems engineering and technical direction. These agencies selected the Martin Company of Denver, Colorado, as contractor for the air frame, control system, and ground-support equipment. The Bell Laboratories-Western Electric team was chosen to develop the guidance system for Titan.

The Titan missile is designed to carry nuclear warheads a distance of more than 6,000 statute miles. It is over 90 feet long and weighs more than 100 tons at lift-off, and is a two-stage rocket. The larger diameter, booster stage is powered by two liquid-fuel rocket engines. These lift the Titan through the heavy blanket of the earth's atmosphere. When the booster stage has completed its task, it is separated from the rest of the missile and falls away. The single engine of the smaller-diameter second or main stage is then ignited. This process of shifting from first-stage to second-stage operation is called "staging." The second stage with attached nose cone is then accelerated to the velocity required to carry the nose cone to the target. Next, the nose cone is separated and follows a ballistic trajectory to the point of re-entry into the earth's atmosphere.

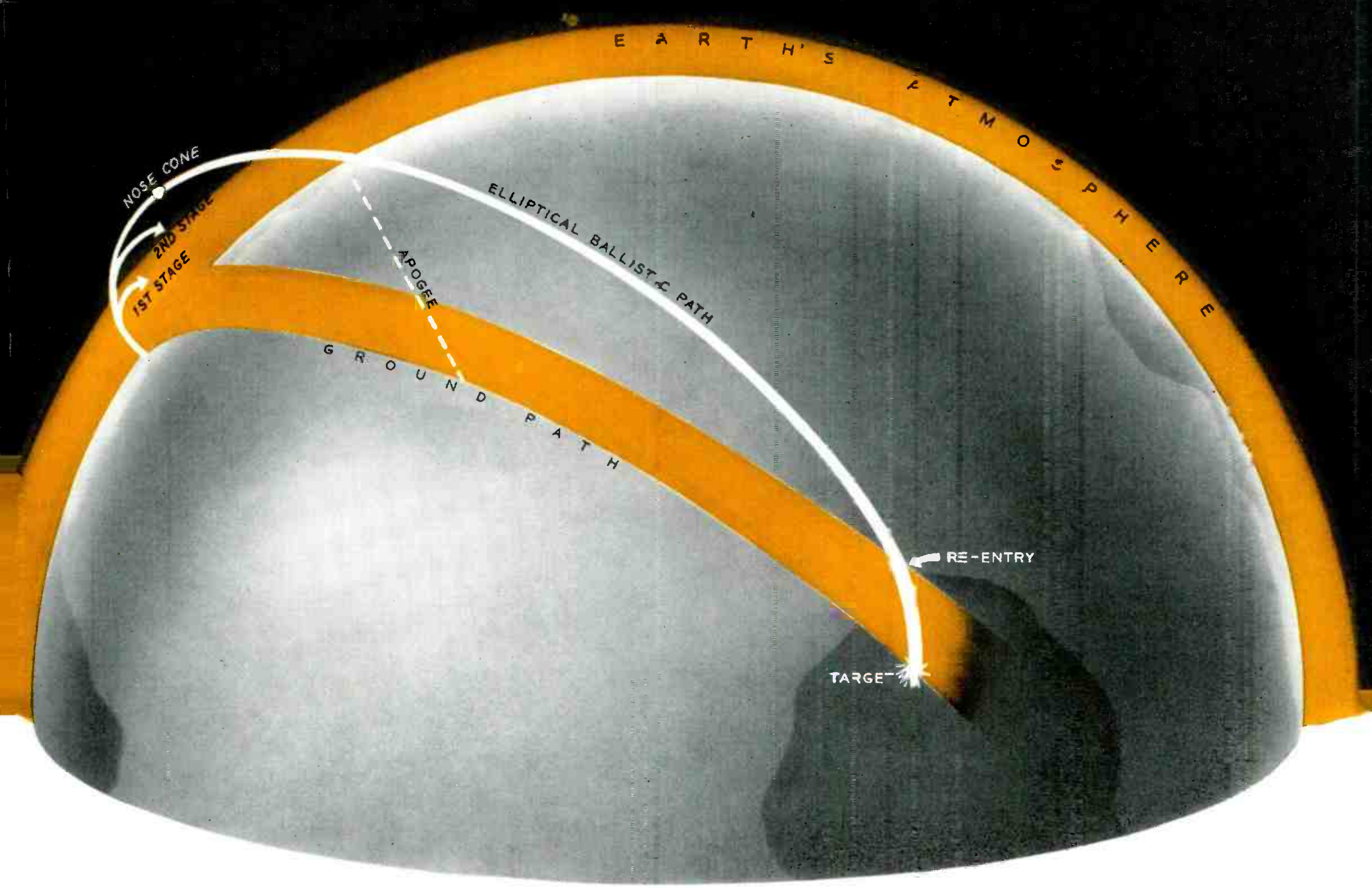


A 90-foot Titan long-range missile, surrounded by its erector and gantry structure, is prepared for launching at Cape Canaveral (Air Force photo).

The ballistic portion of the trajectory is several times longer than the powered stage and includes the apogee or point of greatest separation from the earth. In ballistic flight outside of the earth's atmosphere, the nose cone, like other heavenly bodies, is governed by the laws of celestial mechanics. As evolved by Kepler and refined by Newton, these laws define the motion of a body influenced by gravitational forces. Classically, the ballistic trajectory or orbit is an ellipse with the center of attraction, in this case the center of the earth, at one focus. In the plane of the orbit, a radius from the missile to the center of the earth sweeps out equal areas in equal times. Determination of exact trajectories, however, is complicated by several effects. The Coriolis effect, due to the earth's rotation, causes a straight path in space to appear as a curved path referred to the rotating earth. In addition, the oblateness of the earth — that is, its departure from a perfect sphere — modifies the trajectory significantly.

Extreme Accuracy

As mentioned earlier, a ballistic missile like Titan is guided during the powered phase of flight. While this simplifies the task from the standpoints of duration and distance of control, it leads to very stringent requirements on accuracy. A target at ICBM range lies a quarter of the way around the earth on a great circle. To insure impact on the target, six parameters must be controlled — the positions and velocities along each of three coordinate axes at the instant of termination of thrust. At this point, the forward velocity may be in the order of 24,000 feet per second. A variation as little as one foot per second can cause a miss of one mile at the target.



The principal features of an ICBM trajectory: after it has been accelerated to its maximum velocity, the missile follows an elliptical ballistic path above the atmosphere to point of re-entry.

The Bell Laboratories guidance system belongs to the general class known as command systems. A ground-based radar continuously determines the position of the missile during powered flight. A digital computer, also on the ground, accepts these data and, by reference to previously stored trajectory information for the particular target, computes appropriate orders to maintain the missile on its proper flight path. These corrective orders are transmitted by radio to the missile and are applied to the missile's autopilot and control system.

The complex elements of the system, such as the radar and the computer, enjoy the more favorable environment on the ground where they can be employed over and over again for firing many missiles. The expendable portion of the system in the missile is kept to a minimum to promote reliability in that far more rugged environment. This also favors reduction of cost and weight. A further advantage of this ground-controlled system is that it provides the Squadron Commander with a quite accurate prediction of where the warhead will land, based on the computer's calculations at the termination of powered flight.

The Bell Laboratories system is termed a radio-inertial guidance system, and the words "radio-inertial" are descriptive of one of its unique aspects. These terms refer to the optimum combination of radio and inertial information in a fashion suggested by Sidney Darlington of the Laboratories Mathematical Research Department during the early study referred to above.

Of the six parameters required in determining the trajectory, the three position measurements present the easier problem. The radar can provide position measurements of more than adequate precision. However, determination of

T. J. Grieser, Bell Telephone Laboratories, and Capt. F. M. Smith, Air Force Ballistic Missile Division, discuss flight-test plans for guidance system at Cape Canaveral (Air Force photograph).

the three instantaneous velocity components is obscured by the presence of perturbations or "noise" in the frequency region above one cycle or so. That is, the missile will appear to be fluctuating in velocity at a rate of, say, one or two cycles per second. But the missile cannot actually be subject to perturbations in this frequency range because of its inertial properties. The force available from the propulsion system, applied to the mass of the loaded air frame under control of the autopilot, cannot produce such rapid motion. The autopilot control system of the missile includes gyros to stabilize the flight of the missile, in the absence of control signals from the guidance system. The autopilot stabilization, the mass of the missile, and the constancy of the thrust, determine the motion of the missile except for the influence of drifts or perturbations at frequencies appreciably lower than one cycle per second.

By taking advantage of available knowledge of these inertial parameters, the actual motion of the missile over periods of several seconds can be predicted with surprising accuracy. However, this accuracy diminishes as the duration of the prediction period is extended. Darlington developed a theory that optimizes the combination of radar measurement and inertial prediction. This involves smoothing or averaging of the radar data which causes a lag in the apparent position of the missile, and an "updating" process based upon the inertial information. Fortunately, the digital computer used in the system lends itself admirably to such processing. This approach has been likened to the "woofer-tweeter" method of obtaining high-fidelity sound reproduction.

Performance requirements for the gyros in the autopilot are several orders of magnitude less severe than for those required in a self-contained, all-inertial guidance system. In an all-inertial system, precise accelerometers are employed to measure the accelerations imparted to the missile along each of three axes determined by gyros. Outputs from the accelerometers are integrated once to provide velocities and a second time to provide position determinations. An airborne computer must then compare these data with a stored trajectory in order to produce steering signals.

The radar employed in the Titan Guidance System is an outgrowth of the target-tracking radar of the Nike-Hercules System. Many modifications and refinements were necessary, however, to meet the specific requirements. For example, optical code wheels were applied to both axes of the antenna to provide angular information in digital form; a completely new transistorized digital range unit was developed; a precise crystal-controlled central timing unit was added; monitoring and recording units were designed to facilitate check-out and analysis of system performance. Research and development models of the radar have been installed at the Whippany, N. J., Laboratories location and at the Cape Canaveral Laboratory.

Radar Redesigned

For operational use, a completely redesigned radar is now in production at the Western Electric Company Plant in Burlington, North Carolina. This redesign has been aimed particularly at minimizing the number of, and easing the tasks of, operating and maintenance personnel. In the underground operational base, one officer will be able to operate both the radar and the associated computer from a single console. Built-in test equipment permits "black box" maintenance. With this equipment, faulty equipment units or "black boxes" can be identified and can be replaced from a complete stock of spare plug-in units maintained in close proximity. The faulty units are then sent to the support areas, depots, or the factory for repairs. This arrangement is expected to contribute significantly to reliability as well as speeding and simplifying maintenance procedures.

The computer for the Titan Guidance System has been designed by the Remington Rand Univac Division of the Sperry Rand Corporation under the technical direction of the Laboratories. It is a completely transistorized digital machine employing diode logic and both drum and core memories. Meticulous attention to factors affecting reliability has yielded trouble-free life significantly exceeding that of any previous large digital computer. The guidance equations and constants are generated by the Bell Laboratories Project Analytical Group with major assistance from the Military Analysis, Military Systems Studies and Mathematical Research Departments. Programming of the computer is handled by Remington Rand Univac, followed by "verification-through-simulation" techniques at the Laboratories.

Flight testing of the Research and Development models of the system is being carried out at the Cape Canaveral Laboratory. Under the direction of T. J. Grieser, the Canaveral staff collects data on the performance of the ground guidance equipment and the missile-borne equipment, as well as handling installation, checkout and countdown.

A second outpost of activity is the Denver Field Office located on the premises of the Martin Company in Denver, Colorado. At this location, a group of Western Electric Field Engineers under the direction of F. H. Shorkley of the Laboratories is engaged in a test program involving the use of the Martin Company ground test facilities.

The project has been brought to its present state through the cooperative efforts of many widely scattered departments of the Laboratories and of the Western Electric Company. In particular, the Western Electric Field Engineering Force has provided almost 100 engineers, who have been working side by side with Laboratories engineers at Whippany, Cape Canaveral, and Denver. Special electronic and semiconductor devices were developed at the Murray Hill, N. J., Allentown, Pa., and Laureldale, Pa., Laboratories locations. The North Carolina Laboratories organization, in addition to carrying out their normal functions, has undertaken the design of a portion of the radar and test equipment. A special area for the manufacture of the missile-borne equipment under carefully controlled conditions has been set up at the Waughtown Plant of the Western Electric Company in Winston-Salem, North Carolina. This includes extensive facilities for 100 per cent inspection of the components employed in these units as well as exhaustive testing of the finished product. A new environmental test laboratory was constructed at Whippany to house special machinery capable of subjecting the missile-borne equipment to extremes of vibration and acceleration. Elaborate failure-reporting procedures have been instituted so that the reliability group can feed back appropriate information to the design groups with a minimum of delay. The instruction-book group at Whippany, in addition to turning out handbooks, has participated in the initial planning for the training program which will be carried out by the Western Electric Field Engineering Force. The drafting rooms have handled thousands of tracings on a "crash" schedule, with military requirements incorporated in the very first issues.

With the rising tide of interest in space projects since Sputnik, it is logical to consider the capabilities of the Laboratories radio-inertial guidance system for space exploration. Experience in a missile other than Titan is currently being obtained from flights of the Thor-Able II Re-entry Test Vehicles. These flights are intended to test the re-entry characteristics of new nose-cone designs. With the aid of the guidance system, two nose cones have been recovered after flights of 5,000 miles (*see May* RECORD, *page* 189). Further extensions of this program may include other missions. Studies of the application of the Laboratories radio-inertial system to the guidance of satellites and space probes are actively underway at the present time.

Left to right: J. W. Smith, the author, O. D. Engstrom and T. W. Winternitz inspecting design features of missile-borne equipment used for the Bell Laboratories radio-inertial system.

Colored polyethylene, when used for insulation on conductors, has permitted new cables designed on the "even-count" principle of grouping pairs of telephone wires. This principle, plus improved manufacturing techniques, should result in simpler and more economical use of the telephone cable plant.

F. W. Horn

"Even-Count" Cable

Suppose a customer visits his local telephone office and asks to see "where the wires come in from the telephones." He probably would be taken to the "cable vault," where he could see a number of fairly large, heavy cables passing through special ducts or openings in a wall. Going away from the central office, these large "feeder" cables fan out into smaller "distribution" cables, and, eventually, an individual pair of wires is terminated near a customer. From here, a pair of wires (the drop wire) completes the circuit to the customer's premises. Inside the office, the pairs from the cables are separated and spread out over the office's "main frame," where they are numbered for identification.

These feeder and distribution cables are very important to good telephone service, and any improvement in them can have a significant effect on the efficiency and economy of operation of the telephone plant. The particular improvement considered here is the "even-count" method of grouping telephone pairs in distribution cables. The terminology "even-count" as applied to cables simply means that the system of grouping pairs of wires within the cable is based on an even number — in this case the number 100, made up of subgroups that can be evenly combined into 100. This contrasts with the older "odd-count" method of basing the groups of pairs on the odd number 101.

To appreciate the significance of the new method, it is necessary to describe some of the design features of odd-count cables. In the early days, narrow paper tape was used as conductor insulation, and later pulp insulation was developed. A few basic colors were employed, primarily to distinguish between the two wires of a pair. Groups of pairs, or units, consisted of as many as 50 or 100 pairs. Since the pairs in a group were all identical in appearance, one pair was specially colored and used as a tracer to permit ready identification and to provide a signaling circuit during the splicing operation. Units consisted of red-white, green-white, or blue-white pairs and were identified by "unit binders" — colored cotton threads wrapping the units.

When the cable industry was in its infancy around the turn of the century, it was found that a certain number of pairs failed during the manufacturing and installation operations. For economic reasons, rather than repair such defects, extra pairs were included in a cable to allow for the probable defective circuits. From the beginning, the philosophy was to have usable pairs in multiples of 100, and to realize this, an extra pair for each 100 or fraction thereof provided the necessary factor of safety.

