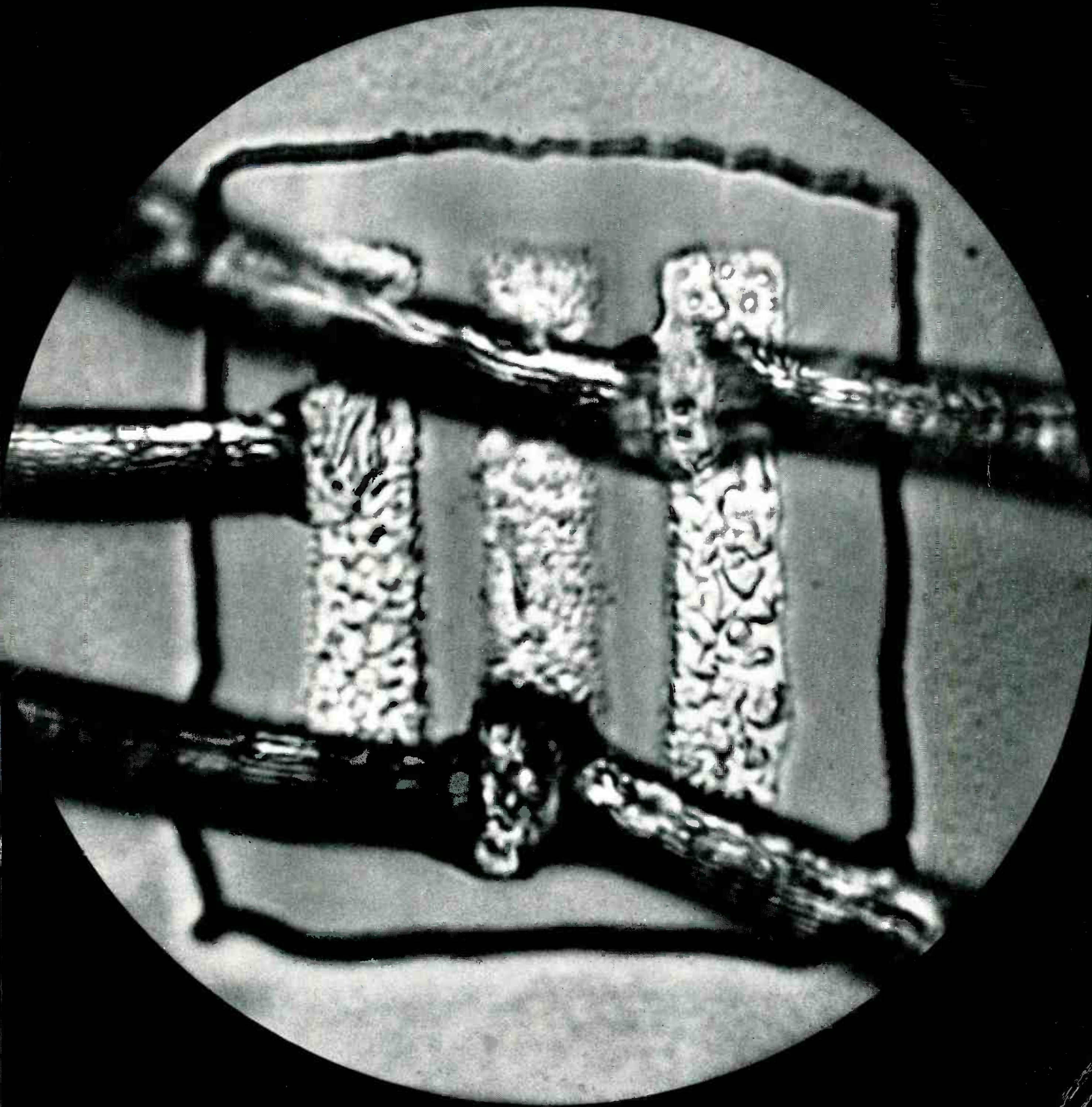
April 1960

Bell Laboratories RECORD



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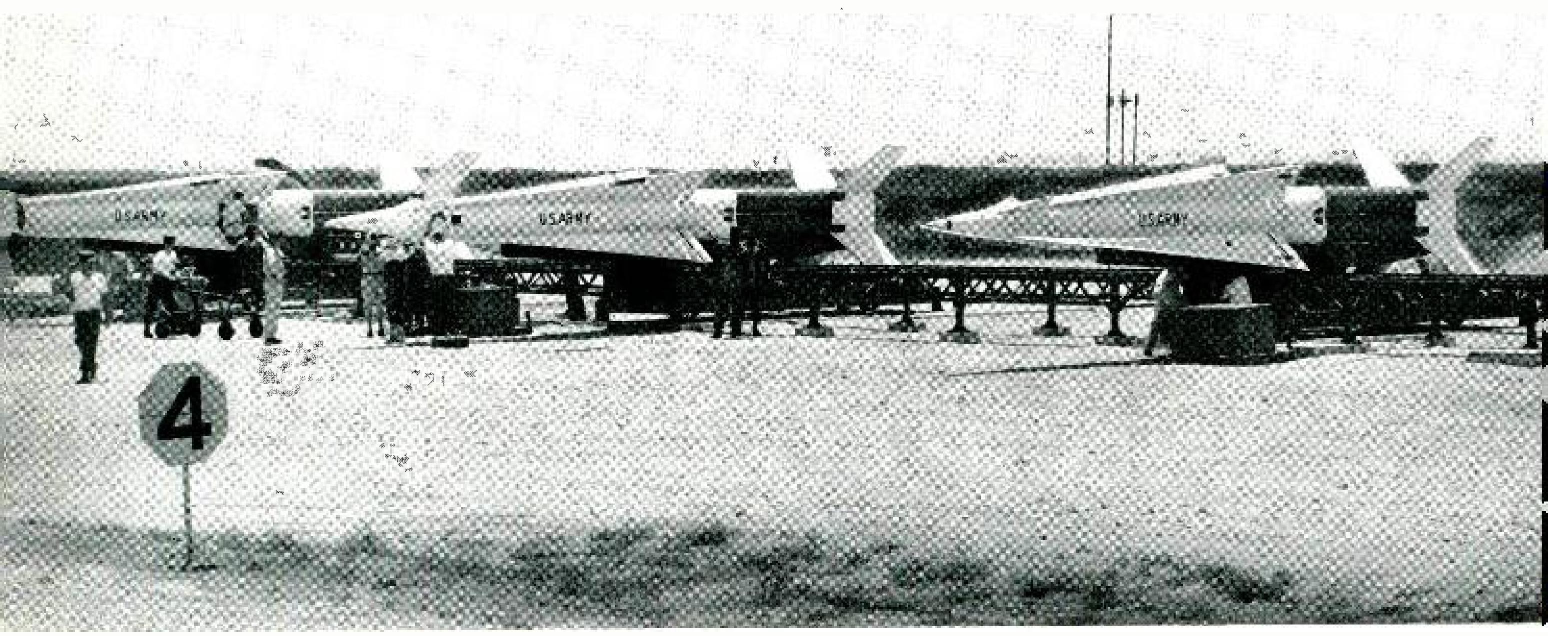
Cover

Mesa of new microwave transistor measures less than two thousandths of an inch across (see p. 151). Circular area represents cross section of an average human hair. Microphotograph, shown here at approximately 2800 diameters, by R. E. Davis of the Transistor Development Department.

NIKE IN THE AIR DEFENSE OF OUR COUNTRY



J. L. Troe

AN ADEQUATE DEFENSE of our country against surprise air attack is vital to everyone. One hundred and forty-four years have passed since the continental United States was last attacked by a foreign foe, but it could happen again and with vastly different results. We must therefore guarantee that the probability of our nation's surviving a surprise aerial attack is high enough to insure our being able to win an ensuing war. Whenever an enemy's and the United States' air arms become equal in striking power, the level of North American air defense may well become the deciding deterrent to war.

Bell Laboratories, as a member of the A. T. & T. Co. and Western Electric Co. team, has played an important role in the country's defense effort for some years. The Nike surface-to-air guided missile systems, the DEW Line, SAGE, White Alice, other major communication networks and BMEWS are a few of the major defense systems for which the Laboratories has had large responsibilities. *(See REFERENCES on page 129.)*

Nike, for instance, has been an important element of our country's air defense since 1953. Several hundred Nike-Ajax systems are now deployed about our major cities, and many others are operational at overseas locations. The last Ajax system was delivered by the Western Electric Co. in 1957.

Nike Ajax is effective against supersonic jet bombers to about 25 nautical miles, at very high as well as low altitudes. The growth potential designed into the Ajax equipment by Bell Laboratories has permitted significant field improvements to be introduced from time to time to

A Nike-Hercules installation. Each missile can destroy an entire formation of enemy aircraft at ranges more than 75 miles from launching site.

The battery commander (center) flanked by his assistants receives enemy target information from his local acquisition radar and from the North American Air Defense Command.

keep its effectiveness at a continuing high level against the ever-changing threat.

Army troops have fired over 1500 Nike-Ajax missiles at drone targets in their training programs in the Fort Bliss, Texas, and New Mexico areas. These Army operations have proven Nike-Ajax reliability and capability.

In 1952, Bell Laboratories performed a study to determine the most effective and rapid way of incorporating atomic warheads in Nike. The potential ability to destroy large formations of aircraft with a single shot was recognized as a major step forward in air defense. With the accuracy of Nike, it was comforting to think that even atomic bombs being carried by the enemy could be completely destroyed. The resulting program became known as Nike Hercules.

The Nike-Hercules systems now being produced and tactically deployed have a considerably increased capability over Nike Ajax. Besides the atomic warhead capability, the Hercules system (1) can fire conventional high-explosive warheads, (2) can fire to a much greater range than Ajax, (3) can fire at much higher targets and at very low targets, and (4) can even fire at surface targets.

Nike Zeus, the third generation of the family, is being designed by the Laboratories to counter the threat of long-range, very high-velocity ballistic missiles. The system capabilities, equipment and techniques are security classified, but the problem is easily imagined. Human beings and electronic equipment will have little time to react — only the very short period between the time a target is detected and the time it must be destroyed. Nike Zeus is the only anti-ballistic missile system in the developmental stage.

To understand the role of Nike defense weapons, of course, we must appreciate their individual capabilities. And within the limits of security, some of the details of the systems are discussed later in this article. If we consider the Nike systems in isolation from the general defense picture, however, we cannot appreciate their full significance. It is necessary first to outline this broad problem of defending the continent and then to show how Nike is integrated into the over-all plan.

The purpose of air defense is to save our population, industry and our retaliatory forces from airborne destruction. The national policy of preserving peace by maintaining strong deterrent forces, such as the long-range bombers of the Strategic Air Command (SAC), and the highly mobile task forces of the Army and Navy, can only be effective if we can protect these forces from unannounced destruction by aircraft or missiles. An enemy can easily define the major targets in the United States, since it is well known that thirteen per cent of our country contains eighty-five per cent of the war industries and fifty-nine per cent of the population.

The entire defense of North America was assigned to the North American Air Defense Command (NORAD) at Colorado Springs, Colorado, in September, 1957. The United States and Canada participate as equal partners. NORAD has operational control of all air defense forces for both countries. It functions to protect primary targets against any aerial invaders of North American airspace. The task of NORAD is to build and maintain a "fence" — twenty miles high and fifteen thousand miles long — along North America's aerial frontiers.

Over-All Air Defense

An effective defense must, of course, have the growth potential to defend against the ever-increasing performance capability of bombers and missiles. Modern navigation and radar bombing devices overcome distances and weather as deterrents to offensive operations. The defense must be able to defend against an attack initiated by an enemy who will have almost unlimited avenues of approach available to him. In building the fence, NORAD makes use of the facilities of the United States Army, Air Force, and Navy and of the Canadian Air Force.

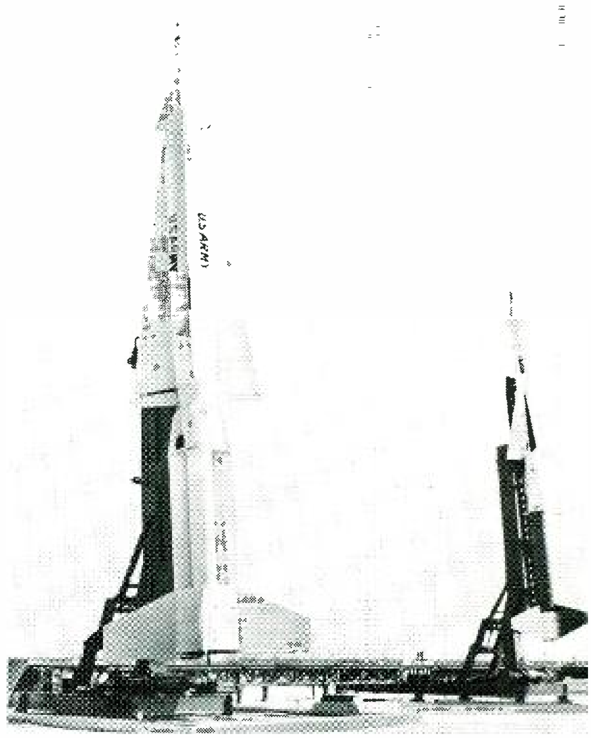
The air defense problem dictates that NORAD must perform three major functions — it must detect targets, identify friends and foes, and destroy the foes. The organization of NORAD and its operational concepts and functions have been based on the supposition that simultaneous, widely diversified air attacks can be directed against any or all of the major targets within the United States at any given time.

In building the defense network NORAD needs first of all an adequate early warning system for quickly bringing its military defense system to its fullest effectiveness and for alerting SAC and the civil defense systems of both countries to the approaching dangers. Consequently, there are now four main radar and communication networks in the integrated NORAD system to provide the required early warning. These are the Pinetree Line, the Mid-Canada Line, the Distant Early Warning or DEW Line, and the extensions of the DEW Line down into both oceans to prevent hostile aircraft from outflanking the transcontinental networks.

The Pinetree System is located in the United States and the populated areas of Canada. The Mid-Canada Line consists of a series of radar detection and warning stations extending across mid-Canada from Labrador westward. The DEW Line, for which Western Electric is a major contractor, is built across the most northerly part of North America. The seaward extensions of the DEW Line have been extended down both flanks of the continent, and far out to sea, with U. S. Navy radar-equipped airplanes, radar picket ships, and lighter-than-air craft, and with Air Force radar-equipped aircraft. NORAD also uses offshore "Texas Tower" radar islands installed on the Atlantic shelf. Most recently it has been announced that the Ballistic Missile Early Warning System (BMEWS) is being installed in the far northern areas of the DEW Line to provide early warning of ballistic-missile attack.

Installation and operation of these warning networks has been assigned to the Air Defense Command (ADC), the Air Force component of NORAD. ADC controls a far-flung organization extending throughout the United States, Canada and Greenland, and must discharge all Air Force responsibilities for the air defense of the United States, including detection and long-range identification and destruction. ADC's inventory of weapons includes the latest types of all-weather interceptors, atomic air-to-air missiles, and the BOMARC guided missile.

These weapons are controlled from a network of strategically located direction centers, whose



The Hercules missile, left, is the second generation of the Nike family. Its design is based on knowledge gained from the Nike Ajax, right.

heart will be the SAGE (Semi-Automatic Ground Environment) system, for which Western Electric is also a major contractor. SAGE includes automatic and manual target-detection, evaluation, and assignment facilities for bringing NORAD weapons to bear on hostile targets with maximum accuracy and minimum delay. SAGE is planned to give long-range ADC fighter-interceptors and BOMARC missiles the time needed to get aloft and perform the long-range destruction phase of air defense. Target information is transmitted to the SAGE direction centers over a Bell System-engineered communications system from the vast network of SAGE radar warning stations. Employing these ADC facilities in a combat situation is the responsibility of NORAD, which maintains a network of combat operation centers throughout North America for this purpose.

Defense in Depth

The Navy participation in NORAD is primarily one of aiding in obtaining early warning of attack. Navy radar-equipped picket ships deployed in the Atlantic and Pacific Oceans move the NORAD fence farther and farther from the shores of North America. During an emergency, the Navy commander at NORAD will be able to bring into the defense picture Naval land-based and carrier aircraft. Although the carrier is primarily an offensive weapon, its ability to launch jet fighters far off the shores, and to intercept incoming raids before they can reach North American borders, might prove valuable in keeping the battle away from the continent itself. Likewise, wartime control of the fighter wings of the USAF Reserve and the Air National Guard will be assigned to NORAD.

NORAD requires ground-to-air guided missiles for the relatively close-in protection of specific major targets against those hostile bombers or missiles which may succeed in penetrating the fighter defenses of the Air Force and the Navy. USARADCOM (United States Army Air Defense Command), the Army wing of NORAD, is responsible for providing final defense against penetrating attackers. The Nike anti-aircraft defense of North American key targets is one of the Army's major responsibilities. Thus the Army, Navy and Air Force have joined to provide what might be called a "defense in depth." Whereas the Air Force and the Navy have been charged primarily with "area" or long-range defense, the Army has been charged with the defense of the most important geographical "points" in the country. The defended points, or zones, are heavily populated areas, industrial areas, or defense and retaliatory bases. Most local-area defenses assigned to the Army cover many hundreds of thousands of square miles.

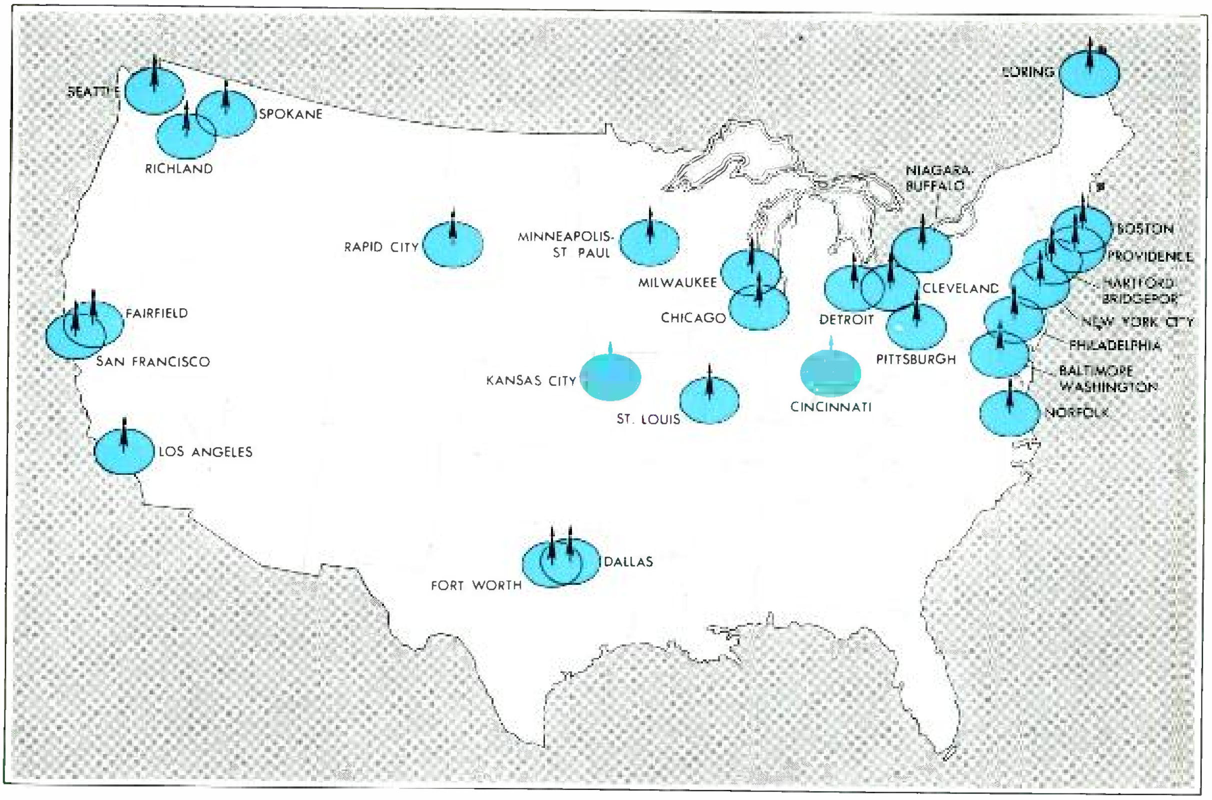
Local defense is based on the concept that an enemy will direct his attack at particular centers which he considers must be destroyed. Army Nike systems are placed around each of those localities. The amount of defensive potential at each locality is determined by the value of that locality in relation to others, limited by military budget considerations.

Army local air defense is based on a building-block concept in which a given area, such as metropolitan New York, is defended by using a number of identical self-contained and self-sufficient Nike systems. The systems are placed relatively close to the local defended area. This keeps the weapons where the battle would be heaviest. In each Nike system the required ground-based radars, computer, launching equipment, and missiles are located as close together as possible. Self-protection of the Nike units is easily achieved since any attack directed at the Nike unit itself, or the particular area which it is defending, places the enemy in the most favorable position for counterattack by the defending units. This is true because the rate of kill of the system increases as the enemy comes closer.

Each of the Nike systems is capable of autonomous operation, or self control. Thus, in case of failure or destruction of the NORAD control facilities, the defense complex built up of a number of these individual units is not vulnerable to attack in each of its several parts. Knocking out one unit of the defense has no effect on the operation and kill capacity of the remaining units in the complex. Since the Nike weapons are essentially "last ditch" weapons, they cannot rely for their continued effectiveness on permanent target detection, identification and assignment by the centralized direction centers of NORAD. They must have within themselves this capability of operating autonomously, if needed — a capability which becomes more and more necessary as bombers and air-launched and ballistic missiles travel faster, and as the reaction time available for detection, identification, and destruction becomes shorter and shorter.

Nike is now the mainstay of the Army local-area defense program. Army National Guard units were relieved of their anti-aircraft gun missions in October, 1958, to convert to Nike Ajax. Army units were then assigned operation of Nike-Hercules sites. USARADCOM is now almost a 100 per cent missile force.

Both the area defense role of the Air Force



This map shows the locations of some of the Nike bases throughout the United States. These bases are an integral part of the over-all air defense of the North American continent. Information concerning other Nike locations in this country and overseas is classified for security purposes.

and the Navy, and the local defense role of the Army, are important in a balanced continental defense program. The area defense weapons engage the maximum number of targets as far from the U. S. border as possible. The local defense units then protect the key target areas of the country from attack by those targets that get through the area defense complex.

The development of each of the Nike family of weapons has been a team effort from the start, the team consisting of Bell Telephone Laboratories, Western Electric Company, Douglas Aircraft Company, Army Ordnance and a very large number of subcontractors. Bell Laboratories has had full responsibility for the complete system design. Close coordination between all of these agencies has always resulted in Nike systems meeting their design objectives on schedule.

In operation and physical appearance, a Nike-Hercules battery is remarkably similar to those of Nike Ajax. The major physical changes are in the missile, in its launcher, and in the tracking radars. However, electronic improvements have been incorporated throughout the system. Nike-Hercules systems are now in production and are being deployed around our major cities and overseas. They can use either Nike-Ajax or Nike-Hercules missiles. The first systems were made operational in June, 1958.

The capability of Nike Hercules is a tremendous improvement over Nike Ajax. The Hercules missile has a range of over 75 miles, and it can engage targets from over 100,000 feet in altitude down to practically right on the ground. During various test programs it has destroyed drone targets flying as fast as Mach 3, parachute targets at altitudes as high as 160,000 feet, and targets in formation. Nike Hercules can out-perform and destroy all aircraft and cruise-type missiles that are operational today, or expected for some years. Its atomic warhead can annihilate entire formations of attacking aircraft, and no known type of enemy "jamming" or evasive tactics can elude it. Hercules is also a potent surface-to-surface weapon — it can deliver its atomic warhead accurately to surface targets at distances up to 100 miles.

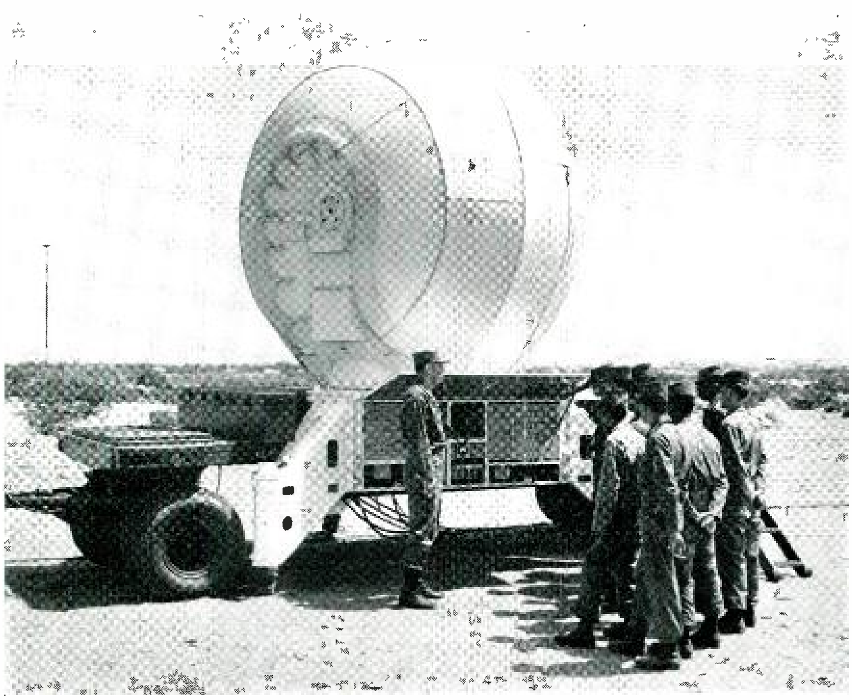
The Nike-Hercules missile, like Ajax, is a two-stage rocket. However, it uses solid propellants in both the booster and the rocket sustainer motor. The Nike-Hercules missile-booster combination weighs approximately 10,000 pounds in the ready-to-fire condition. It is about 40 feet in over-all length, and is over twice the diameter of the equivalent Nike-Ajax unit.

Like Nike Ajax, Nike Hercules is a mobile system designed for field army use. It can be installed at semi-permanent sites about our cities. In fact, Nike Hercules is often installed on the same sites that were used for Ajax. This fact has resulted in tremendous savings to the taxpayer. another advantage of Nike growth potential.

Nike Installations

Nike Ajax has been accepted as a permanent resident of the American neighborhood. Most neighbors now accept Nike Ajax even though they may have been fearful at first that the missile would constitute a threat to the physical security of the community. USARADCOM personnel and civilians in the communities adjacent to Nike sites may be initially concerned that the Nike-Hercules nuclear warhead seriously endangers nearby life and property. Such fears are unnecessary. The safeness of such explosives is assured by highly trained personnel operating under stringent safety procedures, by electrical and mechanical safeguards, and by the characteristics of the explosive itself. The exact safety measures and devices used to assure that an atomic warhead is not accidently detonated are security classified, but experience shows they have been effective. Steady improvements in methods and materials make it very unlikely that an accidental detonation will ever occur. Nuclear detonation requires an extremely complicated series of operations virtually impossible to duplicate unintentionally. All nuclear warheads have built-in safety features intended to preclude unintentional detonations from severe heat or shock, or from electrical or other energy from an outside source. As stored and carried, Nike atomic warheads emit no harmful radiation and present no radiation hazard to persons living near or passing by locations where the missiles are employed. People work safely in the vicinity of such nuclear weapons every day.

Some may think that Nike defenses cause the protected area to become a more desirable enemy target. A logical consideration of the facts shows the truth to be to the contrary. The Nike-Hercules system provides a superior weapon of defense. It is not a weapon of offense. It is not a threat to another nation except when that nation attacks us. Because of its great kill capability, Nike Hercules is a weapon to be avoided by enemy aircraft at all costs. It has been mentioned that Nike Hercules gives a "point" defense as opposed to an area defense. The coverage of a single Nike-Hercules battery is actually about 400,000 cubic miles — a rather large point!



The operation of precision tracking radar is an important part of a soldier's training. At Fort Bliss, Texas, an officer explains how Nike's radar "locks on" to a target.