As manufacturing techniques improved, more and more of the spare pairs became usable. All good pairs were used, and this developed into an uneven or "odd-count" numbering system for both the cables and central-office frames. In a large cable, for instance, successive groups had pairs 1-101, 102-202, 203-303, and so forth. However, since all pairs in the group looked alike and had no identity except that assigned to them in the particular installation, the odd-count method was a workable system.

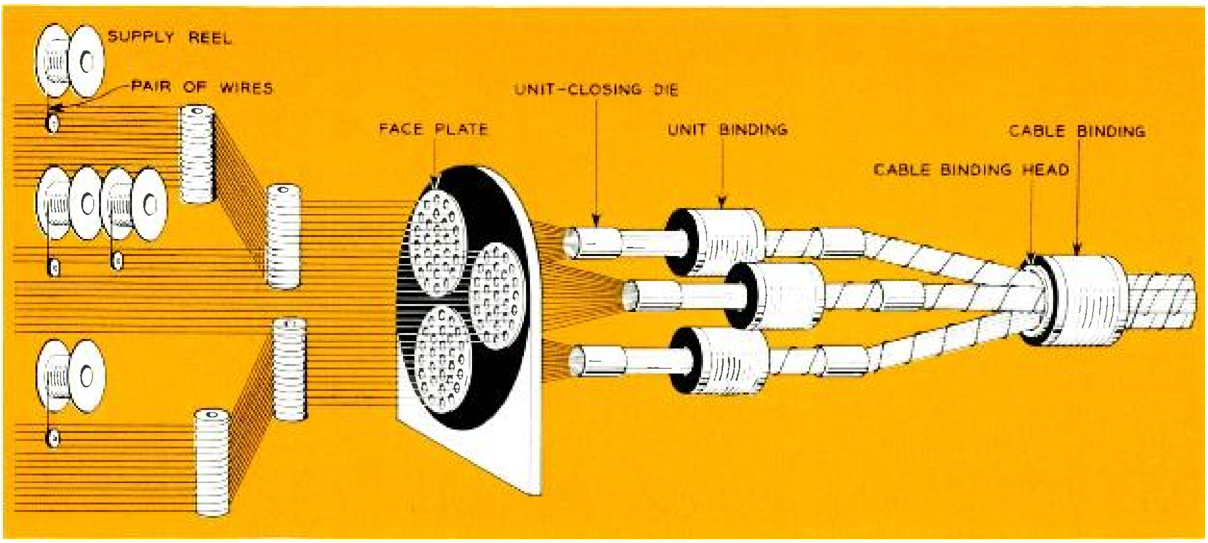
Random splicing was used to keep pair capacitance unbalance and crosstalk to a low value. That is, when two cable ends were to be spliced, the workman randomly chooses pairs of conductors from like units. Since all pairs looked alike, color continuity was no problem and random splicing caused no hardship.

The new even-count principle differs in several respects from the odd-count system. The new concepts are described in some detail below, but briefly stated, there were four contributing factors. First, the advent of polyethylene insulated conductors (PIC) permitted the manufacture of cable in which all pairs of conductors are guaranteed usable, and second, with polyethylene it was possible to develop an easily memorized color code. These two developments naturally led to a third: use of the same colors continuously through cable splices ("straight-through, color-to-color" splicing). And finally, the even-count principle was made attractive by the availability of economical stranding and cabling equipment.

The first of these factors — 100 per cent usable pairs — points up a significant fact concerning the even-count method. With no need to compensate for defective pairs, spare pairs are not included in the numbering, and the numbering sequence is therefore not interrupted.

The second factor, an easily memorized color code, can be appreciated by considering the job of the workman who has access to the conductors in a cable and who wishes to determine which pair is which. With odd-count cable, an electrical signal is employed on the particular pair to be identified. The workman then probes through the 100 like-colored pairs until he finds the tell-tale signal. This is obviously a time-consuming job.

A logical solution, of course, is to "color-code" the wires, but this had to await the availability of suitable colored insulation. The introduction of cable using conductors insulated with polyethylene was a solution to this problem. Initially, however, polyethylene insulation had only a few colors, and these were used only as an aid in manufacture. Later, the Plastics Development Department at the Laboratories developed a special series of eleven distinct colors of insulation, and it then became possible to identify all pairs in a cable. There were not enough colors, however, to make devising an identification plan a simple matter. Use of pastel colors might have



The "one-operation" principle of stranding and cabling. From the left, the twisted pairs pass through face plates and are then grouped into "units." These units are next wrapped with colored binder threads and are grouped into cable. Finally, the cable is bound prior to sheathing.

The author (left) and G. H. Webster examining arrangement of pairs in new even-count cable.

helped, but these are difficult to distinguish in poor light.

With "N" colors, $N(N-1)/2$ pairs may be identified, so that with 11 colors, the maximum number of pairs that could be fully color coded is $11x(10)/2$ or 55 pairs. Actually, a series of polyethylene-insulated cables was designed around 50-pair and 51-pair units that were completely color coded. That is, with a 50-pair unit, for example, a workman could inspect all of the 50 pairs and pick out, from the colors alone, a particular pair associated with a known telephone number or number on the main frame. As before, the separate units were identified with different colors of binder threads — in this case, threads made of nylon.

This system was in use for about three years, and it permitted full identification of all pairs in exchange-area cables for the first time. Grouping pairs in the smaller units of 50 and 51 entailed a modest manufacturing penalty, but this was more than offset by the advantages of color-coded pairs in field operations.

The most recent chapter in this history must make reference to the "ready-access" terminal (RECORD, *November*, 1958). This is the structure that merely provides a "roof" to keep out wind and rain, since polyethylene-insulated cable has electrical characteristics that are insensitive to moisture. To connect a drop wire from the customer's telephone to a cable pair, a workman merely opens the new-type terminal, finds the correct pair, and makes the connection to binding posts on a small terminal block. The entire operation takes only a few minutes. It is apparent that quick identification of the pair is a necessary part of this efficient type of operation.

In this respect, however, the 50-pair system had a shortcoming that was recognized from the beginning. To make a complete identification, the workman must do more than spot the desired pair — he must also determine which is the "tip" side of the line and which is the "ring" side. This is an important electrical distinction in making a telephone connection, and it derives historically from the "tip" and "ring" contacts of the telephone operator's switchboard plug.

If the same colors are always retained for tip and for ring, the formula for the maximum number of identifiable pairs per unit becomes $N^2/4$. Hence, with 10 of the 11 available colors, $10^2/4$ or 25 pairs could be grouped into a unit. The 10 colors can be divided into two groups of 5 each: BLUE, ORANGE, GREEN, BROWN and SLATE comprising one group, and WHITE, RED, BLACK, YELLOW and VIOLET the other. The 25-pair identifications are achieved by matching each color from one group in sequence with all colors of the other group. For example, BLUE, ORANGE, GREEN, BROWN and SLATE are matched respectively with WHITE to get five of the identifiable pairs. Treating the other 4 colors of the second group in a similar manner gives the total of 25. This general type of color code has been applied for many years in textile-insulated cables for switchboards, PBX wiring and other purposes where ease of identification is an advantage. Familiarity with this easily memorized color-coding plan was a reason for adopting it in outside-plant cable (*see cover photograph*).

Originally, it was thought that a reduction in the size of a unit to 25 pairs would be economically prohibitive, so a modified color-coding plan was worked out on the basis of 50-pair units. In effect, 5 additional colors were to be obtained by choosing either the tip or ring color groups, and adding to the insulation of wires in this group annular or ring-like bands of different colors. These 5 "ring-marked" colors, used in sequence with the 5 solid colors of the other color group, would have given the desired 50 identifiable pairs in one unit. With this plan, inking or otherwise applying the color bands was a difficult problem, but there is no reason to believe that it could not have been solved.

In the meantime, however, Bell Laboratories and Western Electric engineers were working out a new concept of "stranding" and "cabling." These are two of the three basic steps in making a cable: the wires must first be *twisted* into pairs; then the pairs must be *stranded* into units; and third, the units must be *cabled* to form the complete core of the cable, ready for sheathing. Great care and study are devoted to these operations, since it is necessary to give the pairs different lengths of twist and to control their relative positions throughout the cable. The object is to produce a cable in which the pairs are, so far as possible, uniform in electrical characteristics and with low crosstalk or interaction between pairs.

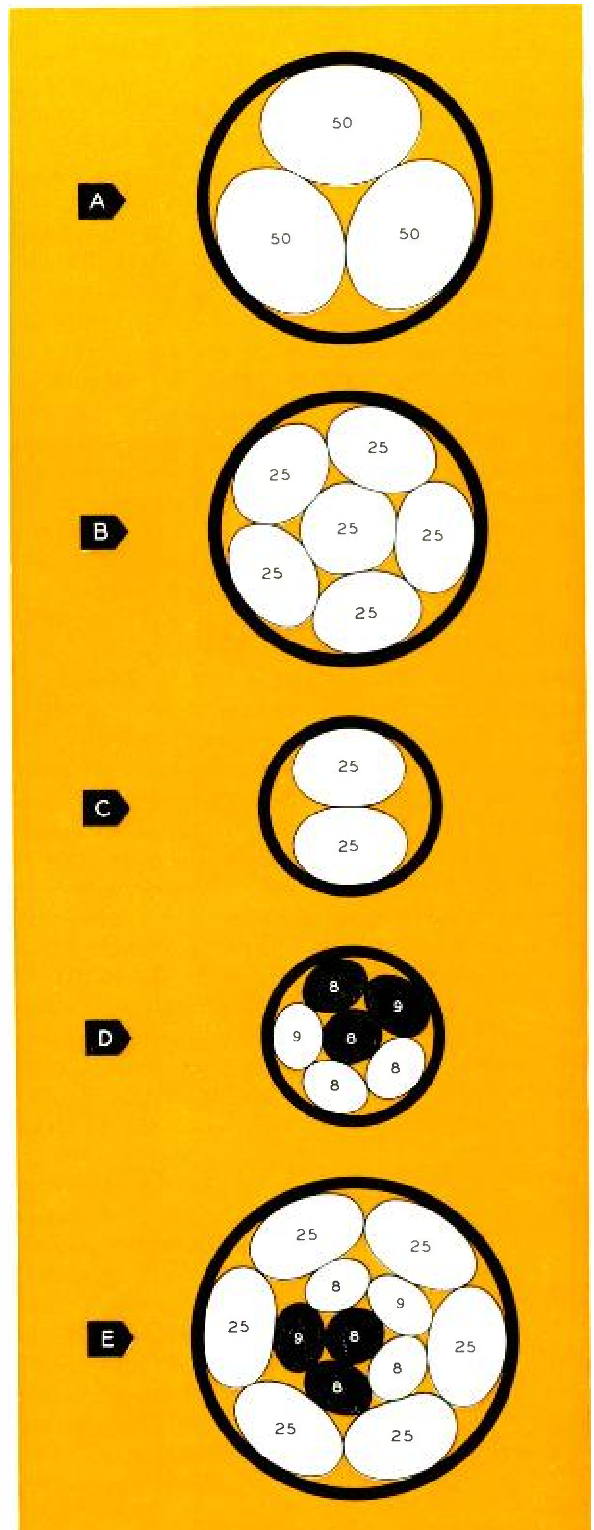
The new concept was to perform the stranding and cabling in one operation, as illustrated in the simplified drawing on page 209. Although this type of operation tends toward increased electrical interference between pairs in adjacent units, such problems have been successfully overcome with the new machine.

A major advantage of one-operation stranding is that units of any size can be used without incurring an economic penalty. This permitted the adoption of 25-pair color groups. Another advantage is that smaller units nest together more compactly, as illustrated in A and B of the second drawing (*this page*). Here, 150 pairs grouped into 25-pair units (B) have a smaller cross-section than the same 150 pairs grouped into 50-pair units (A). As will be seen later, this same advantage applies, of course, to units smaller than 25 pairs.

With this break-through in machine limitation, the ideal color scheme became practical. The workman goes to a color-coded cable and quickly finds the desired color group by noting the colored binder threads. These follow the same color combinations used for the pairs. Of the 25 pairs in the chosen group, he can easily locate the desired pair and identify the tip and ring sides.

At this point in the development, there remained only one more obstacle — the elimination of the spare pairs. As noted earlier, this became possible because of the superior qualities of polyethylene; cables with 100 per cent good pairs could be manufactured without serious economic penalty.

One very important consideration in eliminating the spare pairs was the 101-type of odd-count numbering system used on the main frame of the central office, as mentioned early in this article. Renumbering more than forty million Bell System cable pairs and their associated service records appeared to be a formidable obstacle. However, engineers of the A.T.&T. Co. made extensive studies of PIC cable and of the costs of conversion, and found that costs were



Cable cross-sections discussed in article: A and B compare 150-pair cable divided into 50- and 25-pair groups; C and D show improved geometry; E shows the use of a 50-pair "multi-unit."

S. T. Meyer, left, D. W. Hagelbarger, and F. E. Froehlich discuss features of equipment which tests error correcting codes on actual telephone lines. Burst lengths and redundancies can vary.

Another kind of noise sounds like faint ticks or clicks, and consists of short electrical pulses. These ticks are caused by such things as relays operating in the central office and lightning strokes near open-wire lines. This impulse noise has very little effect on analog type signals. To understand why this is true, consider a typical analog message — speech.

The remarkable thing about tea parties, receptions and other conversational free-for-alls is not that it is difficult to understand someone talking to you, but that anybody understands anything at all. We are so accustomed to picking out one talker from a cacophonous background that we don't appreciate what a difficult task it is. In selecting one conversation from the hub-bub, we are aided by visual clues from the speaker's expression, and by our ability to concentrate our attention on one voice. We are further aided by the fact that our language is highly redundant — we do not have to hear every sound to understand what is said.

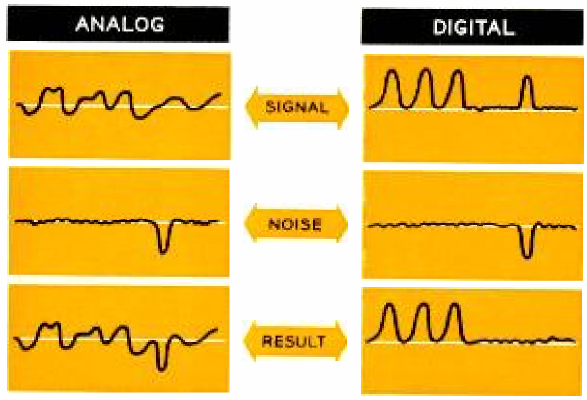
Examples of Redundancy

As an example of language redundancy, the following series of words contains many wrong sounds. But read it aloud and the intended meaning becomes immediately obvious: "Bun, Boo, Bee, Bore, Bive, Bix, Beven, Bait, Bine, Ben." Note that while "Bive" is not an English word, by comparing it with earlier and later words in the series we know that it must mean "Five."

In certain noisy situations we even add more redundancy. On the battlefield, communicators use nomenclature such as "Radar Baker" and "Radar Dog" instead of "Radar B" and "Radar D" which would be easily confused.

Because of this redundancy, faint ticks cause us no trouble at all in listening to speech over the telephone. In fact, we are usually unaware of them. But digital data, representing payroll information, for example, contains very little redundancy. Furthermore, noise pulses may resemble the authentic pulses used to transmit the data, permitting not just errors but *unnoticed* errors. The drawing on this page shows the effects of noise pulses of both analog and digital signals.

A common method of data transmission uses binary signals. Here every digit — every bit of information — can be only one of two possible things; "on" or "off" "yes" or "no," "0" or "1." A character sent over this system is represented by a group of binary digits or "bits." Thus a change in one digit will change the character, which in the case of numbers may change the meaning of the message.