A Nike-Hercules battery, like Nike-Ajax, includes three radars, a computer, tactical control facilities, launchers and missiles, and equipment for testing and assembling the missiles. Early warning information concerning the presence of a threat, and its general character and probable direction of attack, is normally furnished to the Nike battery from the NORAD early warning system through an Army "Missile Master" direction center. At the Nike battery, the acquisition radar continuously surveys at long-range the whole area about the defended city. The battery control officer watches for the approach of the threatening attack. After he is informed that a target is hostile, he initiates steps that identify the target for the precision target-tracking radar, which from then on automatically tracks the target to be engaged, and continuously furnishes accurate target-position information to the Nike computer. The computer continuously calculates a predicted point at which the missile will intercept this target. The predicted point is displayed in front of the battery control officer on a map of his defense area. With this information, and using the acquisition radar's presentation of other possible threats, the control officer chooses the optimum time to fire the missile.

During this process, a third radar, the precision missile-tracking radar, has been trained on the selected missile to be next fired from the launching area. This radar continuously tracks the missile previous to launching, after launching, and through flight until the warhead is detonated. The missile is launched in a nearly vertical direction. The booster gives it an initial thrust and drops off. Within seconds, it accelerates through the sonic barrier and into supersonic flight. Its own rocket engine then causes it to fly rapidly up and over to the target. The boosters all fall into a predetermined area without damage to population or property, regardless of the direction of the target. Errors in the missile's flight path, or changes in target's course, are continuously determined through flight by the computer, using the data on the positions of the missile and target. The two tracking radars feed this information to the computer. Corrective orders are sent to the missile throughout flight, using the radar beam of the missile-tracking radar as a communication link.

The precision of the radar data, the rapidity of the order computations, and the maneuverability of the missile permit the system to counter any evasive action of the target, with no loss of intercept effectiveness. At the appropriate moment, the warhead is burst by command from the computer, and one more enemy target or flight of targets is destroyed.

Acquisition radar constantly surveys the area to be defended in case of attack. This equipment identifies potential enemy targets at long range.

It appears that air defense will be a long continuing challenge to the country. Bell Laboratories, in its further efforts on Nike and on the other associated defense programs, will continue to be an important participant in this air defense story, one of the most vital stories of the 1960's.

REFERENCES

The following are references in the RECORD to information concerning Bell Laboratories work on Nike and the various defense communications services. For NIKE, see the issues of February, 1954, p. 74; August, 1955, p. 317; December, 1956, p. 447; April, 1957, p. 147; September, 1958, p. 346; February, 1959, p. 53; February, 1959, p. 71; April, 1959, p. 135; September, 1959, p. 350; November, 1959, p. 399; December, 1959, p. 446 and p. 478; January, 1960, p. 26; March, 1960, p. 105. For the DEW LINE, see August, 1956, p. 308; January, 1957, p. 18; May, 1957, p. 194; October, 1957, p. 435; November, 1957, p. 450; January, 1959, p. 2. On the WHITE ALICE SYSTEM, see January, 1957, p. 21; May, 1958, p. 184; August, 1958, p. 279. For the SAGE SYSTEM, see October, 1957, p. 401; September, 1958; p. 335. On the BMEWS LINE, see April, 1958, p. 130.

Metallurgy has progressed far beyond traditional methods of alloying and processing. Today many special-purpose alloys are refined to extremely high purities and are subsequently worked to very small dimensional tolerances.

D. H. Wenny, Jr.

New Dimensions in Metallurgy

For the 29th Annual Institute of Metals Lecture, held in February 1950, the Metallurgical Director of Bell Laboratories, Dr. E. E. Schumacher, spoke on the subject, "Metallurgy Behind the Decimal Point." In this lecture, Dr. Schumacher stressed the vital role of minute quantities of elements added to many of the alloys used in communication apparatus, and he forecast that workers in metallurgical research would need to strive continuously for higher-purity materials and more precise process control. Now, ten years later, it is interesting to review some recent developments to see how far to the right of the decimal point metallurgy has been able to go.

This article deals primarily with metals prepared in relatively large quantities by pyrometallurgical techniques — that is, by such familiar processes as furnace melting, refining, alloying, casting, heat-treating, rolling and drawing. These techniques, though old in principle, have been developed to high precision. Today, we quite commonly work at impurity levels of 50 parts per million or better — unheard of a few years ago except for small quantities and laboratory samples. Further, we frequently must control dimensions within a few millionths of an inch.

Of several developments which illustrate this work, a good example is a study of a high-purity magnetic material, Supermalloy, for use in cores of special transformers. This study combines the need to hold metallic impurities to less than 20 parts per million (less than 0.002 per cent by weight) and the requirement that the final strip be rolled to a finished thickness of only 0.0002 inch within an accuracy of 10 millionths of an inch.

Supermalloy, developed in the Metallurgical Department at Bell Laboratories, has a nominal composition of three major constituents—nickel 79 per cent, iron 15 per cent, and molybdenum 5 per cent—and two other elements present in smaller amounts—0.5 per cent each of manganese and cobalt. The manganese is added to combine with any sulfur that might be picked up from furnace refractories or from atmospheres in heating furnaces employing oil or gas fuel during commercial processing. It was found that without the manganese, sulfur present in concentrations as low as 50 parts per million (0.005 per cent) would make the alloy so brittle that it would break up during rolling.

The 0.5 per cent cobalt is introduced as an impurity from the nickel, and there was no knowledge of its effect on the magnetic quality of the alloy. So, to get fundamental information on the properties of a Supermalloy containing neither cobalt nor manganese, K. M. Olsen and P. H. Schmitt prepared a very high purity melt. They were able to control impurities to such an extent that no metallics were detected except copper and silicon (both less than 0.001 per cent). Of the other impurities, sulfur was less than 0.001 per cent, and carbon, oxygen, hydrogen and nitrogen were also brought to very low levels. Thus, the melt was free of cobalt and manganese, with very little impurities of any kind. By comparison, a standard, good quality melt would have an impurity level about ten times higher.

The study called for the 0.0002-inch thickness of the Supermalloy strip as part of an investigation to determine why magnetic quality degrades when the material is reduced to thin gauges. This phenomenon plagues all "soft" magnetic materials—that is, those with high permeabilities. It would be of great value to learn why a strip 0.014 inch thick, for example, has superior properties, while the same material at ultra-thin gauges does not.

Metallurgical Processing

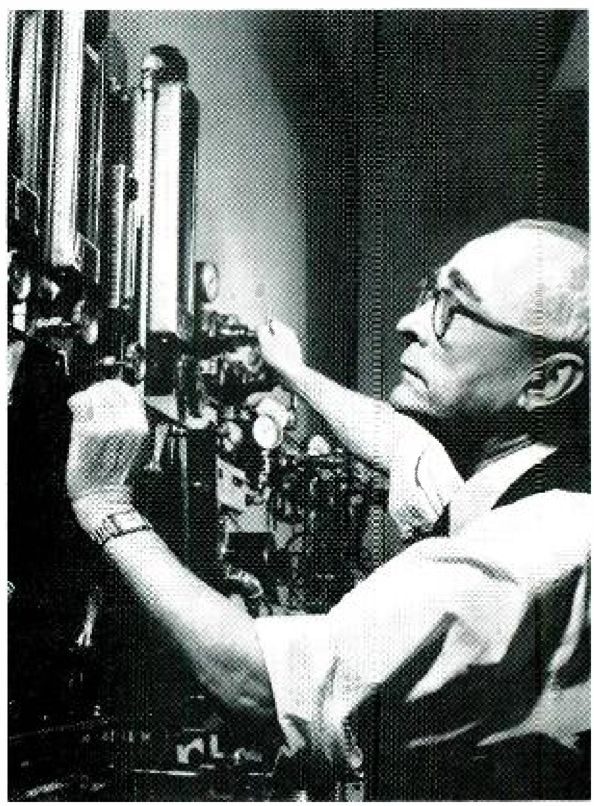
In this study, an ingot was first hot-rolled and cold-rolled to a thickness of 0.001 inch with intermediate anneals. Then it was reduced to the final 0.0002-inch thickness on a high-precision mill having a cluster of 20 rolls (*see photograph on page 134*). This mill can roll hard alloys to thin gauges very accurately.

The heat-treating and testing program is far from complete, but preliminary results indicate that cobalt and manganese, in the concentrations mentioned, are desirable for securing the optimum magnetic properties of Supermalloy at normal thicknesses. In addition, it appears that high purity does not prevent magnetic quality from degrading at the ultra-thin gauges. The problem of maintaining the magnetic characteristics at these gauges is evidently one of achieving a strain-free recrystallized alloy. With high-permeability materials, it has long been known that complete freedom from strain is essential to the development of the highest magnetic quality. This becomes difficult when the thickness and width dimensions become very small—that is, when so much of the material lies at or close to the surface.

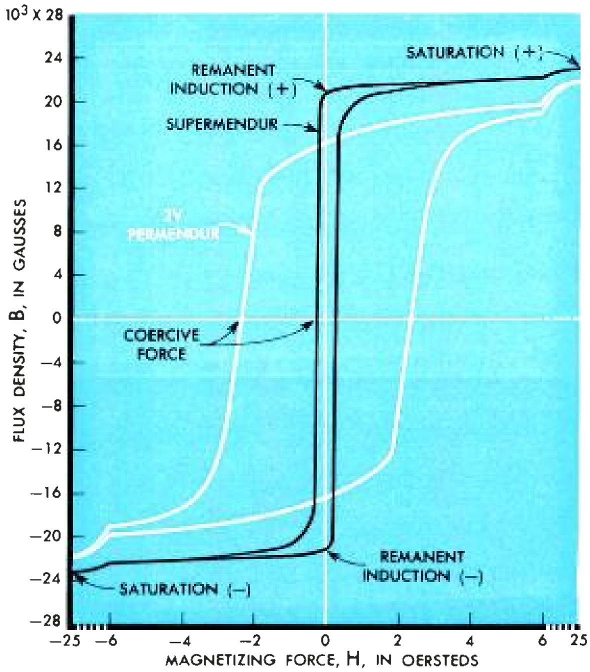
Another project again illustrates the need for precise control of size, and also the need for uniform magnetic quality over great lengths of fine, flat wire. This wire, used for Twistor memories (RECORD, *November*, 1959), is made of molybdenum Permalloy by flattening a round wire to a cross section 0.00035 inch thick and 0.00325 inch wide.

Producing this fine cross section by rolling on a standard wire-flattening mill soon becomes unsatisfactory because the rolls begin to wear detectably after only 60 minutes of rolling at 100 feet per minute. The significance of this problem is apparent from the fact that with the specified dimensions, one pound of Permalloy produces about 60 miles of Twistor wire. This amount of wire has a potential of storing over 30 million bits of information.

Another method for preparing fine, flat wire is to draw it through a slit formed by a pair



O. J. Barton regulates the flow of hydrogen used during the purification cycle of Supermendur being melted in a controlled-atmosphere furnace. The addition of other gases is similarly controlled.



The hysteresis loops of Supermendur and standard 2V Permendur each measured on a core made from toroidal strip only 0.004-inch thick.

of diamond dies. Since molybdenum Permalloy has no abrasive characteristics that would wear the diamonds, the thickness of a 20,000-ft. length of flat wire does not vary. This project requires even greater accuracy than the Supermalloy for transformers; here the thickness is controlled to only a few millionths of an inch.

To reduce a one-pound bar only 8 inches long to 60 miles of extremely fine wire, it is evident that considerable processing is necessary. And, since such processing controls the metallic structure of the end product, current fundamental studies in metallurgical research are designed to establish a better correlation between structure and magnetic characteristics. These studies are vital to an understanding of materials at very small dimensions.

A third metallurgical problem illustrates still another aspect of communications work—in this case not so much the gross dimensions of a structure, but the nearness to perfection of one of its surfaces. In the circular waveguide type of transmission system, the inside surface of the waveguide is an important factor in efficiently propagating the electromagnetic energy.

Radio researchers at the Laboratories envisage a communication system using a steel pipe, with an inside diameter of two inches, buried along a railroad or turnpike right-of-way. This pipe, lined inside with copper and using a 50,000 mc carrier frequency, has an awesome capacity for handling telephone, data and television signals. Unless the inner surface of copper is very smooth and straight, however, the signals attenuate rapidly with distance. A. C. Beck, S. E. Miller and others at the Holmdel, N. J., Laboratory have shown that the propagated wave is very fussy about the kind of pipe in which it travels (RECORD, *December*, 1954). Minute surface irregularities in circular waveguides generate spurious modes of transmission.

There would be practically no problem if we could work an outside surface to the desired smoothness and then turn the pipe inside out! But until someone invents such a method, we must be content with fabricating the structure with more realistic techniques. In practice, some pipe has been made by hot-piercing a solid copper billet and then by cold-drawing the resulting shell into the desired length of pipe. In the piercing operation, however, the copper billet is passed between rollers to force the metal over a mandrel, and in the process the billet rotates. As a consequence, the inside surface is not smooth but develops an irregular pattern. This pattern is persistent, and although it is elongated in the final cold-drawing operations, it still remains. These imperfections take the form of random wiggles of the waveguide axis when the sections of pipe are coupled together. Calculations and experiments show that variations of the waveguide axis having random wiggle components ranging between 1 to 4 feet (and primarily in this range) can cause serious transmission variations. For example, if the axis has deviations of 0.002 inch, with wiggle components in the 1-to-4-foot range, these deviations increase the transmission loss by about 60 per cent.

Considerable improvement is promised, however, by using an extrusion process in making a copper shell for cold-drawing to the desired waveguide dimensions. Since the inside surface is smoother, axis variations and corresponding transmission losses are reduced by cold-drawing the final pipe from the extruded shells.

In these examples, dimensions are controlled as a way of achieving certain magnetic or electrical properties. Another project currently being carried out in metallurgical research is the processing of a magnetic alloy to secure a specified thermal coefficient of the modulus of elasticity.