Comparison of effect of noise pulse on both analog and digital signals. When added to the analog signal, the noise pulse results in merely a faint tick. When added to the digital signal, however, the noise shown here turns a pulse into a no-pulse.

For example, in one commercial system, the difference between a "seven" and "one" is the difference between 11100 in one case and 11101 in the other. Look what can happen when something goes wrong with that fifth digit during transmission. A food processor orders "100 carloads of winter wheat." Because of a lightning surge on the transmission line, the shipper receives the order as "700 carloads of winter wheat." Thus one digit, reversed in the transmission of the message, will cause the food processor a storage problem.

Redundancy Codes

One way engineers can approach this noise difficulty is to make the digital system redundant by adding extra pulses. Schemes for deliberately introducing redundancy into digital information to overcome noise have been used since the early 1930's. For example, in 1950, R. W. Hamming of the Mathematics Research Department described the Systematic Parity Check Codes to correct single, isolated errors in data transmission (RECORD, *May*, 1950).

Other codes and methods have since become available to correct "bursts" of errors. A burst is a group of related errors from a common cause such as a lightning flash. A new coding system — an outgrowth of the Hamming code — also will correct bursts of errors. Furthermore, this system needs much less expensive encoding and decoding equipment than did previously available codes.

In the simplest form of the new coding system, a message is sent as alternate "data" and "check" digits. In other words, after transmitting a message digit the equipment inserts an extra digit whose only purpose is to aid in the correction of possible errors. This simplest form of the code has a redundancy of one-half.

To understand how the code works, let us take for an example this code with a redundancy of one-half, designed to correct bursts of six digits or less in length. Operators prepare a message for transmission by sending it through an "encoder" having a shift register capable of holding seven digits at one time. As the message moves through this register, one digit at a time, the equipment selects its check digit according to the value of the data digits that appear in positions one and four of the register at each instant.

The check digit is chosen to make the sum of it and the two data digits in those positions equal either to "0" or to "2." For example, if data-digit one is "0" and data-digit four is "0", the check digit will be "0" to give a sum of "0." However, if data-digit one is "0" and data-digit four is "1", then the check digit must be a "1" to make a total of "2." Whatever the combination of digits in the first and fourth position, the check digit will be chosen to make the sum of the three of them even. In other words, the "parity" — evenness or oddness — of these three digits will be even.

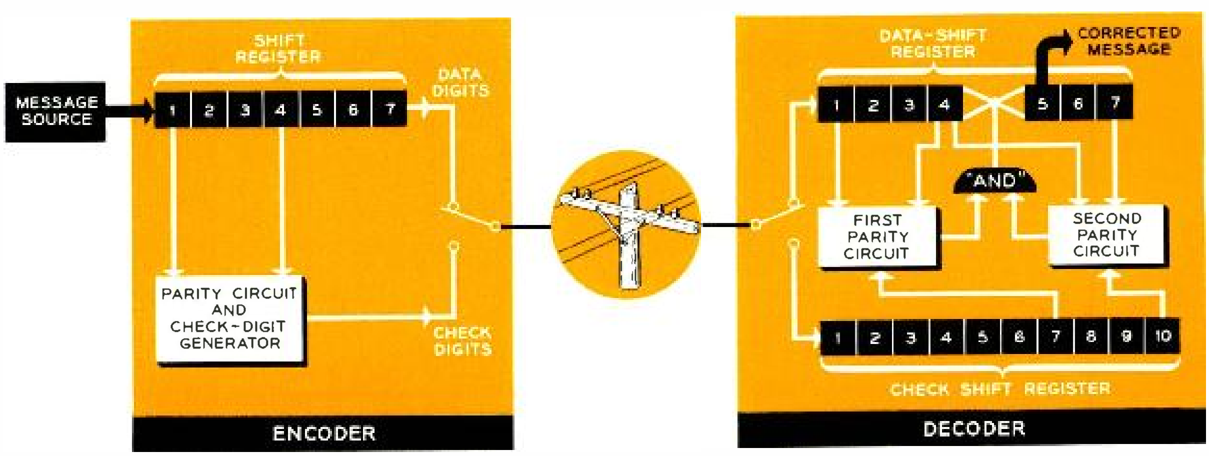
The check digit is transmitted just before the data digit in position seven of the shift register. All digits in the register move up one place and the encoder generates a new check digit. Thus the message appears on the transmission line as a series of alternate data digits and check digits. Note, however, that adjacent digits are not related. Any check digit is involved with data digits several places later in the message.

Decoder

At the other end of the transmission line a "decoder" receives the incoming coded message. This machine immediately separates the check digits from the data digits and sends them to two different shift registers. It is at this stage that the equipment determines if any errors have been incurred during transmission. Furthermore, this is where any errors are corrected — the "0's" are changed to "1's" or the "1's" changed to "0's."

The decoder contains two copies of the parity checking circuit. In the first circuit, it checks the parity relationship of the data digits in positions one and four and the checking digit in position seven. In the second circuit, it checks a similar relationship between data positions four and seven and checking position ten. In the absence of error, of course, the sum will in each case be either "0" or "2"— the parity will be even.

To determine if an error has been made on any one digit, the equipment must look at both parity circuits. If either or both of the two checking patterns show the "expected" digit — that is, even parity relationships — then the digit in position four is correct. If only the second check-



Block diagram of arrangement and operation of the encoder and the decoder used in the error correcting code. Note in decoder that the data digits are inverted in going from position four to five only if both parity circuits are odd. This is the "correcting" step of the new coding method.

ing pattern shows an error, then the checking digit in position ten is wrong — this however, does not affect the message. Also, if only the first checking pattern shows an error, either the data digit in position one or the checking digit in position seven is wrong. But again no action is necessary because the data digit will be tested again when it reaches position four.

On the other hand, if both circuits show an error, then one has indeed occurred. The equipment corrects this error by changing the data digit in position four as it is shifted to position five. In other words, if neither of the two checking circuits indicates either "0" or "2," then we know that the data digit in position four is wrong and we therefore change it as it moves to position five.

The new error-correcting code may be adjusted in two ways, according to the number and type of errors that occur on any given transmission line. First, the length of the burst handled may be increased. This will, however, increase the guard space, or "clean data" section necessary between bursts. The code of our example, which can handle bursts of 6 digits or less, requires a guard space of 19 consecutive digits without an error. If the burst capability is increased to 8 or fewer digits, the guard space requirement increases to 25 error-free digits.

Redundancy Adjustment

The second adjustment of the code involves its redundancy. Instead of placing a check digit after each data digit, the equipment may place it after every second, third, or at any chosen interval. However, this requires more complicated and more costly terminal equipment. In addition, lowering the redundancy also increases the guard-space requirement.

An extra piece of equipment may be attached to the decoder as a warning device. This usually sounds or flashes an alarm whenever a group of errors exceeds the number the equipment was designed to handle. The person receiving the message can then have that portion of it re-run.

Laboratories engineers have built a device to demonstrate the use of the code. This equipment has a punched-tape reader, an encoder, a transmission line, a decoder and a tape printer. Digits in the encoder, transmission line, and decoder are displayed on lamps, and with switches in the transmission line an operator can deliberately insert errors in the encoded message. Thus he can demonstrate the code at any step in the procedure by the lamp displays.

The author with the code-demonstrating device. Lamp displays demonstrate the code at any step in procedure of correcting errors in data signals.

Other engineers at the Laboratories have built experimental equipment for testing these codes on actual telephone lines. The apparatus is flexible so that codes for different burst lengths and redundancies can be tried.

Data transmission is a field of communications that is growing rapidly. Therefore, it is becoming increasingly important to bring under control the problem of electrical noise. An error-correcting code is one way to meet this problem.

One of the many versatile communication services offered by the Bell System is mobile telephony. To expand this service, particularly in metropolitan areas where the "air is crowded", engineers at Bell Laboratories have developed new radio equipment for mobile-telephone service in the 150- to 160-mc frequency band.

D. D. Sagaser

New Equipment For Mobile Telephones

American people like to ride and like to talk. Proof of this fact is the tremendous use we make of the automobile and the telephone. Yet, when he is in his car, the busy telephone customer is sometimes isolated from his normally accessible telephone contacts. To serve this potentially large number of mobile customers, the Bell System, since 1946, has offered mobile telephone service (RECORD, *July*, 1946; *April*, 1950).

Mobile telephone service is essentially a two-way radio connection between a telephone in the customer's vehicle and the regular Bell System telephone network. The sketch on the next page shows in simplified form how a typical mobile-telephone system is arranged. With a telephone handset connected to a radio transmitter (and receiver) in his car, the customer contacts (or is contacted by) the mobile-service operator through a "base station." She then handles his call through a connection to the regular "land-line" telephone switching and transmission facilities.

At the present time, the Operating Companies that serve certain metropolitan areas can supply this service to only a small fraction of their potential customers, because the number of mobile telephones is limited by the radio frequencies available to the Bell System for this use. Until early 1958, only nine channels in the 30- to 44-megacycle band and six channels in the 152- to 162-megacycle band were assigned to this service. Six additional channels, in the 450- to 460-megacycle band, were not used because suitable equipment was not available.

To help the Operating Companies put these channels to use, Bell Laboratories undertook the development of new transmitter and receiver equipment for the base stations. The principal items of base-station equipment developed were one hundred-watt and fifteen-watt transmitters, a receiver package containing one to three receivers, and filters of the coaxial-cavity type. The other necessary items of radio equipment — mobile units for customers' vehicles — were made available through arrangements with manufacturers of radio sets. Generally, the manufacturers provided versions of their standard equipment, modified to meet the special requirements of the Bell System.

The Northeast Electronics Corporation of Concord, N. H., assisted transmission engineers at the Merrimack Valley location of the Laboratories in the development of the 450-mc system. Under the direction of Bell Laboratories, Northeast did most of the evaluation of outside suppliers' equipment, and built and tested developmental models of the base-station equipment.

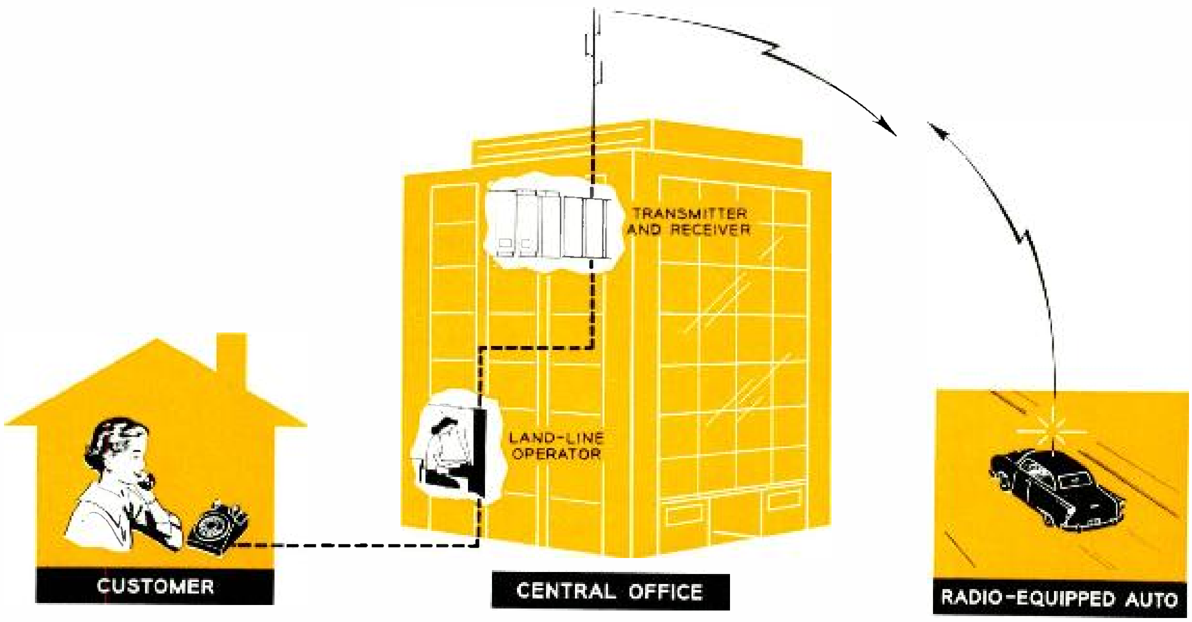
As the accompanying sketch of a typical mobile telephone system shows, the transmitters at the base station are mounted side-by-side, and the antennas are mounted in close proximity on a common mast. This arrangement minimizes differences in the strengths of received signals at receiving locations on the different channels, minimizes adjacent-channel interference, and maintains a unified equipment layout. The physical association of the transmitting equipment, however, causes the greatest single difficulty in the operation of a multi-unit transmitting system — the suppression of inter-modulation products generated in the non-linear stages of the transmitter.

Intermodulation occurs when the output of one transmitter couples into the circuits of another transmitter, either by way of the antennas or directly between cabinets. The two primary output frequencies then mix to form a third frequency that falls exactly in another channel. This third frequency — a spurious emission — may cause interference in another radio system (one allotted for another communication purpose), or it may make one of the idle channels of the mobile telephone system appear "busy."

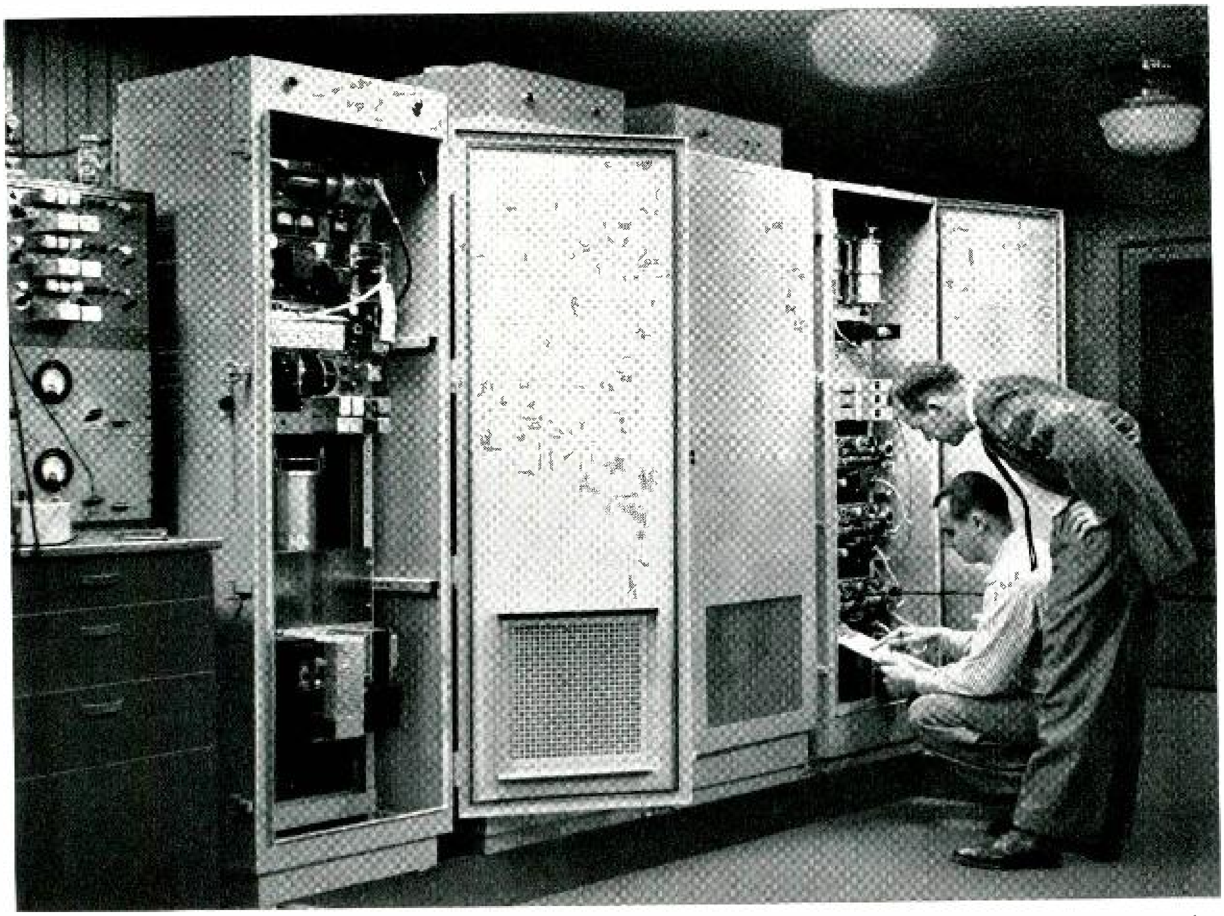
Intermodulation Prevention

To prevent this type of interference between radio systems, the Federal Communications Commission has established requirements on such spurious emissions from transmitters. These requirements are met in the new multi-transmitter, mobile radio installations by minimizing the coupling between transmitters. This is done in four ways: (1) judicious assignment of the antennas on the common mast, (2) extremely sharp filtering in the transmitter outputs, (3) electrical shielding of the transmitter cabinets, and (4) filtering of all leads into the cabinet.

These measures prevent intermodulation products generated during transmission from interfering with other radio systems. Unwanted frequencies can still cause interference within the mobile-telephone channels, however, if the vehicles happen to be close to the transmitter. To prevent this, the transmitter can use what is termed "coordinated FO operation."



This sketch shows broadly how mobile telephone service works. Customer's car is equipped with radio equipment for both transmitting and receiving. These are generally located in the trunk, and the telephone is mounted on the dashboard. The connection from the "regular" telephone customer to the central office is established over standard Bell System links. Antenna is centralized.



Photograph inside the "test shack" used in trials of new radio equipment, showing the general arrangement of the transmitters and receivers. *The author, standing, and a Northeast Electronics Corporation engineer are checking a receiver. Cavity-type receiving filter is at top of the cabinet.*

This merely means that when any one transmitter is broadcasting, the idle transmitters are also placed on the air, but without modulation. Unmodulated transmission quiets the receivers on all idle channels, and prevents "false busy" signals from being generated by intermodulation in the transmitters or in the receivers. In the 100-watt transmitter, the "FO" operation is at a reduced power level of about one watt.

The Radio Transmitter

The 100-watt transmitter consists of a 450-mc exciter unit (a transmitter with a 15-watt output), a 100-watt power amplifier, a trunk-termination panel, a power-control panel, and mounting arrangements for the coaxial-cavity filters. The general arrangement of the transmitters and receivers and the cabinet structure are shown in the photograph above. Sponge-metal gaskets on the front and rear doors of the shielded cabinet insure intimate contact with the cabinet proper, and therefore insure adequate electrical shielding when the doors are closed. A thermostatically operated exhaust fan cools the equipment. Filters for the audio, control and power leads are also part of the cabinet.

Wherever possible, the designers of the transmitters took advantage of existing equipment available from outside suppliers. The 450-mc exciter unit, for example, is manufactured by the Radio Corporation of America, and is a modification of one of their standard designs. The 100-watt power amplifier, supplied by the Communications Engineering Company, was also adapted from an earlier design.

The trunk-termination panel in the transmitter serves the important function of connecting the radio portion of the system to the standard telephone facilities. Specifically, the panel terminates the telephone line from the remote-control terminal, and separates the voice signal to be applied to the modulator in the exciter from the dc control signals, which are also transmitted over the telephone trunk.

A polarized, multi-contact relay on this panel permits remote control of the transmitter. This relay acts from signals on the control lead of the trunk: a positive signal causes the transmitter to be keyed, and a negative signal disables it. The circuits controlling "FO" operation and local operation of the transmitter are also located on this panel.

Power-Control Panel

The power-control panel in the transmitter has several functions. It contains the switches and fuses for controlling primary ac power, serves as a mount for a blower for cooling the output stages of the exciter, controls two lights on the outside of the cabinet that indicate operation at full power (100 watts) or reduced "FO" power (1 watt), and contains the "carrier on" indicator circuit. This circuit sends a dc signal over the trunk to the land-line control terminal to indicate to the telephone operator there that the transmitter is operating. The signal that actuates the carrier-on circuit is a rectified sample of the transmitter output.

The 15-watt transmitter is similar to the 100-watt unit except that there is no power amplifier and the exciter output is used directly. Also, the output power is not reduced for "FO" operation.

The Receivers

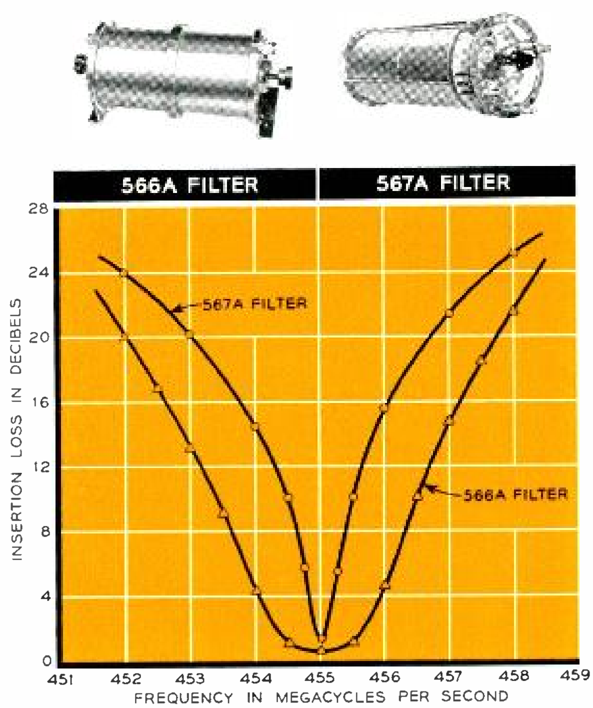
The other major units of the base-station equipment — the receivers — are packaged in the same type of shielded cabinet as the transmitters. Electrical shielding is less important for the receivers, but it does improve operation when the receiver cabinet is located very close to the transmitters. One, two or three receivers are mounted in a cabinet, along with an antenna coupler when more than one receiver is used. There is also a trunk-termination panel for each receiver, a power-control panel, and mounting arrangements for the coaxial filters.

These receivers, which are of the crystal-controlled, FM type, are manufactured by RCA and are adaptations of that Company's commercial 450-mc receiver. A single antenna coupler can connect as many as four receivers to a single antenna, without the loss that would be incurred if the receiver inputs were merely connected in parallel. It is also possible to connect together several antenna couplers, each feeding up to four other units (receivers or couplers), so that many receivers can be linked to one antenna. The coupler units are manufactured by Motorola, Inc.

A voice signal from the output of a base-station receiver is combined with the dc supervisory signal from the carrier-operated relay in the receiver, and is then transmitted to the control terminal. This supervisory signal indicates to the mobile-service operator that the carrier frequency from a vehicular transmitter is being received, and that the mobile telephone customer is requesting service. The components for combining the voice signal and the dc signal are mounted on the trunk-termination panel in the receiver cabinet.

As in the transmitter, frequency interaction between receivers can cause difficulties in radio reception. In this case, however, the interaction is between receivers within a cabinet, and if uncorrected, this interaction would cause false signals to be received by the telephone operator. This undesirable operation of the receivers is controlled by judicious shielding, and by filtering all leads entering the individual receiver chassis.

Two separate coaxial-cavity filters were developed by Bell Laboratories for the 450-mc system. Response characteristics of the filters, which are very accurately compensated for changes in temperature, are shown in the accompanying set of



Loss vs. frequency curves for the cavity filters developed for the mobile radio equipment. Insets show general appearance of the two filters.

curves, along with photographs of the filters on the preceding page.

The transmitting filter (567A) is a high-Q, loop coupled, half-wavelength type, with a coaxial cavity 6 inches in diameter. The cavity is tunable over the 450- to 470-mc band by varying the length of the resonant cavity.

This filter reduces intermodulation products by virtue of being placed in the transmission line between the transmitter and the antenna. Through a reduction in the amount of antenna coupling between the output circuits of the transmitter, the filters also reduce the magnitude of the intermodulation products and any other spurious output of the transmitter. The filter has rotatable loops to change the bandwidth from 0.35 mc to 0.15 mc at the 1-db discrimination points, and at the same time it maintains a constant, 50-ohm impedance.

Two-Cavity Receiving Filter

The receiving filter (566A) is a two-cavity, in-line structure that uses "aperture-coupling" between the two 4-inch cavities. It is loop-coupled at the input and output. This filter is also tunable over the 450- to 470-mc band, providing a 1.3-mc pass band between the 1-db discrimination points. The filter has less than 1-db loss in the midband, and a loss of more than 25 db at points 5 mc from the midband. Its bandwidth can pass simultaneously all twelve of the base-station receiving frequencies presently assigned in the 450-mc band, since it was designed to be placed in the transmission line between the receiving antenna and the antenna couplers serving several receivers.

This filter prevents the transmitters from overloading the input circuits of the receivers when the receiving antenna and transmitting antennas are mounted in close proximity. Two or more filters may be used when it is desirable to place a single transmitter and receiver on the same antenna. A filter may also be used in the transmitter line to prevent noise from the transmitter from interfering with a receiver that has an antenna close by.

An experimental system composed of a base station with three transmitters and three receivers and two vehicular installations was tested in the Concord, N. H., area. A photograph of this installation appears on this page. The tests included measurements of the areas of satisfactory communications between the mobile units and the base station, measurements of the intermodulation frequencies generated by the system, and measurements of several other indices of system performance. In all cases, these tests showed that the design of the new base-station equipment was adequate for high-quality mobile telephone service.

This new 450-mc equipment is now available to the Operating Telephone Companies. With it, the Bell System is able to offer to a greater number of customers the service and convenience of mobile-radio telephone.

Location of experimental system at Concord, N. H. Antenna mast is in foreground and building housing base-station equipment is in background.

Certain semiconductor devices have characteristics that make them useful in the switching field. Such a device is the p-n-p-n transistor developed at Bell Laboratories. Its special characteristic is its ability to be switched into and held at either one of two stable states.

J. M. Goldey

Two-Terminal p-n-p-n Switches

When the transistor was announced by Bell Laboratories in 1948, many people immediately recognized that it would revolutionize electronics. Even then, it appeared to have innumerable applications in both transmission and switching circuits. These early visions are now coming true, for transistors and related semiconductor devices are now in widespread use.

Recently, Bell Laboratories engineers have developed a new member of the growing family of solid-state devices — a two-terminal p-n-p-n switch. The essential element of this unit is a crystal of silicon which has four alternating conductivity sections.

An electrical switch is a device or circuit having two or more stable states. In the simplest case, a common household light switch for example, there are only two stable states. One of these, "off," presents an infinite or very high impedance to electrical current, while the other, "on," presents zero or very little impedance. A stimulus is required to switch the device from one state to the other.

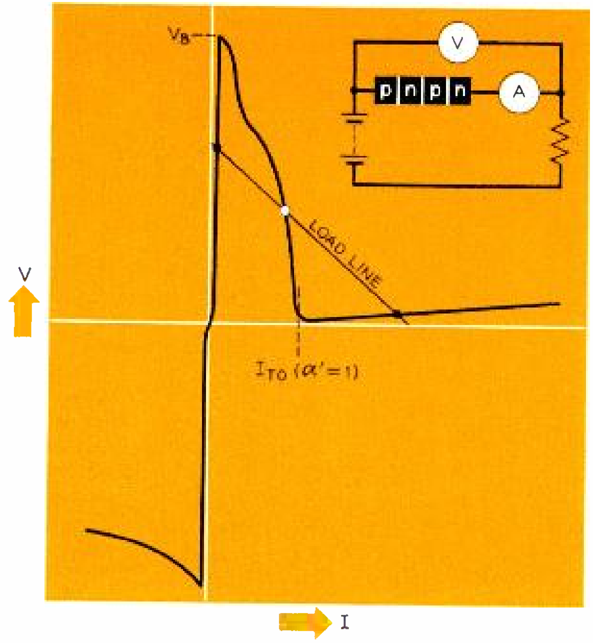
Switches may be classified generally as "non-regenerative" or "regenerative." When a stimulus changes the state of a non-regenerative switch, the new state persists only so long as the stimulus is present. When we operate the button of a doorbell, for instance, the bell rings only so long as the button is pressed in. However with a regenerative switch, the new state is maintained even after the stimulus is removed. This type of switch is "locked" by a mechanical force, as in a household light switch, or by some sort of electrical feedback.

Regenerative Switch

The two-terminal p-n-p-n transistor is a regenerative switch. Its general features can be described with the aid of the first of the accompanying drawings (p. 224). Notice in the figure that if we start at the origin and increase the current through such a switch, the voltage first rises to a maximum then drops and levels out at a fairly low value. Across this curve we draw a "load line," which defines the operating conditions for a particular output or load applied to the device. The three intersections of the load line and the V-I curve identify three operating points of the switch.

Two of these operating points — the heavy black dots on the graph — are stable, one at high impedance ("off") and one at low impedance ("on"). In between, the third operating point — the open circle — is unstable. This unstable state is in a region of "negative resistance" — the voltage decreases as the current increases.

To aid in our understanding of the four-region, three-junction switch, we should recall how a single p-n junction diode responds electrically.



Voltage-current characteristic of a two-terminal p-n-p-n switch. The two stable regions are connected by a region of negative resistance. High impedance state persists for voltages less than the breakdown voltage, V_B. Low-impedance state is maintained when currents greater than the turn-on current (I_{TO}) flow. Both V_B and I_{TO} are designable parameters. Note that device blocks for negative voltages (see third quadrant). Reverse blocking (breakdown) voltage may be larger than V_B.

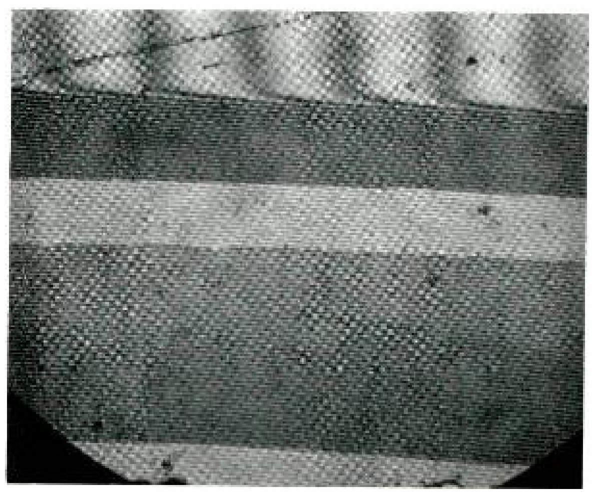
The V-I curve in the condition of reverse bias, or "difficult current flow," for such a device rises to a high value of voltage with negligible current flow. But at a certain voltage, V_B, "avalanche breakdown" occurs (RECORD, *February*, 1958) and the current then increases rapidly with small increases in voltage. On the other hand, in the forward biased or "easy current flow" condition, the current increases rapidly and continuously with the applied voltage.

Junction Bias

Part (a) of the illustration on the next page shows three single-junction diodes in series. For the polarity indicated, the junctions at the two ends are both forward biased, and therefore are of low impedance. The center device, however, is reverse biased and presents a high impedance to current flow when voltages lower than the breakdown voltage are applied. If the interior n and p regions are merged, as in the (b) part of the figure, a single device of p-n-p-n structure results. Now, as long as the interactions between the outer junctions and the inner junction remain small, the p-n-p-n structure acts like the three separated single-junction devices to maintain a high impedance characteristic. This characteristic is shown by the solid line of part (d) of the figure.