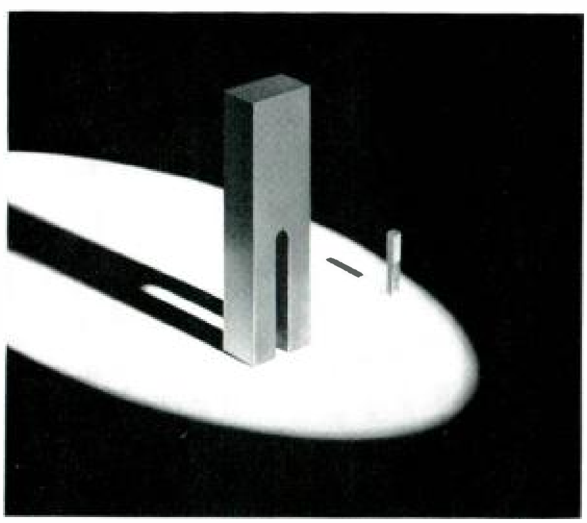
The problem is as follows: Some receivers for mobile radio and personal paging systems use metal tuning forks that respond to specific incoming frequencies. The signals are applied to a magnetic circuit associated with the forks, and those forks that are resonant to the applied frequencies are set in vibration. It is desired, of course, that the resonant frequency of a tuning fork should stay constant, even though the alloy of which it is fabricated expands or contracts, and the modulus or stiffness varies with temperature.

For a particular application by L. G. Bostwick and K. F. Bradford of the Switching Systems Development Department, small reeds, measuring only 0.006-inch thick, 0.1-inch wide and less than 1-inch long, were fabricated into precise, miniature tuning-fork resonators. These reeds had to vibrate at a constant frequency over a wide temperature range. Also, they must have good fatigue properties, be relatively stainless, and be capable of being driven magnetically.

New Vibralloy Forks

The name given to the material used for this purpose is "Vibralloy," with a composition of 48.5 per cent iron, 42 per cent nickel, 9 per cent molybdenum, and 0.5 per cent manganese. To obtain the desired modulus, composition and processing must be very accurately controlled, since the frequency will stay constant only when the temperature coefficient of the modulus balances the temperature coefficient of expansion. The two must be equal in magnitude and opposite in sign.

To achieve this result with such small reeds, it was necessary to control many critical variables. Since the resonant frequency of a reed is a function of its physical dimensions, these had to be held to very close tolerances—if possible to plus or minus 0.0001 inch or less. Furthermore, the amount of cold working in the rolling processes has an important effect on the modulus coefficient, on the tensile strength, and on the magnetic properties of the stock.



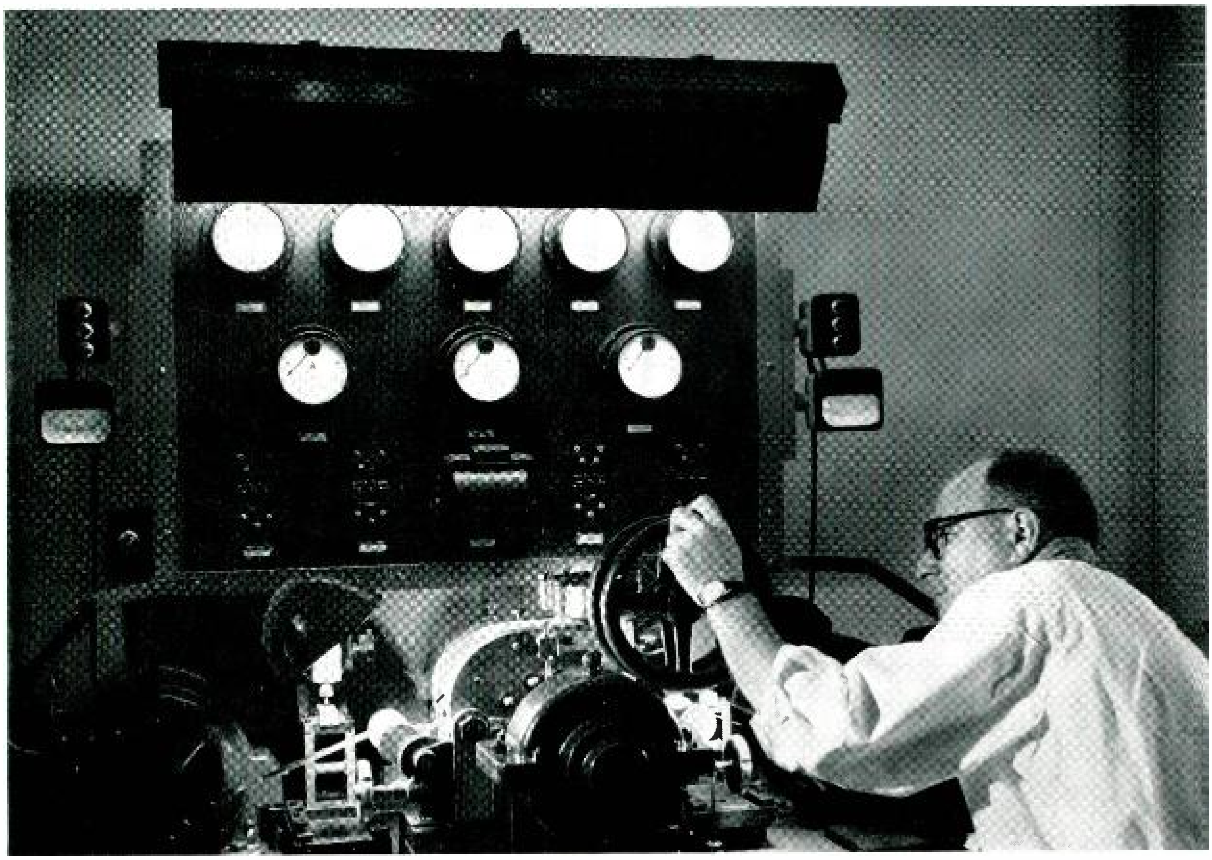
A miniature tuning fork for the personal paging selector and older experimental fork. The smaller fork (¾-inch high) has the lower frequency.

An older-model tuning fork weighed 175 grams, and was machined from a block of metal weighing more than a pound. The alloy used for this unit, although produced successfully in the laboratory, was never made satisfactorily on a commercial scale. By contrast, the new Vibralloy unit weighs only 0.9 grams. With careful adherence to processing steps developed at Bell Laboratories, 300-pound melts are being successfully processed commercially.

As a final example of the dividends from metallurgy behind the decimal point, the magnetic material called Supermendur again illustrates the result of fundamental metallurgical research and careful control of composition and processing steps. Supermendur, a descendant of the 2V Permendur developed at Bell Laboratories and used for the diaphragm of telephone receivers, shows remarkable improvement in three respects. Of all magnetic materials, it has the highest remanent induction (highest remaining magnetic strength after the applied field is removed); it has the highest permeability associated with high flux densities; and it has a rectangular hysteresis loop with the greatest swing from the point of minus remanence to the point of plus saturation. The accompanying graph shows some of these characteristics for a typical Supermendur, along with a hysteresis loop of a standard 2V Permendur for comparison.

The constituents of 2V Permendur are chiefly cobalt, iron, and vanadium, but this alloy also contains small amounts of many impurities. In particular, small quantities of carbon, oxygen, sulfur, phosphorus, and nitrogen complicate achieving a strain-free final product. This, as mentioned earlier in connection with the work on ultra-thin Supermalloy, has a very important influence on magnetic quality. Atoms of these impurities take positions in the crystal structure in such a way that they strain the lattice severely. Their control depends on judicious selection of raw materials, carefully controlled purification throughout melting, and precise processing. To develop Supermendur, the concentrations of carbon, oxygen, sulfur and nitrogen were reduced by a factor of ten.

In a cooperative effort with H. L. Gould of the magnetics application group at Bell Laboratories, high-purity Supermendur was first prepared in 250-gram melts, and later was successfully pre-



R. F. Jack, of the metals processing laboratory, adjusts the setting of the cluster-type mill for rolling a strip of Supermalloy to 0.0002 inch. Dials above the mill indicate tension on strip.

pared in a series of 25-pound melts. Then, with the cooperation of commercial suppliers, Supermendur melts from 400 to 2000 pounds were made and processed to take care of special design needs for military apparatus.

Aside from its unusual combinations of magnetic properties, Supermendur has other important advantages. The original 2V Permendur composition was extremely difficult to roll to 0.002 inch, but Supermendur is easily rolled to one-tenth this thickness. Also it was impractical to reduce 2V Permendur to a fine wire, but with Supermendur, a fine, hard-drawn wire has been reduced from a diameter of 0.05 inch to 0.0009 inch without intermediate annealing. This fine wire has been used in delay-line structures, and the thin-gauge strip, hitherto unavailable, is being used in special transformer designs.

Three, four and more zeroes to the right of the decimal point have thus become vitally important. As metallurgical techniques becomes more and more exact, better communications components and devices inevitably follow. And of comparable significance is the fact that many of the techniques described in this article can be translated to tonnage production. In this respect, another illustration is the high-purity nickels prepared by K. M. Olsen of the Laboratories (RECORD, *February*, 1960). These nickels, to be used in fabricating cathodes for high-performance vacuum tubes having a very long life, are to be produced in large quantities by the Western Electric Co. Works at Hawthorne, Illinois.

Since 1950, developments at Bell Laboratories have indeed shown the crucial value of "metallurgy in the millionths." Further, the trend is evident generally throughout the metallurgical industry. Semiconductors, high-temperature and corrosion-resistant alloys, atomic-reactor materials, and numerous electronic and magnetic alloys are now available—in quantities and with purities that were considered impossible only a few years ago. Many have already found application in the Bell System, and without question, such improvements will be more rapidly introduced in the future.

Making decisions is a major concern of a telephone switching system. Electronic switching systems, faced daily with making millions of decisions, will rely on logic circuits to make them. These circuits, in turn, will rely on semiconductor devices for rapid, yet dependable, operation.

W. B. Cagle

LOGIC CIRCUITS

For an Electronic Switching System

An experimental electronic switching system (ESS) was recently placed in operation at Bell Laboratories (RECORD, *October*, 1958). This system was built to evaluate many of the devices, designs, and systems techniques that may be used in electronic switching systems of the future. In particular, it was built as a forerunner of a field-trial system to be installed at Morris, Illinois.

One of the most important features of this first ESS is its extensive use of semiconductor devices — transistors and diodes. To a large extent, how practical electronic devices will be in telephone switching systems of the future depends on the high reliability, low cost, fast speed, and low power consumption that appear to be possible with them.

This experimental ESS uses over 1,500 transistors and 15,000 diodes. The transistors are germanium alloy-junction units designed especially for switching applications of medium power and speed (RECORD, *March*, 1959); the diodes are germanium point-contact types. Bell Laboratories developed both of these devices specifically for this system and for the field-trial system to follow.

Although many electron tubes are used in the control circuits of the two memories of ESS — the Flying-Spot Store and Barrier-Grid Store — it will be possible to replace most tubes with transistors in future systems. Other major elements, however, such as the central control, the scanner, the signal distributor, and the network marker, are now almost entirely constructed with semiconductor circuitry. Almost all of the transistors and diodes used in this system are employed in "logic" circuits. To understand what such circuits do, let us review briefly how the ESS operates.

Basically, the functions of a telephone switching system are: (1) to receive and remember the information arriving on lines and trunks by dial pulses, tones, or dc voltage levels; (2) to correctly interpret what these signals mean; and (3) to perform the physical actions specified by the input data, such as giving dial tone, setting up a talking path, or ringing a number.

These actions roughly correspond to those performed in humans by the sense organs, brain, and the muscles. Furthermore, the actions corresponding to those of the brain can be subdivided into: (1) memory, and (2) interpretation or decision making. Logic circuits perform electronically the functions corresponding to interpretation or decision making.

In ESS, as in digital computers, information is in "binary digital" form. This means that each piece of information is treated as a number, and that each digit of the number can have only one of two possible values — commonly designated as "0" and "1". Binary digits, or bits, are convenient for machine use since their value can be specified by two-state devices: mechanically, open or closed relay contacts; electronically, conducting or non-conducting transistors, electron tubes, or diodes.

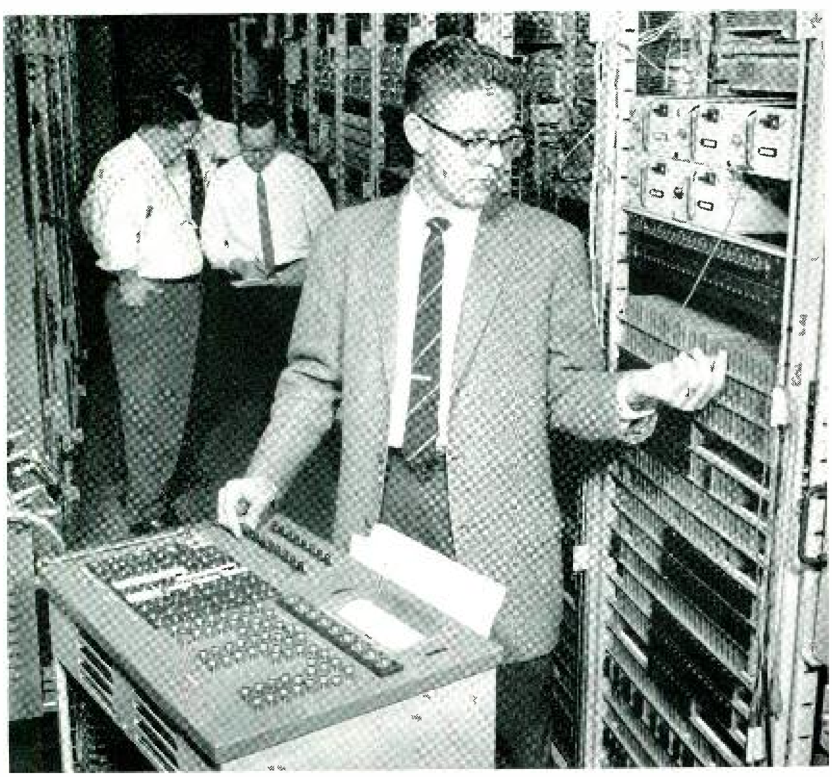
The simplest logic circuit is a "black box" whose output represents the binary answer to some simple question regarding the bits supplied to the inputs. In the electronic switching system, only two types of such circuits are required. One asks, "Are *all* the input bits in their 1 state?" The other asks, "Are *any* of the input bits in their 1 state?" With both of these circuits, the output should be a 1 if the answer is yes and a 0 if the answer is no.

The first circuit is commonly known as an "AND" gate, since the output will be a 1 only if input No. 1 *and* input No. 2 . . . *and* input No. n are all in the 1 state. An analogy can be made with an electric wall outlet and an associated wall switch. When a lamp is plugged into the outlet, both lamp switch and wall switch must be turned on (both inputs in the 1 state) before the lamp will light (output in the 1 state).

"OR" Gate Circuit

The second type of circuit is known as an "OR" gate since the output will be in the 1 state if one or more of the inputs are in the 1 state. Its action is similar to that of a dome light in an automobile. This light goes on when either of the front doors open. In other words, operation of either door switch (input 1) will turn the light on (output 1).

It is possible to interconnect AND and OR circuits to perform very complicated logical functions. In fact, with a third circuit capable of



Author using central control manual tester. Equipment tests operation of central control logic circuits by putting control orders worked out elsewhere into the system.

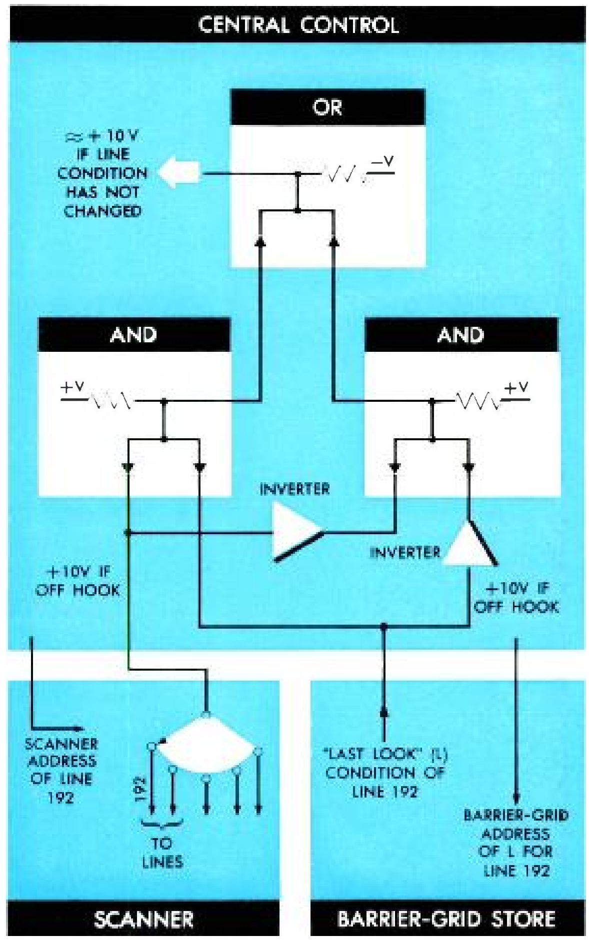
inverting the "sense" of a bit (from 1 to 0 or vice versa), it is theoretically possible to perform any logical function.

Because high-speed operation, reliability, and low cost are important, Laboratories engineers chose semiconductor diodes as the basic elements in the ESS logic gates. These simple semiconductor devices have the binary property of having a very low impedance when biased in one direction, and a very high impedance when biased in the other.

Let us illustrate the method by which diodes can be used to construct circuits capable of performing AND and OR functions by an example which also involves one of the fundamental system operations in ESS. For purposes of this explanation, assume that a 1 signal is represented by +10 volts and a 0 signal by 0 volts. With these conventions, we can make simple interconnections of diodes and resistors perform AND and OR logical functions.

In these basic circuits, AND gate diodes are polarized in such a way that any input in the 0 state (0 volts in this case) will "clamp" the output of a gate and prevent it from being "driven" positive towards +10 volts. Thus, *all* inputs must be in the 1 state, or at +10 volts, before the supply voltage can drive the output towards +10 volts and, hence, put it in the 1 state.

The other configuration of diodes is such that *any* input in the 1 state will drive the output into the 1 state. In both of these circuits, the diodes prevent interaction between inputs. Diodes appear back-to-back in both circuits between any pair of inputs, so the inputs can exist in either of their two states independent of the state of any other input.



Decision-making circuits as they are used in system operation of electronic switching system. Information on a particular line, taken from the scanner and barrier grid store, gives central control's logic machinery — gates and amplifiers — facts needed to decide what to do with that line.

ESS Application

The action in ESS illustrated in a simplified form by this example (*see diagram on this page*) is that of determining whether the condition of a certain telephone line has changed since it was last scanned, a small fraction of a second earlier. If the condition has not changed, the switching system proceeds with other business. If it has changed, the system stops and takes further action for this particular line.

To perform this action, the central control — the unit that manipulates the logic and memory of ESS — directs the scanner, the electronic equivalent of a selector switch, to "look" at a line—for example, line number 192. Simultaneously, central control directs the barrier-grid store — the "temporary" memory — to look at the L (last-look) spot for line 192. The L spot contains the state of the line determined from the last scanning operation. Central control thus receives two bits of information (call them P and L) representing the "present" and the "last-look" conditions of line 192.

The logical function to be performed in the central control is: if P AND L are both 1, OR if P AND L are both 0, then the output signal should be a 1. This indicates that the state of the line has not changed since the last scan and that central control can proceed to other business. If, however, P and L do not have the same value then the output signal should be 0 to indicate that central control must stop and take action on this particular line. This function can be obtained with two AND gates, an OR gate, and two inverters. The inverters are transistor amplifiers and will be discussed in some detail below.

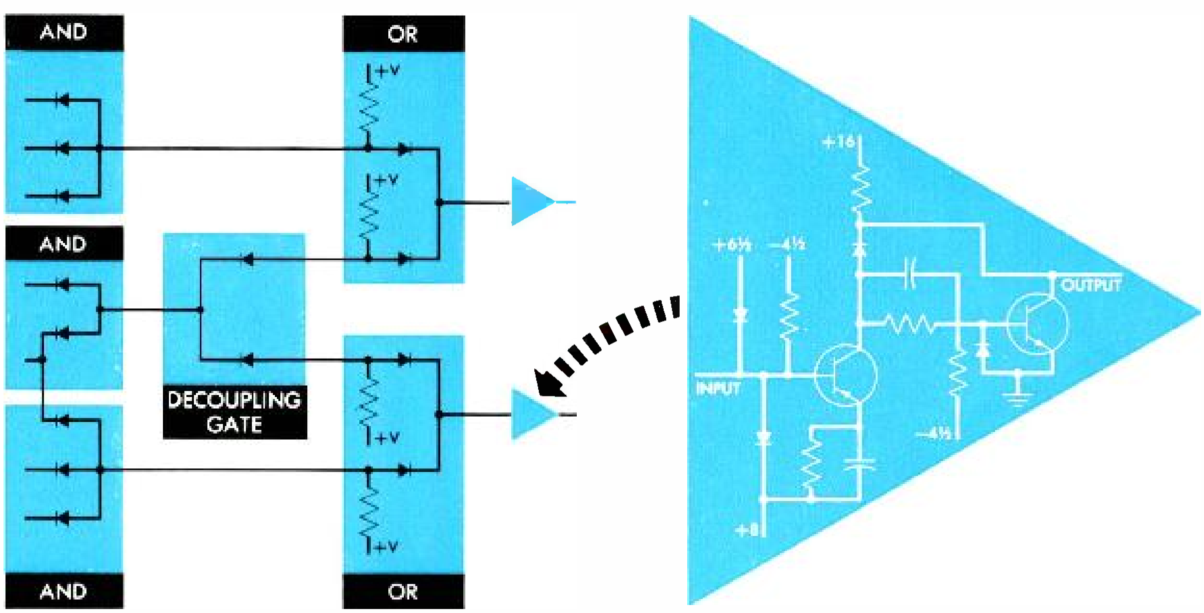
In performing the logical function, one of the AND gates detects when both P AND L are 1. If both bits are 0, the two inverters invert them so that the inputs to the second AND gate will both be 1. The output of the second AND gate will thus be 1 if both P and L are in the 0 states. The outputs of these two AND gates are then applied to an OR gate. Because of the nature of the OR gate, the output of the combined circuit will thus be 1 if both L and P are in the 1 states, or if they are both in the 0 states.

Resistance Values

The value of resistance necessary in such AND and OR gates must be selected according to such factors as the available supply voltages, the desired 0 and 1 voltage levels, the number of inputs to the gates, and the pattern of the interconnection. In addition, since these AND and OR gates contain no active elements, the signal voltages will attenuate when applied to complicated interconnections of such gates. A large system such as an electronic switching system requires thousands of gates, and thus it is desirable to use amplification with these gates for efficient operation, economic design and manufacture, and flexibility.

Engineers were able to use transistor amplifiers efficiently in ESS because of the availability of "universal" diode AND and OR gates. "Universal" means that all AND gates are identical and all OR gates are identical except for different numbers of inputs. To make this possible an amplifier "follows" every OR gate to restore signal levels and to make circuits compatible. OR gates being always followed by amplifiers eliminate the problem of proper selection of the correct output resistors for the gates. It is only necessary to ensure that the amplifier gets a specified amount of drive current when the OR output is in the 1 state.

To eliminate the problem of selecting the proper resistor for an AND gate, design engineers "split" this resistor into many separate resistors, one of which is placed on an input lead to each OR gate. The value of this resistor is selected to give the amplifier following it the correct drive current. If an AND gate is tied to only one OR gate, the effective value of resistance tending to drive its output positive will be one "unit" of resistance. However, if an AND gate drives several OR gate inputs, the effective value of resistance will automatically become



The left-hand portion of the diagram shows the gate circuits and their gate amplifiers, center, in a typical pattern used in the logic circuits of the experimental electronic switching system. The AND and OR gates perform the actual logic functions, and the decoupling gates prevent interaction among these circuits. Typical amplifier, right, restores losses in passive elements.

the resistance divided by the number of gates. Thus the proper value of resistance is applied to the AND gate by the pattern of the interconnection.

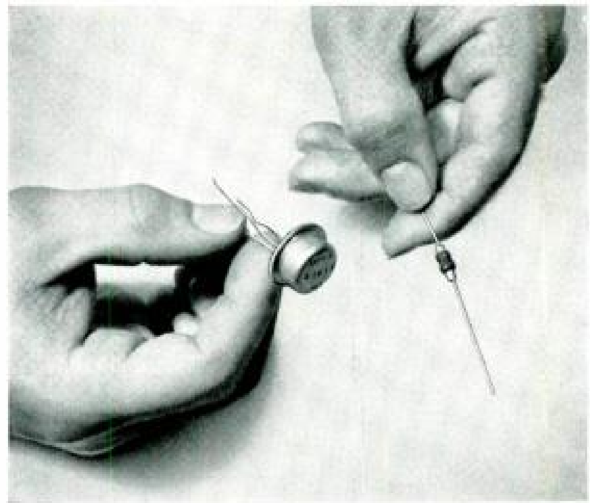
The splitting of the AND gate resistor and its replacement by individual resistors on the OR gate input leads permits designers to use special diode gates known as decoupling gates. These perform no logical function but do permit the use of amplifiers having very low input impedances to be driven from a common AND gate without interaction of the driving signals *(see diagram on opposite page)*. For instance, if an AND gate were to drive two separate OR gates, which in turn drive amplifiers, an amplifier with a very low input impedance located after one OR gate could rob current from a regular amplifier being driven by the other OR gate. The decoupling gate is simply a way to place diodes back-to-back between OR gate input resistors to prevent the driving signals from affecting each other.

We discussed above two transistorized amplifiers — an inverter, and an amplifier that follows OR gates called the gate amplifier. Several other amplifiers are used for special purposes such as cable driving and buffering. However, we will discuss only the gate amplifier since it illustrates how the designers have used transistors in this system.

The gate amplifier is a direct coupled, non-inverting circuit providing both current and voltage gain. It is a switching amplifier in the sense that its transistors are always either fully conducting or fully non-conducting. Using transistors as switches eliminates many of the problems that might occur from variations in the parameters of the transistors.

Changing States

Consider the gate amplifier having two transistors biased so they will be driven into conduction when the OR gate output (the amplifier input) is in the 0 state. In this condition, the output of the amplifier is clamped to ground through the second transistor. When an OR gate input goes into the 1 condition, current will be driven through an OR gate diode and a resistor to raise the potential at the base of the first transistor to a value above its emitter bias voltage. It will then be turned completely off. When it is off, the negative bias voltage acting through another resistor will turn off the second transistor and the output signal will rise to the amplified "1" state.



Left, p-n-p alloy-junction germanium transistor, one of the complementary pair used in logic circuit amplifiers in ESS. Right, point-contact diode, a fast acting device used in ESS logic circuits.

To keep the amplifier output state from lagging these input signal changes by several microseconds, the transistors must not be overdriven. Thus the circuit must be relatively complicated to avoid the overdriven condition for wide tolerances of the devices and components.

To prevent overdriving, the designers incorporated "gated feedback" techniques in the gate amplifier. Basically, this is done with two diodes and a resistor. Two other diodes limit the voltage "swings" at the bases of the transistors to minimize the effects of transistor junction capacitance on the speed of the device. Through these techniques the gate amplifier responds to input changes in less than a microsecond. It will function properly over wide ranges of transistor parameters — current gain, leakage currents, and breakdown voltages.

The general-purpose nature of the diode gates and transistor amplifiers affords great flexibility to the system because the logical-design part of ESS was separated from the electrical circuit design. Moreover, the allotment of generous margins in the circuit designs, to allow for aging and variations in device and component parameters, has resulted in excellent reliability of the circuits during the laboratory operation of this ESS. From this experience, the Bell System can reasonably expect to maintain its present standards of reliability in future telephone switching systems using semiconductor circuits.

The value of modern radio techniques is somewhat diminished wherever different forms of propagation get in each other's way. For example, radio services are sometimes affected adversely by undesired radiations from military and civilian radars. Investigations at Bell Laboratories have revealed some ways to control this problem.

R. L. Robbins

RADAR INTERFERENCE WITH MICROWAVE RADIO

Long distance communications in the Bell System are continuously expanding. To provide the needed paths for these communications, transmission engineers at Bell Laboratories have used the art of carrier on wire, coaxial cable, and radio. Of these, microwave radio relay is growing the fastest. From its first trial in 1947 as a transmission medium for television, microwave radio in the Bell System has grown to where, by the end of 1959, it consisted of 139,000 channel miles of one-way broadband transmission in telephone service, 76,000 channel miles in television service, and 70,000 channel miles of automatically switched protection against service failures.

There has also been a mushrooming growth of military and civilian radar applications since the end of World War II. As we travel the nation's highways and byroads we find radar speed traps along the way, guided-missile radars on hill tops around our important cities, and airway radars at the airports. Sometimes we see huge radomes enclosing powerful radars that search distant skies for approaching enemy missiles or aircraft. And, there are those radars we don't see — in the aircraft overhead and on naval and merchant ships along our shores.