In essence, we want to retain this "off" aspect of a reverse-biased diode, but in addition find a way to turn it "on," into a stable state of low impedance. This "on" state is like a forward-biased diode — one with a potential applied in the direction of "easy current flow." In other words, what we want is the seemingly impossible: a type of diode that can be either reverse biased or forward biased with the same direction of current flow.

The p-n-p-n device can perform this feat if the restriction of negligible interaction between the junctions is removed. When the interaction between junctions is small, the interior n-region is essentially devoid of holes, and similarly, the interior p-region contains only a few electrons. (These regions are known as the n-type base and p-type base respectively.) If the interaction between junctions is very large, however, a large number of injected holes is distributed through-



Top view of a piece of four-region silicon material cut on a bevel of two degrees. An etching process is used here to differentiate, by chemical stain, between the p-type and n-type silicon. Optical techniques (interference of sodium light) permit measurement of the thickness of each layer by counting lines. Distance between each line is a little greater than 10 millionths of an inch. The upper dark region is the top p-region and measures 220 millionths of an inch. The light region is the internal n-region and is 174 millionths of an inch thick. The thickness of the internal p-region measures 522 millionths of an inch.

out the n-type base and a large number of injected electrons is located in the p-type base.

A high concentration of holes in the n-type base effectively short circuits this region for the flow of holes and a high electron concentration in the p-type base similarly short circuits that region for electron flow. Thus, with large junction interaction, the p-n-p-n structure acts like three single-junction devices in parallel, or effectively a single forward-biased junction. This is illustrated schematically in part (c) of the figure on this page. The voltage-current characteristic in this case is shown as the dotted line in part (d) of the illustration.

The p-n-p-n can also be regarded as a conjugate pair of transistors — a p-n-p and an n-p-n connected so that they have a common collector junction. We know that two transistors (or other active devices) can be connected to form a bistable switching circuit. Some sort of feedback, however, is required to produce this characteristic. When two separate devices are used, this is done externally; in the p-n-p-n, feedback comes from the minority carriers in the base regions.

Junction Interaction

Summarizing to this point, we may say that the four-region two-terminal p-n-p-n transistor acts as a reversed biased p-n diode if the junction interaction is small and as a forward biased p-n diode if the interaction between junctions is large. A good switch could be obtained if both these characteristics were combined in a single device. Our problem is to make the junction interaction vary enough and in a controlled way to allow us to choose either of its electrical states.

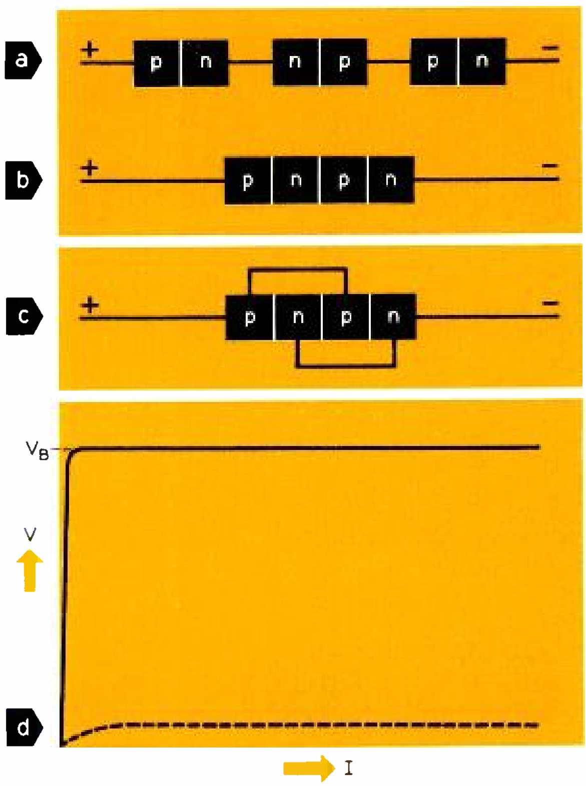
Designers have several methods by which they can vary the junction interaction. One of these makes use of certain imperfections in the crystal that may be produced either chemically or mechanically. These imperfections suppress junction interaction in a semiconductor when low currents flow but permit interaction at moderate and high current levels.

With the aid of these imperfections, the p-n-p-n can be made into a bistable device. At low currents, the interaction is low and the high impedance state results. This high-impedance state is maintained to the breakdown point where the current flow begins to increase rapidly. As the current increases, interaction between the junctions also increases. And when this interaction becomes large enough, the device switches to the low impedance state. The critical value of current is called the turn-on current, and is indicated in the figure on the left-hand page.

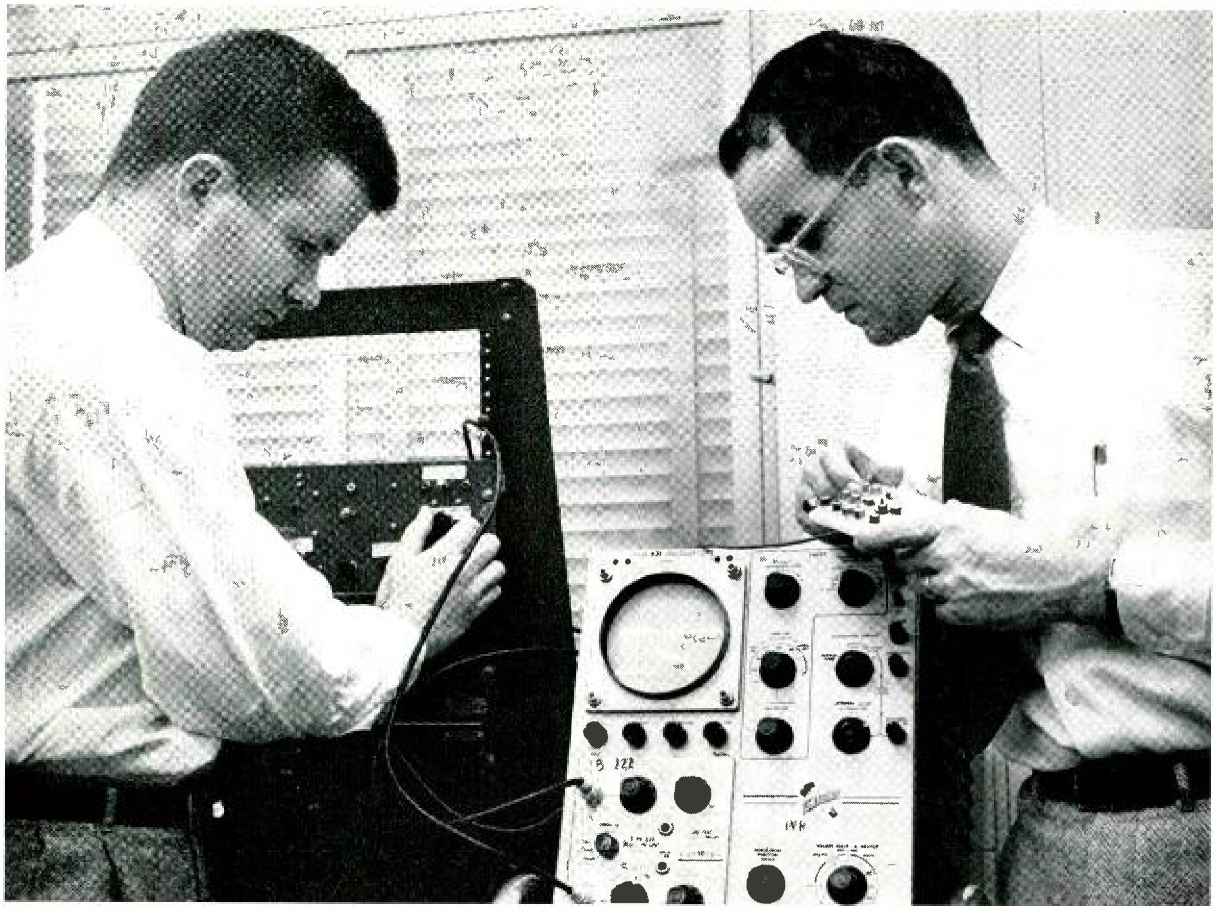
The p-n-p-n transistor can be made of several materials and by a variety of techniques. For many applications, manufacturers use silicon because of its low reverse current and excellent temperature characteristics. Of the several fabrication techniques, perhaps the most desirable at the present is the diffusion process (RECORD, *December*, 1956).

Diffusion Process

This process consists typically of a diffusion of n-type layers into two sides of a p-type silicon wafer followed by a diffusion of a p-type layer on top of one of the n-type layers. Also, in this technique we must insert a controlled number of imperfections so that the turn-on current has the right value. One way to do this is to bombard the silicon with high-energy electrons from an electrostatic generator or a radioactive source. Such bombardment produces the desired imperfections in the form of displaced silicon atoms.



Three single-junction p-n diodes in series (a) furnish V-I characteristic similar to a p-n-p-n device with negligible junction interactions (b); p-n-p-n structure with large junction interaction acts like three parallel diodes (c). In part (d) solid line depicts V-I characteristic when junction interaction is small, dotted line when large.



A. N. Baker, left, and J. M. Goldey study the dynamic response of a typical p-n-p-n transistor.

One use for four-terminal device might be as a talking-path switch in a telephone central office.

The technique is controllable and can be monitored while being carried out. As a result, we can adjust the turn-on current — the parameter most sensitive to the number of imperfections.

The fabrication procedure thus makes use of two highly controllable techniques: (1) solid-phase diffusion process, to produce desired geometries and concentrations of donor and acceptor impurities; (2) high-energy electron bombardment, to give the proper number of imperfections.

Typically, the breakdown voltage of a p-n-p-n transistor, used as a telephone talking path switch, is 50 volts. Both the forward and reverse breakdown voltages are designable, however, and thus devices can be made with many values of these parameters. Similarly, the turn-on current is typically 1 milliamp but controlled high-energy electron bombardment permits this parameter to be adjusted between 50 microamps and 100 milliamps. The speed of this device is such that it can be switched on and off in a fraction of a microsecond.

There are a number of applications for the two-terminal p-n-p-n transistor, in addition to its use as talking path switch in a telephone central office. These include pulse generators, logic elements, and photosensitive devices. In the future, demand for a switch of this type will undoubtedly increase as new applications become apparent.

The familiar neighborhood sight of the telephone construction truck and linemen is undergoing a change. Mechanized equipment, such as the earth auger, has resulted in more efficient procedures for setting poles and stringing wires.

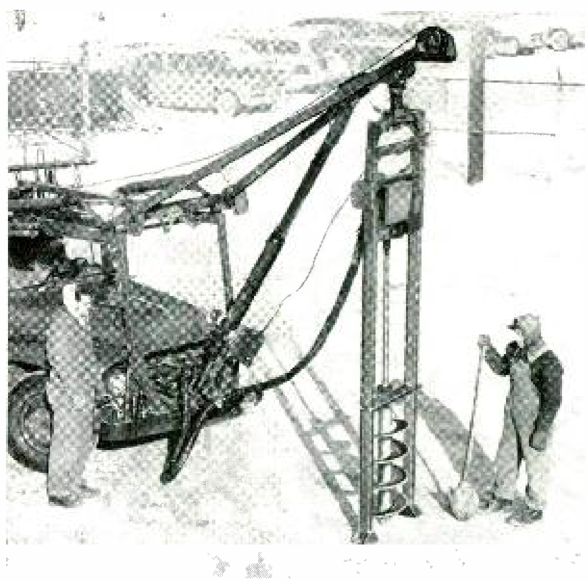
New Methods for Outside Plant Crews

The telephone construction truck with its crew of linemen is a frequent sight to most of us. Some of us, however, may not have noticed that most of these trucks are smaller than they used to be and that fewer men are accompanying them. Until a few years ago, almost all aerial line construction and maintenance work — with the exception of cable splicing — was done by five-man crews using large, elaborately equipped trucks. One of these men was the line foreman. Today, a line foreman often supervises and plans the work for as many as five small line crews, most of which have two men. The two-man crew uses a smaller, more highly specialized truck than did the five-man crew.

Similar changes have been made in the cable-splicing crews. Each cable splicer formerly had a helper, but today more and more, splicers are working alone.

This trend to smaller outside plant crews is an increasing one. In 1953, only 20 per cent of the line crews were of the two-man type. But in 1958 about 75 per cent of all line crews were two-man crews. Solo cable splicers have increased from about 2 per cent of all splicing crews in 1954 to about 60 per cent in 1958.

Many factors have contributed to this trend. In construction work a major factor has been the provision of more power tools. Over a long period of time, combined tool and automotive equipment development has been carried on by Bell System engineers, with the objective of doing more of the work with less manual effort. For instance, setting a pole once required men with shovels to dig the hole and a crew of men with pike poles



Two telephone linemen operating a truck-mounted derrick and earth auger dig the traditional telephone pole hole minus the backbreaking effort.

to raise the pole and set it upright in the hole. Now, however, two men with a truck-mounted derrick and earth auger, both powered from the truck engine, can dig the hole and set the pole in less time and with less fatigue.

As tool development proceeded, more and more outside plant construction work came within the capabilities of smaller crews, until at present there are more two-man than five-man jobs in line construction and maintenance. In addition to pole setting, two-man crews handle a large part of crossarm placing, open wire stringing, guying, and, to a lesser extent, strand and cable placing. However, there are still some construction jobs where large crews are required. Good examples are moving pole lines incidental to a road widening, pulling in underground cables, and retransposing open wire lines for carrier operation. Even in these cases, however, it has been found that combinations of several small crews are often preferable, because of the greater number of power tools thus made available.

The comparative lightness of new rural and urban wire facilities has also contributed to the broader application of the two-man line crew. Formerly, when it was necessary to extend or expand outside-plant circuits, the plant engineer had a choice of bare wire or cable. Now, he may choose either six or twelve pair "Rural Wire" or sixteen-pair "Urban Wire" (RECORD, *May*, 1954; *May*, 1956). These wires are light and are strung under less tension, which makes them suitable for installation by two-man crews similar to the one pictured on this page. The use of light-weight polyethylene instead of lead for sheathing also makes present-day cables easier to handle.