These radars pose a problem of compatibility with the microwave-radio communications network of the Bell System. It is true that radars are assigned frequencies outside the bands assigned to the common-carrier microwave systems. But the high powers some radars use, along with their wide dispersion across the countryside vastly increase the likelihood of interference with radio communications systems.

Such interference does not necessarily come from the direct, powerful radar pulses; it may be from harmonics or from spurious emissions.

Interfering signals may arise also from maladjustments of a radar, causing occasional full-power pulses to be transmitted in the frequency bands assigned to radio communications. Or, the interference may originate in the frequency spectra of the pulses transmitted by the radar.

Radar interference appears as a rough buzzing noise in telephone circuits; as moving, almost randomly located white dashes in a television picture; and as errors in data signals. Such interference is likely to be of a fleeting nature, depending on the hours of operation of the radar, and on how rapidly the radar scans its assigned sector. Interference with ordinary telephone conversations and with television viewing is a commercially objectionable nuisance. However, with circuits carrying data signals, especially those required for national defense by systems such as SAGE (RECORD, *October*, 1957), any interference cannot be tolerated.

Bell Laboratories has been cognizant of the interference problem for some time, and has taken three simultaneous courses of action. First, Bell Laboratories and A.T.&T. Company engineers have discussed the problem with representatives of the Armed Services, the manufacturers of radar equipment, the Federal Aviation Agency, the Weather Bureau and the Federal Communications Commission. The second course of action has encompassed experiments conducted in the laboratory to determine how strong an interfering radar signal may be without causing excessive interference. Finally, Laboratories engineers have measured radiation from operational radars in the field to determine the frequency and power of the unwanted components of emission. This three-pronged approach has been beneficial to everyone involved with the problem of interference with microwave transmission.

Laboratory Experiments

The laboratory experiments simulated an interference condition by injecting a pulsed microwave signal (representing the radar interference) into a receiver with a signal from a microwave transmitter (representing the desired transmission). By using an assembly of waveguide couplers and variable attenuators, engineers were able to adjust independently the strength of each

Mobile laboratory for measuring radar interference. J. M. MacMaster, of the Transmission Engineering Department, is adjusting the pickup horn on the roof of the truck while Long Lines men N. Caserta, left, and W. E. Nelson observe. Scanning and signal-measuring gear is inside truck.

of these signals at the receiver input. They found that as the peak value of the interference signal approaches the peak value of the desired signal, the interfering noise in telephone circuits rises rapidly.

The noise is negligible when the ratio of peak signal to peak interference at the receiver input is more than 5 db. But it is intolerable when the ratio is unity (0 db or less), because at 0 db the interference is as strong as the wanted signals. Other tests have indicated that data signals, such as are used in the SAGE system, are not seriously affected by radar interference when the circuits do not have too much interference for ordinary telephone usage.

TV Effects

Similar tests with television signals indicated that they are more sensitive to radar pulse interference than are telephone signals. Here, it appears that the ratio of peak signal to peak interference must be more than 15 db — the signal power must be about 32 times stronger than the interference — to avoid degraded television pictures.

For the typical Bell System microwave receiving systems, Laboratories transmission engineers have estimated the maximum tolerable interference power which may be radiated from a radar without causing interference. A tabulation of the estimates is given in the table below for various relative locations of the radar and the receiver. Since some radars have spurious outputs of effective radiated power as high as five megawatts (+97 dbm), steps must be taken either to reduce the spurious emission or to keep it from reaching the microwave receiver input. Each course of action has a number of practical limitations.

To investigate the radiation from radars in the field, Laboratories engineers use a "mobile" laboratory. They drive a test truck to a site having an unobstructed view of the radar they wish to test. This site must have no apparent reflecting areas, such as a flat highway or pond, in or near the transmission path.

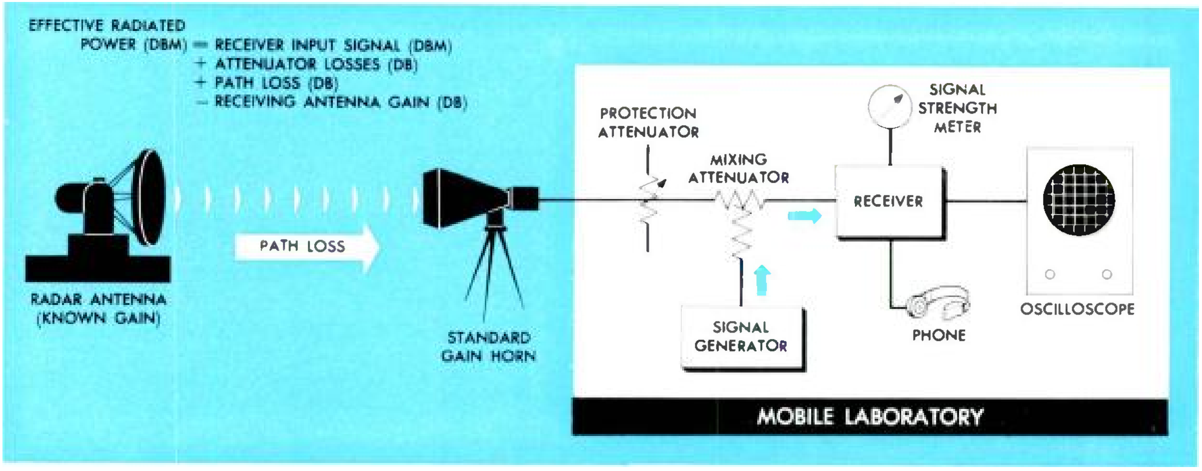
Engineers then set up a receiving "horn" on a tripod on the roof of the truck and aim it toward the radar by a simple optical sight. The testing engineer tunes in the main radar signal on his receiver and directs the radar operator by telephone to aim the beam of the radar precisely on the receiving horn. The engineer observes the radar signal on a signal-strength meter and on the oscilloscope.

When aiming is completed, the engineer matches pulses from a signal generator with those from the radar in frequency, pulse length and pulse rate; he also measures the peak pulse power received. Having done this, he determines the actual loss in the propagation path from the radar to the test truck and compares this measured path loss with the theoretical value. If the two are in good agreement, the engineer pro-

INTERFERENCE EFFECTS

Radar's Location With Respect to Communications Receiver	Maximum Tolerable Effective Radiated Power of Radar Spurious Output in dbm	
	Television Channels	Telephone Channels
Anywhere beyond a few hundred yards.	−25	−10
On the same site, receiving antenna pointed away from radar.	+15	+30
Anywhere, except along 1-mile corridor centered on microwave route.	+25	+40

Table of estimated tolerable interference effects from radars. Estimates include 30-decibel allowance for fading.



With interference-measuring equipment, operator can determine actual loss of signal strength in propagation path, then scan entire frequency band for harmonics and spurious signals from radar.

ceeds with the tests. If not, he must move to a better test site.

Having checked the propagation path loss (and incidentally the operation of the radar), the engineer scans the entire frequency band for harmonics and spurious signals. When he finds a spurious signal, he matches the signal generator to it. From this he can compute the effective radiated peak power of the radar at that frequency. Measuring equipment now available covers the frequency spectrum between 950 and 26,000 megacycles.

Specific Tests

With the cooperation of the armed services, the Laboratories has investigated eleven different types of radars. Their peak power outputs ranged from 140 kilowatts to 5 megawatts. All were found to radiate harmonics or spurious signals of substantial strength, and all of them radiated signals in one or more of the common-carrier frequency bands. These, then, are potential sources of interference to communications.

Fortunately, however, there have been relatively few cases of actual radar interference reported. Laboratories engineers give several possible reasons for this. First, many of the microwave receivers are shielded from the radars by natural obstructions such as hills, or by man-made obstructions such as tall buildings. Second, potentially interfering radars may be operating on frequencies at which their spurious outputs simply do not fall into the particular frequency bands assigned to common-carrier radio relay employed in the vicinity of this radar.

A third reason may be that interference occurs only during fading periods and hence its proper identification is made difficult. Fourth, only a few of the many types of radars in existence are now installed and operating. A final reason may be due to failure of operating personnel to recognize and report radar interference troubles because of confusion with other types of interference or other causes.

But even the few cases of radar interference with microwave transmission must be dealt with. Radar users and manufacturers are becoming increasingly aware of the potential seriousness of interference with microwave radio facilities. As a result, radar manufacturers are taking steps to minimize extra-band radiation by improving their designs. For example, they are using improved magnetrons and klystrons, better methods of filtering, and equipment with more favorable pulse shapes.

In addition, radar users are striving to improve their operation and maintenance procedures. Also, there is close coordination between Bell System engineers and the government agencies in the selection of new sites both for microwave radio stations and for radar stations.

Finally, microwave systems engineers themselves employ a number of schemes to reduce interference. Such factors as antenna directivity and cross-polarization of the communication waves with respect to the radar radiation are among the devices they use. By means such as these, interference problems which might otherwise reach intolerable proportions are being brought under control.

The several types of recording-reproducing machines used in the Bell System must be acceptably free of flutter—the effect of variations in the speed of the storage medium. Apparatus recently developed at Bell Laboratories makes it possible to measure flutter readily both on the production line and in the field.

W. J. Brown

A NEW FLUTTERMETER

During the many years engineers have spent improving electronic communications, one problem has continuously haunted them — the phenomenon of distortion. In communications equipment this takes such forms as variations in the intensity of the sound or interference from "foreign" signals. A common example is electrical noise — the "shushing" sound in a telephone receiver or the "snow" in a television picture.

Modern recording-reproducing machines are candidates for all the common distortions. But in addition, they are subject to a unique and serious form all their own — one commonly called "flutter." This is a varying deviation in pitch from the original of a reproduced sound — essentially a frequency modulation of the original. It results from the non-uniform speed of the storage medium — tape or disc — as it moves past the recording or reproducing transducer, or "pickup."

Other terms used to identify this form of distortion include "rate" or "frequency" — the number of times per second a change in pitch occurs. "Percentage" describes the ratio of the change in pitch to the original pitch. "Wow" is a term for rates of less than five cycles per second.

People react subjectively to flutter according to its rate, and this reaction is not the same for everyone. But as a general rule our ears react to various rates as follows: Below 10 variations per second the change in pitch sounds like a tremolo. (Sustained notes at this frequency, particularly those of a violin or piano, have an unnatural quaver.) Between rates of 10 and 20 the signal is heard as though there were a rapid variation in loudness accompanied by a change of pitch. Above 20 variations per second, flutter sounds as a harshness or roughness like the distortion from an overloaded amplifier or loudspeaker.

The human ear is quite tolerant of many forms of distortion. For example, spurious harmonics and electrical noise comprising several per cent of the original sound may be undesirable but not necessarily objectionable. On the other hand, the ear is extremely sensitive to flutter. In recorded music, flutter as low as 0.2 per cent at certain frequencies is apparent to practically everyone and above 0.5 per cent is considered intolerable by many. In terms of the speed of a phonograph turntable, this means that for a 33-1/3 rpm record, an essentially instantaneous deviation in speed of 0.06 rpm is noticeable; one of 0.16 rpm is intolerable.

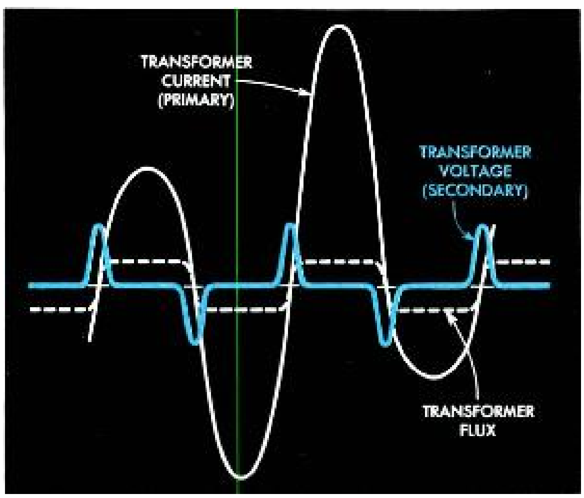
Audio engineers have made numerous investigations to determine the acceptable limits for flutter, and while their results are not in complete agreement, because of the subjective nature of the phenomenon, those listed in the accompanying table are commonly accepted.

It would be desirable, of course, to keep the flutter in all recording equipment at a very low value. Unfortunately, limiting flutter substantially raises both complexity and cost. Therefore, for reasons of economy, and in many cases physical size, engineers must design equipment close to the limit of acceptable quality for the particular type of material to be recorded. As a result, manufacturers face severe problems in quality control, since relatively minor inadvertencies in production can result in unsatisfactory recording equipment.

The Bell System has a strong interest in the control of flutter, mainly because of the growth in the use of recordings in the telephone plant. Probably the best known of these are the recorded time and weather announcements. Also a popular service is automatic telephone answering. And even people who make dialing mistakes may hear recorded voices, telling them they have reached a wrong or non-working number. To improve the results of recording-reproducing machines, Bell Laboratories developed a quantitive way to determine flutter during their production or testing. This is the KS-16570 Fluttermeter — a device that also indicates the qualitative rate of flutter.

TOLERABLE LIMITS OF FLUTTER

Recorded Material	Maximum Limit	Desirable Limit
High Quality Program	0.2%	below 0.1%
Medium Quality Music	0.5%	below 0.25%
Medium Quality Speech	1.0%	below 0.5%



Saturating transformer generates uniform voltage pulses every time input current wave crosses zero axis. Pulses are independent of frequency.

Heretofore, a number of instruments have been available to measure flutter directly. However, these are relatively expensive and are primarily intended for laboratory use. Futhermore, they require considerable skill for operation and interpretation of the measurements and therefore are not considered completely satisfactory for use on a production line or as field test equipment.

The use of comparison standards of recordings having known percentages of flutter is also unsatisfactory. Flutter may result from many different malfunctions of equipment — vibration, unbalanced motors, defective gears, bearings and pulleys — and each may produce a different rate. Obviously, it is impractical to have standards for every possible source and their combinations.

Moreover, the subjective judgment of inspectors has not proven reliable. This is because environmental, psychological and emotional factors influence a person's reaction to flutter and, consequently, his consistency of reaction. If an inspector is overtired, or coming down with a cold, his judgment of flutter will be impaired.