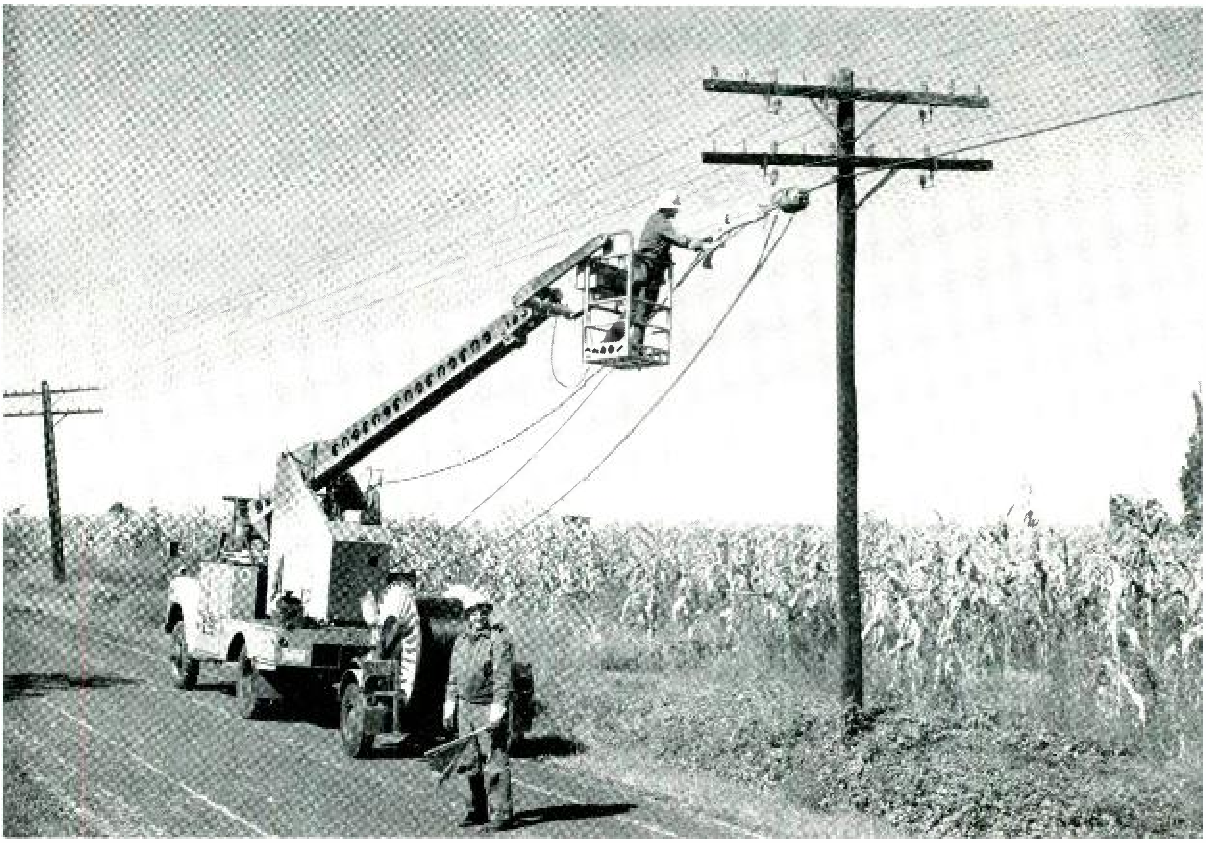
Auger and derrick are powered from truck engine. Truck-mounted derrick swings the prepared telephone pole swiftly and gently into place with no additional strain on two-man crew. These studied innovations help to speed and safeguard work.

The analogous trend — to smaller crews in cable splicing and maintenance work — is again largely the result of new developments in tools and methods. Historically the traditional splicing crew consisted of a splicer and helper, but one-man cable splicing and repairing were started in the cable maintenance field. For example, the development of the insulation-breakdown set, utilizing high voltage to burn in a fault and reduce it to low resistance, provided a one-man method for locating cable troubles. Similarly, the "slit-sheath" repair method, by which a small acetylene torch is used to reclose a lead sheath, produced the complementary repair. These, combined with a much earlier development — the use of a desiccant to absorb moisture in pulp- and paper-insulated cables — made possible the basic ingredients for one-man operation. To these have since been added other developments, such as an exploring coil (for following the tracing tone to a cable fault) designed for handling from the ground, lightweight pole and strand-mounted platforms, ladder supports and platforms that facilitate working from ladders, and a one-man tent to protect work and workmen in bad weather.

Increasing use of solo splicers for cable maintenance work naturally focused attention on the cable splicing part of construction — joining new cables and cutting in new terminals on paper-insulated cable conductors. Splice cases and cable terminals that required no soldering, but were bolted around the cable, were developed (RECORD, *November*, 1954). Not until a man working alone could identify a cable pair, however, was the over-all picture complete.

In joining new lengths of cable and connecting terminals to them, the cable pairs must be identified before being spliced. Formerly, when the splicer cut in each terminal in a new cable not yet in service, the helper was sent to other terminals to place tone on pairs that would appear at the new terminal. By contrast, the solo splicer now connects all the pairs to a simple test set at one end of the cable, and thereafter identifies each pair at any point by resistance measurements.

A test set has also been made available for use on working pairs. This set can be connected by



The new and efficient two-man crew work at the familiar task of stringing telephone cable using the new powered aerial lift. This modern unit is speedily and safely operated from the cage panel.

special plugs to as many as 100 pairs at the main distributing frame of a central office. The splicer in the field, by using a test set and control pair, connects tone to the pair he wishes to identify.

The introduction of cables with polyethylene-insulated conductors that are fully color coded has also favored one-man splicing operations. (*See article on "even-count" cable, page* 208.) This type of cable does not require the restoration of a hermetically sealed enclosure at splices and terminals. The distinctively colored conductors of these cables have materially reduced the need for identifying pairs by electrical testing methods. This combination of features led to the standardization of the "relay-access" type terminal, which one man can install when there is a need to make cable pairs available for service connection.

With the use of smaller line crews and solo splicers, much consideration has been given to the safety of the workman. For this reason, solo splicers have, in general, been used primarily on aerial and buried cable.

Some of the operating companies have recently begun to use one-man splicing crews in underground cable work — but only where a man can work safely alone. In some cases two nearby craftsmen can aid each other. An example of this would be two men working in adjacent manholes on the same cable. In this case, the splicers could aid each other in removing the manhole covers, testing for gas, placing signs, or taking other safety precautions. After the splicers have separated to their respective manholes, they could easily establish a talking path for use in an emergency.

The use of these smaller construction and maintenance crews has had considerable impact on outside plant costs and on the plant personnel. Although this practice has conserved manpower for the companies, it has also required an increase in the capital investment in tools and automotive equipment. An interesting sidelight is that small crew operations seem to have resulted in craftsmen having much greater interest and pride in their work.

J. A. Carr
Outside Plant Engineering

NEWS

W. H. Brattain Elected To National Academy

W. H. Brattain, of the Physical Research Department, has been elected a member of the National Academy of Sciences. Dr. Brattain, one of the 30 scientists just elected to membership for distinguished and continued achievements in original research, was co-winner of the 1956 Nobel Prize in Physics for his part in the discovery of the transistor.

The National Academy of Sciences was established in 1863 as a private, non-profit organization of scientists to advance science and advise the government on scientific and technical matters. Among its members are Dr. J. B. Fisk; H. W. Bode, Vice President — Military Development and Systems Engineering; J. R. Pierce, Director of Research —Communications Principles, and two retired Presidents of the Laboratories, Dr. M. J. Kelly and Dr. O. E. Buckley.

J. A. Morton Elected To Tau Beta Pi

J. A. Morton, Vice President—Device Development, was one of the 21 men recently inducted into Tau Beta Pi, national honorary engineering fraternity, at Wayne State University. The ceremonies took place in Detroit on May 2 at the McGregor Memorial Conference Center.

Mr. Morton, who graduated in 1935 from the University — and has also received from it an honorary degree as well as a distinguished alumnus award — was the featured speaker at a banquet following the induction. He spoke on "The Impact of Military Science and Technology on Economic Security."

Laboratories Members On I.R.E. Committees

A number of Laboratories people are actively engaged in committee work of the Institute of Radio Engineers for the 1959-1960 year. The list of committees and members is an follows:

Standards Committee: J. G. Kreer, Jr., Vice Chairman, M. W. Baldwin, Jr., J. T. Bangert, W. R. Bennett, S. Doba, Jr., Iden Kerney, A. E. Kerwien, and W. T. Wintringham; *Antennas and Waveguides:* R. L. Mattingly, Vice Chairman, and P. H. Smith; *Audio and Electroacoustics:* Iden Kerney, Chairman, F. K. Harvey, F. L. Hopper, and R. E. Yaeger; *Circuits:* J. T. Bangert, Chairman, W. R. Bennett, A. R. D'Heedene, B. K. Kinariwala, and E. H. Perkins; *Electron Tubes:* H. B. Frost; *Electronic Computers:* J. R. Johnson and W. O. Olander; *Feedback Control Systems Committee:* J. C. Lozier; *Information Theory and Modulation Systems:* E. R. Kretzmer, Vice Chairman, and J. G. Kreer, Jr.; *Measurements and Instrumentation:*

D. A. Quarles, Former Vice President of the Laboratories, Dies

Donald A. Quarles, Deputy Secretary of Defense and a former Vice President of Bell Laboratories, died suddenly in Washington, D. C., on May 8.

After a distinguished career in the Bell System, Mr. Quarles was named by President Eisenhower in July, 1953, to be Assistant Defense Secretary for Research and Development. Mr. Quarles was appointed Secretary of the Air Force two years later, and in 1957 was named Deputy Secretary of Defense. At the time of his death, President Eisenhower spoke of Mr. Quarles' "extraordinary talents" in the service of his country. "His contribution," President Eisenhower said, "was of inestimable value to the security not only of the United States but of that of the entire free world."

He attended summer sessions at the University of Missouri, and later enrolled full time at Yale University, from which he was graduated in 1916. He was a member of Phi Beta Kappa and Sigma Xi, honorary scientific society. He also attended Columbia University Graduate School.

In 1919, Mr. Quarles joined the Western Electric Company's engineering department, which in 1925 became Bell Laboratories. Until 1924 he was concerned with transmission engineering and research, and later was in charge of apparatus inspection.

He was made Director of Outside Plant Development in 1929 and became Director of Transmission Development in 1940. He remained in this post until 1944, and during this time, under his direction, the efforts of the Transmission Development Department were largely concentrated on military electronics, particularly radar. In 1944, he was named Director of Apparatus Development and served in this post until his election as a Vice President of the Laboratories in 1947. During his Bell Laboratories career he directed numerous electronic developments of great importance. These included, in addition to his military work, coaxial cable systems for multi-channel telephony and television.

Mr. Quarles was named a Vice President of the Western Electric Co. and President of the Sandia Corporation in 1952, and held those posts until called into government service.

C. D. Owens, Vice Chairman; *Mobile Communication Systems:* N. Monk; *Piezoelectric and Ferroelectric Crystals:* I. E. Fair, Vice Chairman, J. H. Armstrong, W. P. Mason, and R. A. Sykes; *Radio Transmitters:* A. E. Kerwen, Chairman; *Solid-State Devices:* J. M. Early; *Symbols:* E. W. Olcott and R. V. Rice; *Television Systems:* M. W. Baldwin, Jr., and W. T. Wintringham; *Video Techniques:* J. M. Barstow, Vice Chairman, and J. R. Hefele; *Wave Propagation:* A. B. Crawford, Vice Chairman, and K. Bullington.

Laboratories Man Consultant on Science Dictionaries

B. J. Kinsburg, of the Transmission Systems Development Department, has accepted an assignment to serve on a consultant panel on Polytechnic Dictionaries, sponsored by the Engineers Joint Council. The work of this panel is to review material now available and evaluate the need for new or revised polytechnic dictionaries and technical glossaries, with particular emphasis on Russian-English translations.

This project is being undertaken by the Engineers Joint Council under the terms of a grant from the National Science Foundation. Each member of the panel has individual knowledge of specific fields of translation or use of foreign literature, especially in connection with the material emanating from the U.S.S.R.

Contents of March 1959 Bell System Technical Journal

The March 1959 Bell System Technical Journal contains the following articles:

The Three-Level Solid State Traveling-Wave Maser, by R. W. DeGrasse, E. O. Schulz-DuBois and H. E. D. Scovil.

Use of Active Material in Three-Level Solid State Masers, by E. O. Schulz-DuBois, H. E. D. Scovil and R. W. DeGrasse.

Engineering Aspects of TASI, by K. Bullington and J. M. Fraser.

System Design of the Flying Spot Store, by C. W. Hoover, Jr., G. Haugk and D. R. Herriott.

Optics and Photography in the Flying Spot Store, by M. B. Purvis, G. V. Deverall and D. R. Herriott.

Beam-Positioning Servo System for the Flying Spot Store, by L. E. Gallaher.

Stable High-Speed Digital-to-Analog Conversions for Storage Tube Deflection, by C. F. Ault.

Verification of the Logic Structure of an Experimental Switching System on a Digital Computer, by D. C. Leagus, C. Y. Lee and G. H. Mealy.

Nonuniformities in Laminated Transmission Lines, by G. Raisbeck.

An Experimental Clogston 2 Transmission Line, by Mrs. R. A. King.

Fundamental Processes of the Short Arc, by J. L. Smith and W. S. Boyle.

A Method for Computing Bivariate Normal Probabilities, by D. B. Owen and J. M. Wiesen.

The Anelasticity of Natural and Synthetic Quartz at Low Temperatures, by J. C. King.

Acoustical Society Honors E. C. Wente

E. C. Wente, for nearly forty years engaged in research on acoustics and acoustical instruments at Bell Laboratories, was recently awarded the Gold Medal of the Acoustical Society of America as a "distinguished contributor to the science of acoustics." The award was conferred by Dr. J. C. R. Licklider, president of the society, on May 16 in Ottawa, Canada.

Mr. Wente has been granted 36 patents for his inventions in many fields of acoustics, one of the best known being the condenser microphone. He retired from the Laboratories in 1954.

D. P. Ling Appointed To N.A.S.A. Committee

The Administrator of the National Aeronautics and Space Administration, T. Keith Glennan, recently appointed D. P. Ling, Director of Military Analysis, to serve on N.A.S.A.'s Research Advisory Committee on Control, Guidance and Navigation. N.A.S.A. Committee memberships are composed of representatives of scientific, industrial, educational, government and military organizations to assure communication and coordination with the entire scientific community.

Members of the committees will play an important role in assisting N.A.S.A. in the formulation of national programs in aeronautical and space research. The groups will review the national research effort now in progress in their fields of interest, recommend problems that should be investigated by N.A.S.A. or other research organizations, and assist in coordinating these research programs.

R. C. Newhouse Honored By Ohio State University

R. C. Newhouse, Director of the Missile Systems Development Department, was one of five Alumni of the College of Engineering at Ohio State University recently honored by the College with the 1959 "Distinguished Alumnus" Awards. The College established these yearly awards in 1954 to recognize distinguished achievement on the part of alumni in the field of engineering by reason of significant inventions, important research or design, administrative leadership or genius in production.

The Certificate of Award presented to each recipient designates him as a "Distinguished Alumnus in recognition of his eminence as an engineer who has achieved a record of outstanding contributions to the advancement of engineering and of related fields of activity."

W. H. Brattain, H. D. Hagstrum Visiting Lecturers

Two members of the Physical Research Department, W. H. Brattain and H. D. Hagstrum, recently served as visiting lecturers at three universities. Several lectures and talks were given at each school and discussions were held with faculty and students. The visits were made under the auspices of the American Association of Physics Teachers and the American Institute of Physics as part of a broad, nationwide program to stimulate interest in physics. The program is now in its second year.

Mr. Hagstrum lectured at the St. Lawrence University, Canton, New York, on April 21 and 22, and at Hamilton College, Clinton, New York, on April 27 and 28. Mr. Brattain spoke at the University of Utah in Salt Lake City on April 27-28.

Two New Books Written By Members Of Bell Laboratories

Two new books written by members of Bell Laboratories have been published recently.

One of these, *Semiconductors*, edited by N. B. Hannay of the Semiconductor Research Department, is a reference work on the physical chemistry and fundamental physics of semiconductors. It is published by the Reinhold Publishing Corporation.

Contributors to the book include Mr. Hannay, J. J. Lander, C. S. Fuller, Howard Reiss, D. G. Thomas, J. M. Whelan, H. J. Hrostowski, R. G. Shulman, A. R. Hutson, F. J. Morin, and C. G. B. Garrett, all of the Semiconductor Research Department. Also contributing chapters were M. Tanenbaum, C. D. Thurmond of the Metallurgical Research Department and J. N. Hobstetter, formerly of that department and now with the University of Pennsylvania; J. T. Law and T. H. Gaballe of the Physical Research Department; and J. F. Dewald of the Chemical Research Department.

Semiconductors emphasizes basic principles and phenomena, including both the chemical and physical aspects of semiconductor behavior. A number of important semiconducting materials are covered individually, and as thoroughly as present knowledge allows.

The second book is *The Measurement of Power Spectra* by R. B. Blackman of the Mathematical Research Department and J. W. Tukey, Assistant Director of Research — Communications Principles. It is available from Dover Publications.

This book contributes to the understanding of techniques of measurement of the power spectrum. These techniques are frequently used in communications engineering, and are being used more and more in other fields of science and technology such as oceanography, aerodynamics, meteorology, seismology, economics, guided missiles, radar tracking, and acoustics. A deeper insight to these techniques is gained by analyzing them from the combined points of view of the theory of statistical estimation and of transmission theory.

Among the topics treated are: autocovariance functions and power spectra; direct analog measurement; distortion, noise, heterodyne filtering and prewhitening; aliasing; variability and covariability of estimates; rejection filtering and separation; smoothing and decimation procedures; pilot estimation; rejection near zero frequency; and planning for measurement.

Also included are an index of notation and a glossary. Recent developments in the practical applications of Fourier transformation are reviewed in an appendix.

Thermistor Widely Used In Modern Applications

U. S. space vehicles have blasted off their launching pads during the past two years carrying one of the most sensitive temperature-measuring device known to modern science. Yet this space-age "thermometer" — called a "thermistor" — was developed at Bell Laboratories almost a quarter of a century ago and has long been used by the tens of millions in telephone equipment.

It is one of the earliest semiconductor devices, and is an ancestor of the Bell Solar Battery and the transistor, both invented at the Laboratories.

The thermistor — short for "thermal resistor" — was developed to exercise fine control over the levels of speech signals, which the 1930's fluctuated widely with changes in temperature in long-distance conductors. Research men discovered that several metallic oxides had the desired characteristics, and that a pin-head speck of one of them was enough.

The thermistor has a negative temperature coefficient of resistance—its resistance decreases, as temperature increases. Because this response is so reliable, and because the effect is twenty times greater than with platinum wire in a resistance thermometer, scientists now use thermistors for the most precise measurements.

Thermistors are ideal for space flights because they are also small and rugged, and because they provide a continuous temperature reading in the form of an electrical signal that can be radioed back to earth. Scientists report that some U. S. space probes and satellites have carried thermistors and that the Russians have almost certainly used them too.

The Operating Companies use the thermistors as automatic volume regulators in carrier systems, as surge eliminators at PBX switchboards, and as temperature regulators.

Capacity Increased for Floating Zone Refiners

A striking improvement in the technique of purifying metals was described recently by W. G. Pfann and K. E. Benson of the Metallurgical Research Department, and by D. W. Hagelbarger of the Communication Techniques Research Department. They reported their results to the American Physical Society at a meeting held in Cambridge, Massachusetts on April 1. The new technique substantially increases the volume of material that can be purified by the floating zone method and, paradoxically, also makes it possible to treat much thinner cross sections.

Zone refining of metals, chemicals and semiconductor materials was invented at Bell Laboratories by Mr. Pfann (RECORD, *June*, 1955). This technique takes advantage of the fact that most impurities are more soluble in molten than in solid material. Therefore, a molten zone traveling along an ingot will pick up impurities and carry them to the end of the ingot.

H. C. Theuerer, of the Metallurgical Research Department subsequently overcame one of the limitations of the original process—contamination by the crucible holding the material. He did this by eliminating the crucible in a method called "floating zone" refining (RECORD, *September*, 1957).

The floating zone technique has proven highly valuable in producing extremely pure crystals of silicon and reactive metals. However, it has been limited to use with small amounts of material.

In conventional floating zone refining, a rod of the material to be purified is held in a vertical position, while a zone is melted by some source of heat. The molten zone is held in place within the rod by its own surface tension. The zone is then made to move along the rod, and the impurities which collect in the molten material move to one end.

The conventional method has been primarily limited by the fact that for any given material, there is a maximum height of molten zone that surface tension can support. Rods with small diameters can be melted through easily without exceeding this maximum height. By the time a rod with a large diameter has been melted through, however, the zone has become so high that the surface tension can no longer hold the molten material.

The new method gets around this difficulty by using specially shaped cross sections, such as are inherent in flat plates or tubes. These shapes provide a cross section thin enough to permit melting through without exceeding the maximum height, and yet wide enough to increase the total cross-sectional area treated. The researchers have shown that molten zones in such shapes are surprisingly stable.

For example, it is extremely difficult to produce a stable molten zone in an iron rod one-inch in diameter. This is because the maximum height of the zone is generally exceeded during the heating required to melt through the rod. However, we can put the iron in the form of a *tube*, two inches in diameter, with a ⅛-inch wall, and can melt the entire cross section without exceeding the maximum height. In both forms the areas are the same.

In the rod floating zone method, as the diameter of a rod decreases, the maximum supportable height of the molten zone also decreases. With the new method, however, this decrease in zone height can be avoided. Hence, treatment of sheets in the order of mils or less in thickness becomes possible.

Stable, wide molten zones have been maintained experimentally in both cross-sectional shapes in several materials. These include silicon, iron, tin, gold, lead, and bismuth.

Laboratories scientists believe it feasible to increase at least five to ten times the cross-sectional areas currently used. Also, this new wide-zone technique should make the floating zone method applicable to materials for which the conventional method was not heretofore practical. This new technique should greatly enhance the floating zone principle in purifying reactive materials.

K. E. Benson (left) positions tubular sample of iron in an induction heating coil while W. G. Pfann looks on. Experiment will then proceed to produce stable molten zones in a large cross section structure.

PAPERS

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

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Alley, R. E., Jr., *In-Pile Measurements of Radiation Effects In Magnetic Materials*, J. Appl. Phys., 30, pp. 284S-285S, April, 1959.

Bateman, T. B., McSkimin, H. J., and Whelan, J. M., *Elastic Moduli of Single Crystal Gallium Arsenide*, J. Appl. Phys., 30, pp. 544-545, April, 1959.

Boyle, W. S., and Rodgers, K. F., *De Haas van Alphen Type Oscillations in the Infrared Transmission of Bismuth*, Phys. Rev., Letters, 2, pp. 338-339, April 15, 1959.

Crawford, R. V., *Transmission Tests on a Trial System of Telephone Service for Aircraft*, I.R.E. Transactions on Vehicular Communications, PGVC-12, pp. 20-26, April, 1959.

Dail, H. W., see Galt, J. K.

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

Geschwind, S, and Walker, L. R., *Exchange Resonances in Gadolinium Iron Garnet Near the Magnetic Compensation Temperature*, J. Appl. Phys., 30, pp. 163S-170S, April, 1959. (Supplement)

Gilleo, M. A., and Geller, S., *Magnetic-Ion Interaction in $Gd_3Mn_2Ge_2GaO_{12}$ and Related Garnets*, J. Appl. Phys., 30, pp. 997S-298S, April, 1959. (Supplement)

Gilleo, M. A., and Mitchell, D. W., *Magnetic Properties of Substituted Manganese-Tin Spinels*, J. Appl. Phys., 30, pp. 20S-21S, April, 1959. (Supplement)

Haszko, S. E., see Van Uitert, L. G.

Lovell, L. C., and Wernick, J. H., *Dislocation Etch Pits and Polygonization in High-Purity Copper*, J. Appl. Phys., 30, pp. 590-592, April, 1959.

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McIlroy, M. D., *Linear Deformations of Conical Shells*, J. Aero/Space Sciences, 4, pp. 253-254, April, 1959.

McSkimin, H. J., see Bateman, T. B.

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Miller, Robert C., and Savage, A., *Direct Observation of Anti-Parallel Domains During Polarization in Single Crystal Barium titanate*, Phys. Rev., Letters, 2, pp. 294-296, April 1, 1959.

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

Och, H. G., see Tinus, W. C.

Pearson, G. L., and Riesz, R. P., *High Speed Switching Diodes from Plastically Deformed Germanium*, J. Appl. Phys., 30, pp. 311-312, Mar., 1959.

Peter, M., *Millimeter Wave Paramagnetic Resonance Spectrum of 6_S State Impurity* (Fe^{+++}) *in $MgWO_4$*, Phys. Rev., 113, pp. 801-803, Feb. 1, 1959.

Phillips, J. C., *Vibration Spectra and Specific Heats of Diamond-Type Lattices*, Phys. Rev., 113, pp. 147-155, Jan. 1, 1959.

Remeika, J. P., see Sherwood, R. C.

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Rodgers, K. F., Jr., see Boyle, W. S.

Runyon, J. P., *Book Review of Switching Circuits and Logical Design*, J. Association for Computing Machines, 6, No. 1, Jan., 1959.

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Slichter, W. P., *Molecular Characteristics of Rubber-Like Materials*, J. of Chemical Education, 36, pp. 185-190, April, 1959.

Sobel, M., and Tischendorf, J. A., *Acceptance Sampling with New Life Test Objectives*, Proc. of Fifth National Symposium on Reliability and Quality Control, pp. 108-118, Jan. 12-14, 1959.

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Whelan, J. M., see Bateman, T. B.

Yager, W. A., see Galt, J. K.

Zammataro, S. J., *The Role of Electrical Measurements in Industry*, Proc. of A.I.E.E. Third National Conference, Analog and Digital Instrumentation, T-113, pp. 18-25, Mar., 1959.

TALKS

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

135TH NATIONAL MEETING, AMERICAN CHEMICAL SOCIETY, BOSTON, MASS.

Anderson, E. W., see McCall, D. W.

Ballman, A. A., see Laudise, R. A.

Batterman, B. W., *An X-Ray Measurement of the Atomic Scattering Factors of Copper and Iron.*

Bott, Mrs. M. C., see Garn, P. D.

Garn, P. D., and Bott, Mrs. M. C., *The Determination of Anthraquinone in Capacitor Dielectrics.*

Hawkins, W. L., Matreyek, W., and Winslow, F. H., *The Effect of Temperature on the Oxidation of Polyolefins.*

Laudise, R. A., and Ballman, A. A., *Hydrothermal Synthesis of Zinc Oxide and Zinc Sulfide.*

McCall, D. W., and Anderson, E. W., *The Electrical Properties of Polyamides.*

Matreyek, W., see Hawkins, W. L.

Slichter, W. P., *Chain Flexibility in Solid Polymers.*

Thomas, C. O., *Ultramicro Gas Analysis with a Gas Dilatometer.*

Thurmond, C. D., see Trumbore, F. A.

Trumbore, F. A., and Thurmond, C. D., *Calculation of Heats of Solution from the Temperature Dependence of the Distribution Coefficient.*

Winslow, F. H., see Hawkins, W. L.

EASTERN PSYCHOLOGICAL ASSOCIATION, ATLANTIC CITY, N. J.

Bruce, Miss S. E., see Deininger, R. L.

Deininger, R. L., and Bruce, Miss S. E., *The Components of Variance Attributable to the Stimuli and the Mode of Stimulus Display in a Key-Pressing Task.*

Pierce, J. R., see Riesz, R. R.

Riesz, R. R., and Pierce, J. R., *Zipf's Law and Reading Time.*

Rothkopf, E. Z., *A Measure of Association Overlap (AO) Among Stimuli and Substitution Errors in Paired-Associate Learning.*

Shepard, R. N., *The Immediate Memory Capacity for Words, Sentences, and Pictures.*

OTHER TALKS

Beach, A. L., and Guldner, W. G., *The Effect of Evaporated Films on the Recovery of Gases Evolved During Vacuum Fusion Analysis*, Conference on Analytical Chemistry Symposium on Gases in Metals, Pittsburgh, Pa.

Becker, J. A., *Study of Surfaces by Using New Tools I — Ion Gauge and Mass Spectrometer; Study of Surfaces by Using New Tools II — Field Emission Microscope; and Theoretical Concepts of Adsorption and Reaction Kinetics*, Stanford Research Institute, Menlo Park, Calif.

Becker, J. A., *Some Adsorption Characteristics of H_2 and C_2H_4 on Single Crystals of Tungsten*, U. of California, Berkeley, California.

Becker, J. A., *Study of Surfaces by Using New Tools I — Ion Gauge and Mass Spectrometer*, U. of California, Livermore, Calif., and Linfield Research Institute, McMinville, Oregon.

Becker, J. A., *Can Individual Molecules Be Seen in the Field Emission Microscope?* U. of Notre Dame, Ind.

Bennett, W. R., *Laplace Transforms*, N. Y. Sections of I.R.E. and A.I.E.E., New York City.

Bomba, J. S., *Some Problems in Machine Recognition of Visual Characters*, Electrical Engineering Department Seminar, Columbia University, New York City; Princeton University, N. J.

Bradley, W. W., *Corrosion Problems and Preventive Measures in the Telephone System*, Newark College of Engineering.

Brady, G. W., *Structure in the Liquid State*, Department of Chemistry, New York University, New York.

Brady, G. W., *Structure in Salt Solutions*, Department of Chemistry, U. of Cincinnati, Cincinnati, Ohio.

Brattain, W. H., *Physics of Semiconductor Surfaces*, Boston Section, Electrochemical Society, Boston, Mass.

Brattain, W. H., *Some Circuit Properties of Transistors* and *Related Phenomena*, Bryn Mawr College, Bryn Mawr, Pennsylvania.

Brattain, W. H., *Development of Concepts in Semiconductor Research and Physics of Semiconductor Research*, U. of Utah, Salt Lake City, Utah.

Brattain, W. H., *Man and the Universe — How Much Does He Know?* Whitman College, Walla Walla, Washington.

Braunwarth, W. W., *Careers in the Physical Sciences*, Madison High School, Madison, N. J.; Wray Junior High School, Gastonia, N. C.

Chapin, D. M., *The Theory and Engineering of the Bell Solar Battery*, Engineer's Club of Philadelphia, Pa.

Cutler, C. C., *Radio Communication by Means of Satellites*, Pittsburgh Section, I.R.E., Mellon Institute, Pittsburgh, Pa.

Drenick, R. F., *Industrial Application of Mathematics*, Meeting of the American Mathematical Association, Lehigh University, Bethlehem, Pa.

Evans, H. W., *Rain Attenuation at 11 kmc*, Cincinnati Section, I.R.E.

Frost, H. B., *Titanium as an Anode Material*, M.I.T., Physical Electronics Conference, Cambridge, Mass.

Geschwind, S., *Paramagnetic Resonance of Fe^{3+} Impurity in Octahedral and Tetrahedral Sites in Yttrium Gallium Garnet*, New York University, New York City.

Gilbert, E. N., *Variable Length Binary Encodings*, Polytechnic Institute of Brooklyn, N. Y.

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

Gupta, S. S., *Selecting a Subset Containing the Best of Several Binomial Populations*, Regional Meeting of the Institute of Mathematical Statistics in Pittsburgh, Pa.

Hagstrum, H. D., *How Does the Physicist Provide His Research Tools? The Role of the Basic Scientist in Industry;* and *The Interaction of Positive Ions with Solid Surfaces*, St. Lawrence University, Canton, N. Y.; and Hamilton College, Clinton, New York.

Hamming, R. W., *Frontiers in Computer Technology*, Mid-Continent Computer Club, Chicago, Ill.

Hamming, R. W., *Fundamentals in Applications of Machines*, Norden Labs, White Plains, N. Y.

Harvey, F. K., *The Physics of Hearing and Music*, Westinghouse Auditorium, New York, N. Y.

Hawekotte, R. M., *Summary of Path Loss Measurements on Tropospheric Beyond-Horizon Radio Paths*, Arctic Communications Conference, National Bureau of Standards, Boulder, Colorado.

Henneberger, T. C., *Planning and Programming in Bell Telephone Laboratories*, Wright-Patterson Air Force Base, Ohio.

Herbert, N. J., *The Impact of the Transistor on Electronics*, Torch Club of the Lehigh Valley, Easton, Pa.

Hershey, J. H., *Reliability and Maintainability of Military Electronic Equipment*, U. S. Army Signal Equipment Support Agency, Fort Monmouth, N. J.

Honaman, R. K., *"What's Ahead in Communications?"* Mercury Club, Kansas City, Missouri.

Huyett, Miss M. J., see Lundberg, J. L.