Thus the Fluttermeter seems to be the most practical answer to field problems. This simple, rugged, and stable device is easily operated and gives a direct reading of flutter. An operator merely records a 1000-cycle tone (a frequency chosen as the best for test purposes), reproduces this tone within wide limits of voltage and observes the reading of an indicating meter on the Fluttermeter. A panel-mounted switch permits him to adjust the full scale readings on the indicating meter for flutter of 1.5 and 3 per cent. Because the flutter content of the recording may vary rapidly, the operator can "damp" the indicating meter to obtain an average reading and thus does not need to depend upon visual averaging of a fluctuating meter needle. Filters are included so that he can also determine the approximate rate of flutter. The 1000-cycle test tone is not supplied by the fluttermeter but by signal generators required for other testing of recording equipment. A test-tone generator in the Fluttermeter would be an unnecessary duplication of facilities for testing.

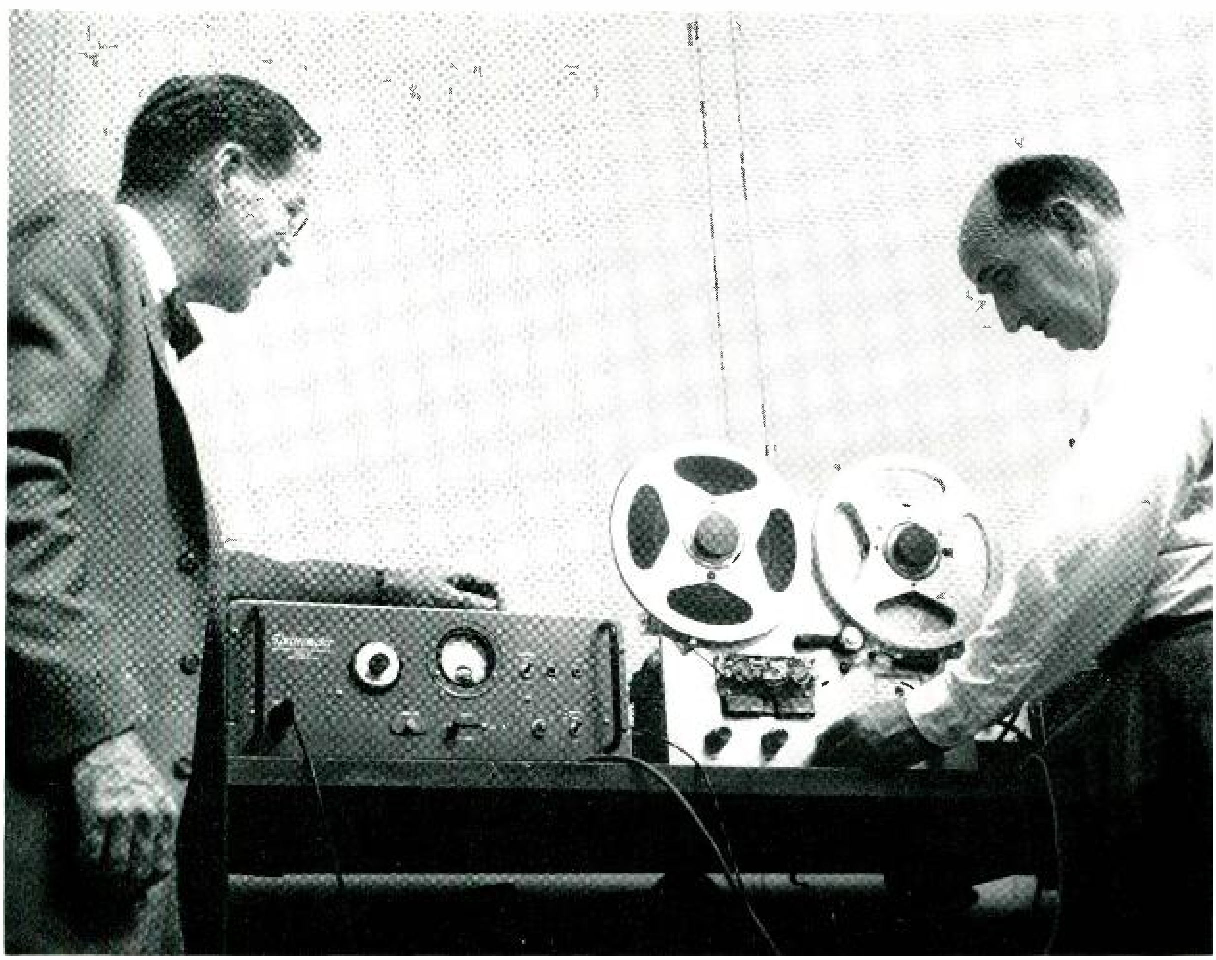
Converter Circuit

The salient feature of the Fluttermeter is the converter circuit which converts deviation in frequency of the 1000-cycle tone to an ac voltage. This voltage contains all the desired information about the magnitude and rate of flutter in a form that can be evaluated readily.

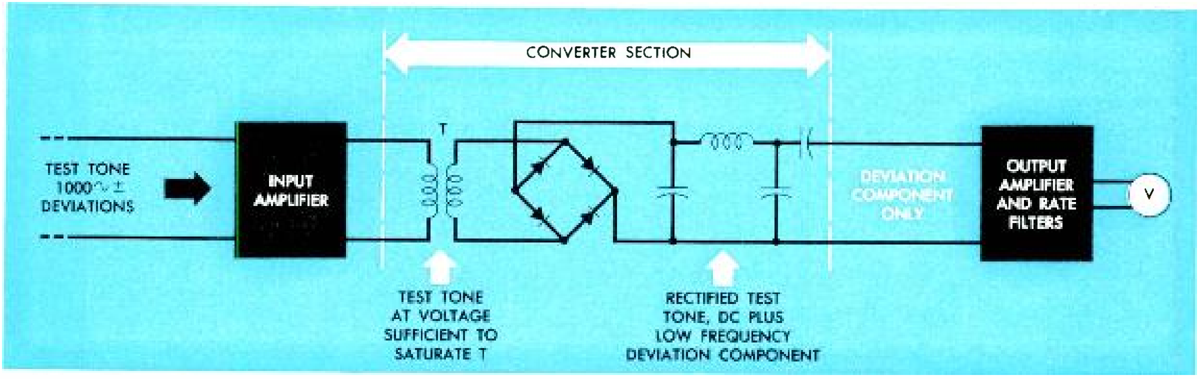
The transformer in this circuit is a saturating one that has the property of generating uniform voltage pulses whenever the alternating input current reverses polarity. These pulses are essentially independent of both frequency and input current, provided the current is above the value that saturates the transformer core.

The pulses are rectified and filtered so that a dc voltage appears across the output of a filter. This voltage is proportional to the number of pulses, or frequency, of the test tone. Thus, changes in frequency resulting from flutter cause the dc voltage to change by an amount proportional to the change in frequency. The rate of change of the voltage is also the same as the rate of the flutter. A capacitor in series with the output of the filter transmits the varying component of the dc voltage to an output amplifier which provides the visible indication of flutter on the output meter.

The ac component resulting from flutter is the product of the dc output voltage of the filter for the steady 1000-cycle tone and the per cent



W. J. Brown, at left, and W. R. Goehner adjust tape recorder for test by the Fluttermeter. The magnitude of flutter can be obtained from the meter which has two ranges of full-scale reading.



Converter section of Fluttermeter converts deviation in frequency of a 1000-cycle test tone to an ac voltage. This voltage, read from the meter, contains information to evaluate the flutter.

flutter. Since the dc voltage is quite large — 75 volts — a low percentage of flutter generates an ac voltage requiring only a nominal amount of amplification to operate the indicating meter. This is a major advantage of the converter circuit, for if the voltage were to be very small, as in many existing fluttermeters, a large amount of amplification would be required.

Amplifier Problems

High-gain, low-frequency amplifiers with uniform response extending below one cycle are complex and susceptible to instability. Furthermore, they require a relatively long time to stabilize after being overloaded, a very evident disadvantage in making numerous measurements that may be required on a production line. Moreover, short stabilization time is an important factor, since accidental overloading occurs frequently during testing. For example, an interruption of the test tone causes the 75 volts at the output of the filter to reduce suddenly to zero. This is the equivalent of applying 75 volts to the input of the amplifier.

The output amplifier in the Fluttermeter is a single-stage plus a cathode follower for coupling to the indicating meter. Its gain may be varied to give full-scale readings on the meter for 1.5 and 3.0 per cent flutter. It responds uniformly over the frequency range of 0.5 to 120 cycles — a range adequate for all usual rates of flutter. The amplifier uses filters of the resistor-capacitor type — one to determine the approximate flutter content for rates above 15 cycles, the other for rates below 15 cycles. Jacks make it possible to use more accurate analyzing equipment for those cases requiring a detailed analysis of flutter rate.

The accuracy of converter circuits used in many other flutter meters depends upon the constancy of the amplitude and frequently the amount of distortion of the input signal. To keep these within the required limits, the input amplifiers are relatively complex. Manual control of the input amplifier is not feasible because the amplitude of the test signal may vary too rapidly to be controlled satisfactorily.

In the Fluttermeter there is no need for automatic control of the output level of the input amplifier, nor for keeping the distortion of the input signal or that generated by the amplifier to a low value. This is because the output of the converter circuit is, for a wide range of frequencies, a function only of the number of times the input signal changes polarity. Distortion of the input signal therefore has no significance. Furthermore, if the converter input signal is kept above the value which saturates the transformer, variations in amplitude also have no effect upon the output.

The input amplifier is a conventional two-stage type with no controls. It has sufficient gain to permit the Fluttermeter to operate at a input level of 50 milli-volts — a sensitivity adequate for all usual applications. An upper limit of 10 volts is imposed to prevent damage to components.

The Fluttermeter was developed primarily for the Western Electric Company to use in the production and field-testing of recording equipment. Because of its proven accuracy and convenience, however, it can be used to test and maintain any recording equipment. It is now being used at the Laboratories in the development of telephone-answering and transcribed-announcement systems. Its features have been of interest to other users of flutter measuring equipment, and a commercial version is now being produced.

Two New Overseas Services Link U. S. With Nassau and Puerto Rico

News of the Bell System

Two important new overseas transmission services started operation early this year. Both are based on transmission techniques developed at the Laboratories. The two transmission systems—over-the-horizon and submarine cable—offer an interesting contrast in modern transmission methods.

The new over-the-horizon radio transmission system links the United States and Nassau in the Bahamas. This method of "lobbing" telephone messages over vast bodies of land and water will serve the expanding telephone traffic between this country and the popular British colonial resort area.

The new system, using a technique of pushing microwaves beyond the curvature of the earth, is equipped to carry 24 simultaneous telephone conversations, and can be expanded to 72 circuits. It was built at a cost of $1,500,000 by the Long Lines Department of the A.T.&T. Company and the Telecommunications Department of the Bahama government. Terminals for the system are 186 miles apart—at Florida City, Florida, and Delaporte Point, a few miles from Nassau on New Providence Island.

Tropospheric Scatter Propagation

Dish-like antennas at each site beam microwaves toward the horizon in the direction of the distant site. As the microwaves pass beyond the curvature of the earth, they continue moving into the troposphere, an air mass surrounding the earth. Here a small part of the energy in the waves is scattered downward toward the receiving antenna. The energy in these falling microwaves is sufficient to provide a reliable signal. Technically, this is known as "tropospheric scatter propagation."

Frequencies used for this system are over twice as high as those used on the first tropospheric scatter system between Florida and Cuba. This makes it possible to use smaller antenna disks (*see opposite page*).

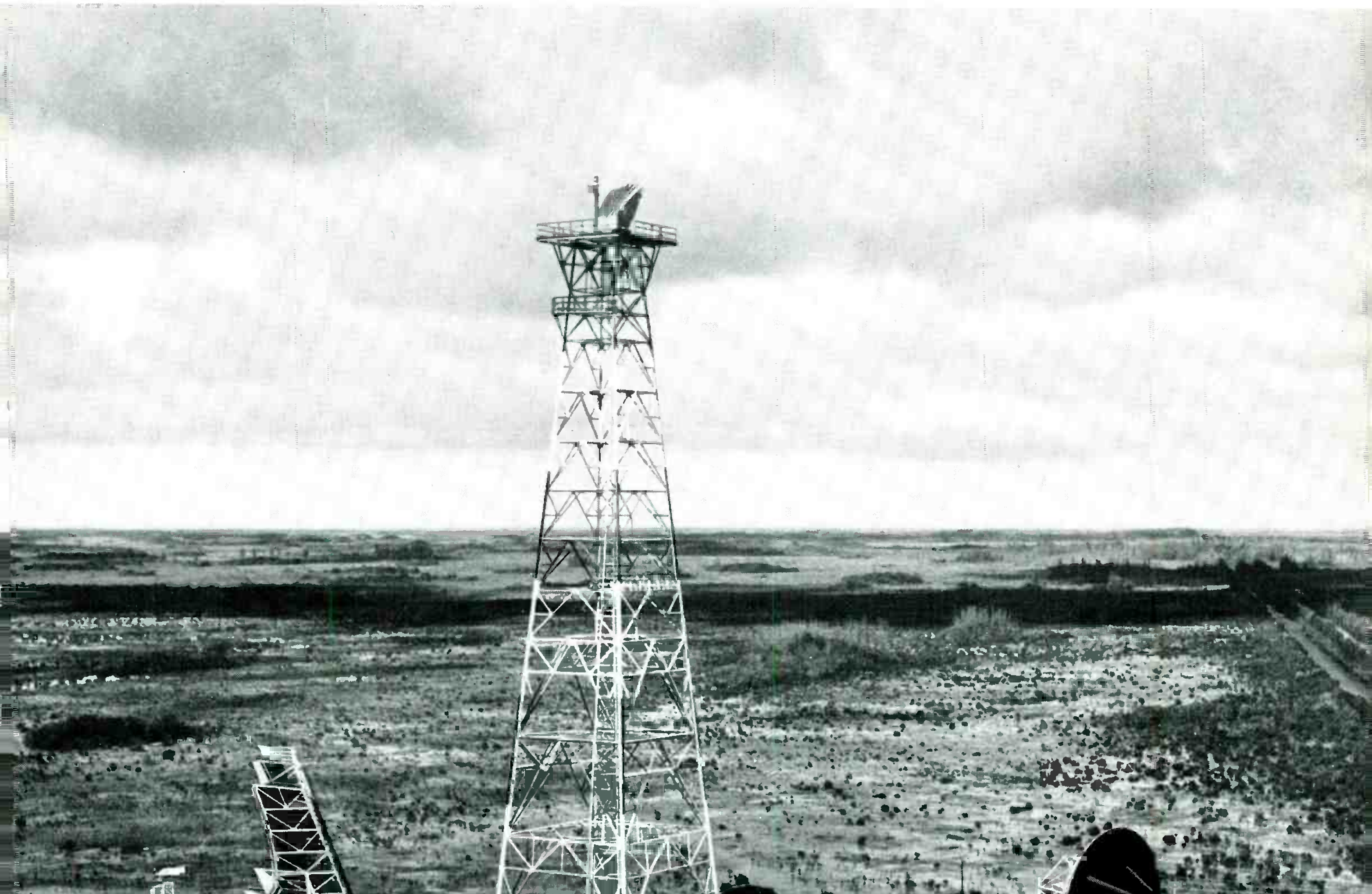
The additional telephone circuits will relieve traffic on the nine radiotelephone circuits now in operation and will substantially improve transmission and permit greater service between the United States and Nassau.