Kohman, G. T., *Hydrothermal Crystallization*, Fairfield County Chemical Engineering Society, Stamford, Conn.

Kompfner, R., *New Microwave Amplifiers*, Westinghouse Research Laboratories, Pittsburgh, Pa.

Ling, D. P., *Space Communications*, New York Section, A.I.E.E., Communication Division, New York City.

Lohmiller, R. V., *Nike-Ajax and Hercules Missile Systems*, Mid-Michigan Section of Society of Automotive Engineers, Bay City, Mich.

Lundberg, J. L., Wilk, M. B., and Huyett, Miss M. J., *Diffusivities and Solubilities of Methane in Polyethylene*, Am. Physical Society, Cambridge, Mass.

Luongo, J. P., *Infrared Investigation of the Molecular Changes Occurring in Polyethylene During Oxidation*, Pittsburgh Conferences on Applied Spectroscopy, Pittsburgh, Pa.

MacColl, L. A., *Topological Aspects of the Restricted Three-Body Problem*, Research Inst. for Advanced Sciences, Baltimore, Md.

MacPherson, D. H., *Memory Devices in Computers*, Engineering and Science Exposition, Hofstra College, Hempstead, L. I., N. Y.

Marcuse, D., see Young, J. A.

Mattingly, R. L., *An Extension of the Dolph-Chebyshev Antenna Concept*, Akron Section, Prof. Group on Antennas and Propagation, I.R.E., Akron, Ohio.

May, John E., Jr., *Thickness-Shear Mode $BaTiO_3$ Ceramic Transducer for Ultrasonic Delay Lines*, Ultrasonic Session, I.R.E. National Convention, New York City.

McCann, T. A., *Time Division Data Link*, U. S. Naval Reserve Composite Company, Nos. 3-6, Chatham, N. J.

Meeker, T. R., *Some Elements of Chemical Kinetics*, Ursinus College, Collegeville, Pa.

Miller, S. E., *Millimeter Waves in Communication*, Polytechnic Institute of Brooklyn, Symposium on Millimeter Waves, Engineering Societies Bldg., New York City.

Morin, F. J., *Transition Metal Oxides*, RCA Laboratories, Princeton, N. J.

Morton, J. A., *The Impact of Military Science and Technology on Economic Security*, Worcester Polytechnic Institute, Worcester, Mass.

Morton, J. A., *Motivation and Reward in Science*, 13th Allentown Science Fair, Allentown, Pa.

Nelson, L. S., *Flash Induction of Thermal Reactions*, Am. Chemical Society, Fort Monmouth, N. J.

Nielsen, J. W., *The Growth of Large Single Crystals of Zinc Oxide*, Am. Chemical Society Meeting, Columbia University, New York City.

Ortel, W. C. G., *Nanosecond Logic by Amplitude Modulation at X-Band*, Symposium on Microwave Technique for Computing System, Office of Naval Research, Washington, D. C.

Patterson, H. J., *The Theory, Fabrication, and Application of Semiconductor Devices*, Instrument Society of America, Hartford, Conn.

Pearson, G. L., *Imperfections in Crystalline Solids*, Ohio State University, Columbus, Ohio.

Pfann, W. G., *Purification of Chemicals by Zone Refining*, Meeting of Princeton Section of Am. Chemical Society, Princeton University, Princeton, N. J.

Pfann, W. G., *Recent Developments in Zone Melting*, N. J. Chapter of Am. Chemical Society for Metals, Newark, N. J.

Raisbeck, G., *The Power Carried by Standing Waves*, Stanford University, Stanford, California.

Ruppel, A. E., *Systems Engineering*, Pratt Institute, Brooklyn, N. Y.

Ruppel, A. E., *The DEW Line Story and Civilian Defense*, East Rockaway Village Hall, East Rockaway, New York.

Ruppel, A. E., *The DEW Line Story*, Navigators' Club of the U.S. Power Squadrons, Woodmere Bay Yacht Club, East Rockaway, L. I.

Schawlow, A. L., *Superconductivity*, National Research Council Laboratory, Ottawa, Canada.

Schmidt, P. L., *Use of Semiconductors in Power Supplies*, Morris Radio Club, Morristown, N. J.

Slichter, W. P., *Nuclear Resonance Studies of Motion in Polymers*, Delaware Section, Am. Chemical Society, Wilmington, Del.

Sobel, M., *Group Testing in a Stochastic Faulty Coin Problem; and Acceptance Sampling with New Life Test Objectives*, U. of Minnesota, Minneapolis, Minn.

Sobel, M., *Group Testing in a Stochastic Faulty Coin Problem*, Symposium on Decision and Information Processes, Purdue University, Lafayette, Ind.

Spitzer, W. G., *Infrared Properties of Silicon Carbide*, Conference on Silicon Carbide, Air Force Cambridge Research Center, Bedford, Mass.

Strnad, A. R., *A Discussion on Electron Beam Melting of Sapphire*, Informal Symposium on Electron Beam Melting of Metals, Hotel Somerset, Boston Mass.

Terry, M. E., *Analysis of Planned Experiments*, Mid-Atlantic Convention of the Am. Society for Quality Control, Atlantic City, N. J.

Terry, M. E., *Factorial Experiments*, North Jersey Section, Am. Chemical Society, Summit, N. J.

Terry, M. E., *The Use of Electronic Computers in Statistics*, Corning-Elmira Section, Am. Society for Quality Control, Corning, N. Y.

Thurston, R. N., *Effect of Electrical and Mechanical Terminating Resistance on Loss & Bandwidth According to the Conventional Equivalent Circuit of a Piezoelectric Transducer, Or, How to Get the Most Out of Your Ultrasonic Delay Line*, 1959 I.R.E. National Convention, New York City.

Torrey, Miss M. N., *Selection of Samples for a Purpose*, Montreal Section, Am. Society for Quality Control, Montreal, Canada.

Unger, H. G., *Round Waveguide With Lossy Lining*, Symposium on Millimeter Waves, Polytechnic Institute of Brooklyn, N. Y.

Van Bergeijk, W. A., *Serendipity, the Ear, and Artificial Nerve Cells*, Iowa Junior Academy of Science, Mount Pleasant, Iowa.

Wasserman, E., *Thermochromism of Bianthrone*, Mellon Institute, Pittsburgh, Pa.

Wasserman, E., *Optical Activity and Biphenyls*, U. of Pittsburgh, Pa., and Carnegie Institute of Technology, Pittsburgh, Pa.

TALKS (CONTINUED)

Weber, L. A., *Data Transmission Over Voice Frequency Channels*, I.R.E., Winston-Salem, N. C.

Weinreich, G., *Fine Structure of Hydrogen-Like Impurity States in Germanium*, Physics Colloquium, U. of Michigan, Ann Arbor, Mich.

Wilk, M. B., see Lundberg, J. L.

Williams, H. J., *Magnetic Domains in Single Crystals and Thin Films*, Long Island Chapter, Am. Society for Metals, Manhasset, L. I.

Wood, Mrs. E. A., *Women and Education: A Mutual Responsibility*, New York University, New York City, New York.

Young, J. A., and Marcuse, D., *Waveguide Measurements in Multimode Cavities*, Symposium on Millimeter Waves, Polytechnic Institute of Brooklyn, New York.

PATENTS

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

Boyle, W. S. and Ketchledge, R. W. — *Self-Propagating Intermittent Discharge Delay Lines* — 2,884,565.

Breen, C. — *Message-Waiting Signal for Telephone Subscribers* — 2,884,491.

Buhrendorf, F. G. — *Magnetic Storage Circuit* — 2,882,518.

Carter, H. T. and Kelnhofer, S. A. — *Multistation Telephone Intercommunicating and Conference System* — 2,883,457.

Cooper, H. G., Jr. and Hines, M. E. — *Electron Lens Systems* — 2,884,559.

Dermond, F. and Nickerson, C. A. — *Indexing Means for Drum-Feed Screw-Type Translating Device* — 2,883,476.

Feder, H. S. — *Potting of Electrical Apparatus* — 2,882,505.

Fisher, J. R. and Rigterink, M. D. — *Formation of Expanded Silica Spheres* — 2,883,347.

Fox, A. G. — *Transmission Line Network* — 2,883,627.

Fox, A. G. — *Gyrating Wave Transmission Networks* — 2,884,600.

Fritschi, W. W. — *Transistor Gating Circuit* — 2,883,474.

Germanton, C. E. — *Call Allotter* — 2,883,471.

Goldschmidt, K. — *Calling Line Identifier* — 2,883,468.

Goodale, W. D., Jr. and Pferd, W. — *Telephone Pay Station* — 2,883,463.

Graham, R. E. and Kretzmer, E. R. — *Circuit for Producing Timing Control Signals* — 2,883,562.

Hines, M. E., see Cooper, H. G., Jr.

Hovgaard, O. M. and Insley, N. — *Switch Manufacture* — 2,882,648.

Insley, N., see Hovgaard, O. M.

Jacoby, G. E. and Rieke, J. W. — *Communication Switching Network* — 2,883,470.

Karp, A. and Yocom, W. H. — *Traveling Wave Tube* — 2,882,438.

Kelnhofer, S. A., see Carter, H. T.

Ketchledge, R. W. — *Communication Switching System Employing Gas Tubes* — 2,883,467.

Ketchledge, R. W., see Boyle, W. S.

Krantz, H. K. — *Electric Circuit Connector* — 2,882,514.

Kretzmer, E. R., see Graham, R. E.

Mason, W. P. — *Piezoelectric Switching Device* — 2,883,486.

Mattingly, R. L. — *Microwave Delay Device* — 2,881,433.

McDermott, B. — *Transistor Gating Circuit* — 2,883,473.

Miller, O. R. — *High Impedance Input Circuit Amplifier* — 2,881,266.

Miller, O. R. — *High Impedance Multiplier Probe* — 2,884,597.

Miller, S. E. — *Nonreciprocal Wave Transmission* — 2,884,604.

Nickerson, C. A., see Dermond, F.

Pferd, W., see Goodale, W. D., Jr.

Radcliffe, F. E. — *Momentary Contact Switch* — 2,883,565.

Rieke, J. W., see Jacoby, G. E.

Rigterink, M. D., see Fisher, J. R.

Ruthroff, C. L. — *Microwave Frequency Discriminator* — 2,883,533.

Shockley, W. — *Radiant Energy Control System* — 2,884,540.

Simkins, Q. W. — *Magnetic Core Current Regulating Circuit* — 2,882,482.

Suhl, H. — *Ferrite Microwave Devices for Use at High Signal Energy Levels* — 2,883,629.

Tien, P. K. — *Microwave Amplifier* — 2,883,481.

Uhlir, A., Jr. — *Semiconductive Nonlinear Capacitance Diode* — 2,884,607.

Wehe, H. G. — *Electron Beam Recording* — 2,883,257.

Weibel, E. S. — *Spectrum Synthesizer* — 2,881,257.

Wernick, J. H. — *Semiconducting Materials and Devices Made Therefrom* — 2,882,192.

Wernick, J. H. — *Semiconducting Materials and Devices Made Therefrom* — 2,882,193.

Wernick, J. H. — *Semiconducting Materials and Devices Made Therefrom* — 2,882,194.

Wernick, J. H. — *Semiconducting Materials and Devices Made Therefrom* — 2,882,195.

Wernick, J. H. — *Semiconducting Materials and Devices Made Therefrom* — 2,882,467.

Wernick, J. H. — *Semiconducting Materials and Devices Made Therefrom* — 2,882,468.

Wernick, J. H. — *Semiconducting Materials and Devices Made Therefrom* — 2,882,469.

Wernick, J. H. — *Semiconducting Materials and Devices Made Therefrom* — 2,882,470.

Wernick, J. H. — *Semiconducting Materials and Devices Made Therefrom* — 2,882,471.

Yocom, W. H., see Karp, A.

THE AUTHORS

E. P. Felch, a native of Madison, New Jersey, received a Bachelor's degree in Physics from Dartmouth College in 1929. Following a brief training period with the Western Electric Installation Department and a year in the Trial Installation Group, he joined the Apparatus Development Department at Bell Laboratories. There he was concerned with the development of electronic measuring apparatus. In 1940 he assumed supervision of development of airborne magnetometers, first for submarine detection and later for aeromagnetic surveying. After World War II he directed the development of the new Bell System Primary Standard of Frequency at the Murray Hill, N. J., location of Bell Laboratories. In 1953 he became Military Systems Development Engineer engaged in the development of transistorized digital data-transmission systems. Since 1955, Mr. Felch has been associated with the Ballistic Missile Guidance Program. Since 1957, as Director of Military Systems Development, he has been in charge of the project, and is the author of the article on missile guidance in this issue. He is a Fellow of the I.R.E. and a member of the A.I.E.E. and the American Physical Society.

E. P. Felch

F. W. Horn

F. W. Horn ("Even-Count" Cable) was born in Chicago and received the B.S. degree in Electrical Engineering from the University of Colorado in 1930. His Bell System experience dates from 1926, and until 1931 he worked on all classes of cable at the Hawthorne, Illinois, W.E. Co. Works. Subsequently he engaged in work on exchange cable at the Kearny, N. J., Laboratories location until 1937, and on toll cable at the Point Breeze Works in Maryland from 1938 to 1946. More recently, Mr. Horn has been concerned with development of Alpeth and Stalpeth sheath and polyethylene-insulated cable at Kearny. He is a member of Eta Kappa Nu and Tau Beta Pi.

D. W. Hagelbarger was born in Kipton, Ohio. He attended Hiram College from which he ob-

D. W. Hagelbarger

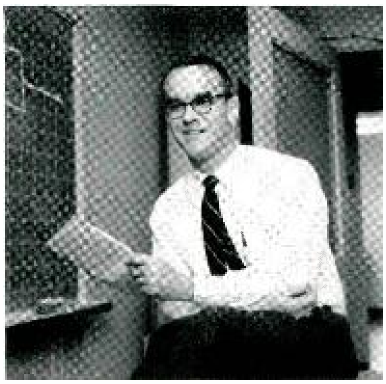
AUTHORS (CONTINUED)

D. D. Sagaser

tained his A.B. degree, and California Institute of Technology where he earned his Ph.D. degree in Physics. He joined the Laboratories in 1949 as a member of the Electron Dynamics Group where he worked on microwave vacuum tubes. In 1953 he transferred to the Mathematics Research Department to work on special purpose computers, and in 1956 he joined the Communications Techniques Research Department where he has continued his work on computers and related topics. Mr. Hagelbarger is a member of the I.R.E., the American Physical Society, and Sigma Xi. In this issue he is the author of the article "A Method for Correcting Errors in Data Transmission."

Donald D. Sagaser, author of the article on mobile radio-telephony in this issue, is from Appleton City, Missouri. He graduated from the University of Michigan in 1948 with B.S.E. (E.E.) degree and immediately joined the Laboratories as a member of the first class of the Communications Development Training Program. In 1949, a year before his graduation from CDT, he became a member of the Transmission Systems Development Department, where he was associated with the development of short-haul carrier systems, negative-impedance repeaters, the transatlantic cable project, and short-haul microwave systems. Since 1955, Mr. Sagaser has been in charge of a group concerned with mobile radio systems, including the development of a pocket-carried personal radio signaling receiver. He is a member of Eta Kappa Nu, Tau Beta Pi, Phi Kappa Phi, Sigma Xi and the I.R.E.

J. M. Goldey, a native of Wilmington, Delaware, received a B.S. in Physics from the University of Delaware in 1950 and a Ph.D. from M.I.T. in 1955. He joined the Semiconductor Device Development Department of the Laboratories in 1954. Mr. Goldey has been concerned with the development of the diffused silicon p-n-p-n transistor. He is the author of the article "Two-Terminal p-n-p-n Switches" in this issue of the RECORD.



J. M. Goldey