By contrast to the over-the-horizon system, the new U.S.-Puerto Rico submarine telephone cable system is the world's deepest telephone cable. Costing $17 million, it is a joint project of the Long Lines Department of the A.T.&T. Co. and the Radio Corporation of Puerto Rico, a subsidiary of International Telephone and Telegraph Corporation. Twin cables—one for each direction of speech—were laid by the veteran cableship *Monarch* during November of last year and January, 1960.

About 75 miles northwest of Puerto Rico, one of the cables drops to a depth of five miles into the "Milwaukee Deep," the deepest point in the Atlantic Ocean. It is part of a gaping, eel-shaped crevice called the "Brownson Deep."

R. M. Riley of the Outside Plant Development Department was aboard the *Monarch* in November when she laid cable from Florida to Puerto Rico. R. A. Kelley and L. H. Morris of the Transmission Systems Development Department were on the cableship in January as she laid cable from Puerto Rico to Florida. T. F. Gleichmann, also of the Transmission Systems Development Department, was at West Palm Beach in November and at San Juan in January. The Laboratories men were present as advisers and observers.

Dish-shaped antennas, right foreground, located at Florida City, Florida, are aimed at Nassau in the Bahamas. Microwaves are reflected off troposphere to receiving antennas 186 miles away. System can carry 24 simultaneous telephone conversations. Other antennas in picture are for television and telephone transmission between the U.S. and Cuba, and for relaying telephone signals.



Annual Report Cites Gains In Earnings and Plant

A record gain in telephones, better service and improved earnings made 1959 "a good year for the Bell System," Frederick R. Kappel, President of the A.T.&T. Company, said in the 1959 Annual Report to share owners. The report went to some 1,737,000 share owners—up 107,000 from 1958.

Mr. Kappel said the accomplishments reflected the efforts of Bell System people (729,000 of them) to devise and market services to fully satisfy individual needs and preferences, increase efficiency and "gain wider public understanding that good profits are as necessary to good performance in our business as they are in any other."

News of the Bell System

Earnings were $5.22 a share, compared with $4.67 a share in 1958. Net gain in telephones was 3,298,000 topping the previous high of 3,264,000 set in 1946.

For the fourth consecutive year, the Bell System spent more than $2 billion on new construction to expand and improve telephone service. The 1959 figure was $2½ billion. To help finance this program the System obtained about $750 million of new capital, largely from the sale of bonds. Interest rates ranged from 4⅜ to 5¾ per cent.

"High interests rates are only one aspect of rising costs," Mr. Kappel said. "Taxes, already heavy, climbed further in 1959. So did wages, which are the largest cost factor in the business." Taxes on Bell System service last year averaged $3.39 per telephone, per month.

"Federal, state and local taxes on operations were $1,690,289,000, equal to $7.66 per share of A.T.&T. stock, or considerable more than the earnings per share of $5.22," Mr. Kappel pointed out. In addition, phone users paid directly some $600 million in Federal excise taxes. "Telephone excise taxes are unjust and discriminatory and should be eliminated completely," he said.

The year's record gain in telephones brought the Bell System total to nearly 58 million—96 per cent dial-operated. Some 15 million telephone customers (nearly twice as many as a year ago) now dial calls to points all over the country.

"Telephone service has never been so fast, convenient and dependable as it is today," Mr. Kappel said. In detailing service achievements, he cited:

OVERSEAS SERVICE—a second transatlantic cable system opened in September. A cable to Puerto Rico went into service recently. One to Bermuda is planned and preliminary work has started on one to Japan and other Pacific points. Overseas calls rose 15 per cent in 1959.

BUSINESS SERVICE—Further advances were made in data transmission, such as with Data-Phone. This service enables machines to talk to machines, using the same network over which people talk with people. Connections are put through just as telephone calls are.

Private branch exchanges of several more large customers (including the Pentagon) were arranged so callers could dial individual extensions without going through a switchboard. A new system for private long distance telephone line customers was developed, allowing each phone to call any other (up to about 80) with only two pulls of the dial. Speakerphones were improved.

RESIDENCE SERVICE—The System's newest telephone, the compact "Princess," was introduced in four states, with excellent customer response. The set will be ready for general introduction throughout the country in the latter part of 1960.

RESEARCH—Work went ahead on installation of the experimental transistorized electronic central office—first in the world—at Morris, Illinois. Bell Laboratories engineers are now testing the equipment, and the first connection with the lines of telephone users will be made in the summer of 1960. The trial at Morris will provide experience and knowledge required for development and production of a system for widespread use. The latter will make possible a wide variety of optional service features.

DEFENSE—Western Electric continued to coordinate work on the SAGE (Semi-Automatic Ground Environment) air defense system and also completed the Aleutian segment of the DEW (Distant Early Warning) Line and went ahead with an eastward extension across Greenland. Bell Laboratories takes part with Western Electric in these projects and in establishing communications for the Air Force's Ballistic-Missile Early Warning System (BMEWS).

As a first step in research in space communications, Bell Laboratories is working with the National Aeronautics and Space Administration and its Jet Propulsion Laboratory, operated by the California Institute of Technology, on "Project Echo," which will study the possibilities of communicating by means of radio microwaves reflected from a satellite.

In "Project Mercury", the nation's undertaking to put a man into orbit in space, Western Electric is leader of an industrial team, including the Laboratories, which has major responsibilities to establish a world-wide network for communicating with the space capsule.

THE FERREED

A New Magnetic Switch

A team of engineers at the Laboratories has invented a very fast electromechanical switch called the "ferreed." This switch uses a new technique for actuation, whose speed is compatible with that of electronic circuits. The ferreed may find use as an interconnecting element in telephone switching networks, where it could be controlled a thousand times more rapidly than the electromechanical switches presently employed. Inventors of the new switch, A. Feiner, C. A. Lovell, T. N. Lowry, and P. G. Ridinger, of the Switching Systems Development Department, anticipate applications for the ferreed in various types of systems where metallic contacts might be controlled by microsecond pulses.

News of Switching Development

Magnetic materials that can be quickly switched between two alternate states have been widely used as "memories" for storing information in digital computers. The useful output from these elements has generally been limited, however, to electrical signals that are transitory.

By contrast, in conventional electromagnetic relays, continuous electrical currents are used to open and close metallic contacts for extended periods of time. But here the disadvantage lies in the speeds, limited by the mechanical motion of the moving parts.

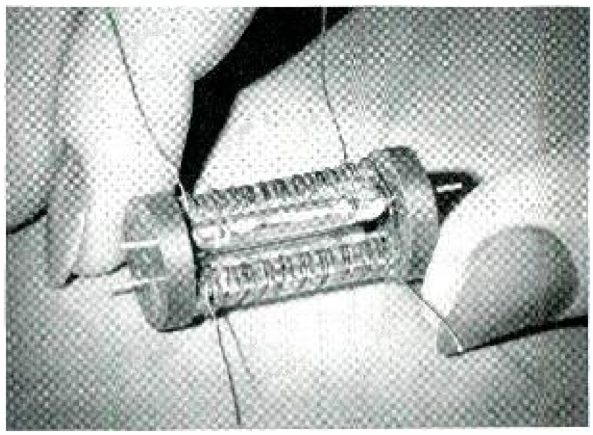
The ferreed combines the ability of bi-stable magnetic materials to switch rapidly with the ability of metallic contacts to exhibit either of two states indefinitely. In several models of the device, a cobalt ferrite has been used as the magnetic material and a magnetic reed switch, sealed in glass, for the output contacts—hence the name, "ferreed."

In operation, the magnetic material is switched by a magnetomotive force. In a typical arrangement, a five-ampere pulse passes through a thirty-turn winding. Control pulses as short as five microseconds will switch the magnetic material, resulting in the passage of magnet flux through the movable members of the reed switch. Actual closure of the contacts is delayed for several hundred microseconds by inertia of the reed.

The contacts are released by cancelling the magnetic flux through the reeds, as the result of another switching operation. Opening the contacts requires less time than closing them.

Several new magnetic materials have been synthesized for use in developmental models of the ferreed. Among these are ferrites exhibiting characteristics midway between permanent magnets and ferrite suspensions in plastic. Physically, the reed switch is similar to a type that has been used in standard electromagnetic relays for the past ten years.

In a telephone switching network, customers are connected by closing, in specified patterns, switches called "crosspoints." A typical telephone central office contains many thousands of these switches; of these, a few dozen are operated for each call. Crosspoints required for a particular connection must be selected by the coincidence of pairs of control pulses. The ferreed's magnetic structure responds to a pair of pulses by closing the output contacts. They are opened by a subsequent single pulse.



This two-branch ferreed consists of two ferrite bars, two glass-sealed magnetic reed switches, and two plastic end-pieces. End pieces couple the bars to switches as well as provide structural support.

Besides providing coincident-pulse operation and rapid actuation, the magnetic structure permits the desired switching by pulses of widely varying current. The result, when ferreeds are used in switching networks, is reliable operation from simple control circuits.

News in Brief

Voice Message Reflected From Sphere in Space

A radio signal carrying a voice message was successfully transmitted recently via balloon from Holmdel, N. J., to the M.I.T. Lincoln Laboratory at Round Hill, Massachusetts. The signal was reflected from a 100-foot aluminum-coated balloon in space. The message, transmitted by the Laboratories Radio Research Group, was the second station-to-station radio signal to be reflected from a man-made mirror in space.

The 130-pound sphere was launched at Wallops Island, Virginia, as part of a series of experiments under the direction of the National Aeronautics and Space Administration (NASA). The purpose of the launching was to test the mechanism for ejecting the balloon from its container and inflating the sphere in space.

Pre-recorded on tape, the message was beamed at the sphere which sped eastward over the Atlantic more than 200 miles above the earth. The transmission consisted of four, 45-second voice sequences spaced one minute apart. The M.I.T. Laboratory and the General Electric Company at Schenectady, New York, reported receiving parts of the message and carrier wave, respectively. The messages were not received totally due to antenna tracking difficulties.

Tests Use 60-foot Antenna

The first station-to-station radio signal reflected from a man-made sphere was transmitted by the same group at the Holmdel Laboratories in January. Both tests used a 10-kilowatt transmitter with a 60-foot dish-shaped antenna. However, no voice was transmitted in the first test.

This spring, NASA plans to send a similar sphere into orbit around the earth. The sphere will serve as a reflector for radio signals transmitted between the Laboratories at Holmdel and the Jet Propulsion Laboratory at Goldstone, California.

High-Speed Diode Switch Described to A.I.E.E.

A silicon p-n-p-n diode capable of switching at extremely high speeds was described in a paper presented at the Winter General Meeting of the American Institute of Electrical Engineers in New York City. The switch, developed at Bell Laboratories (RECORD, *June*, 1959), is a result of the joint efforts of A. N. Baker, J. M. Goldey and I. M. Mackintosh, all of the Transistor Development Department.

This device is useful in switching moderate amounts of power (several watts) with extreme rapidity. Typical applications are in-line pulsers and high-speed gates used in certain types of telephone equipment now under development. The diode turns on or off in about ten milli-microseconds. More refined measurements show that the value of the current is reduced to approximately one-ten thousandth value in less than 100 milli-microseconds.

In the "on" condition, this diode has a resistance of about 2 ohms, and its impedance when "off" is represented by a capacitance of 5 micromicrofarads. At room temperature, the device has an extremely low leakage current —about one millimicroampere.

The p-n-p-n diode has a triple diffused structure, starting with a wafer of n-type silicon. This wafer is "etched" to form a mesa-type construction to reduce its area, resulting in a unit with the capacitance of 5 micromicrofarads.

High-speed operation is achieved by the thin base layers and by reducing the lifetime of the charge carriers—the electrons and holes. Reducing lifetimes can be done either by irradiating the device with high-energy electrons or by diffusing tiny amounts of gold into the base.

Two New Books by Laboratories Authors

Two books for high-school science courses have been written recently by members of the Laboratories. They are: *Waves and the Ear*, by W. A. Van Bergeijk, J. R. Pierce, and E. E. David, Jr., all of the Research in Communications Principles Department; and *Crystals and Crystal Growing*, by Alan Holden, of the Physical Research Department, and Phylis Singer, teacher of mathematics and art at the Far Brook School in Short Hills, N. J.

These books are part of the Science Study Series, whose volumes serve as a supplementary library to courses conducted using texts and techniques prepared by the Physical Science Study Committee. This organization, made up of leading teachers, college educators and a select group of representatives of industry, including Bell Laboratories, assumed the job of redesigning the high-school physics curricula to improve teaching effectiveness and to include the important concepts of modern theory.

Waves and the Ear discusses the physical nature of sound waves and the physiology of the ear itself. The book covers basic knowledge of sound and its perception. *Crystals and Crystal Growing* explains the theory and practice of the modern crystallographer's art and presents simple methods whereby the reader can grow and experiment with a dozen basic crystal types. Both books are published by Anchor Books, Doubleday & Company, Inc., Garden City, New York.

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

AMERICAN CHEMICAL SOCIETY—MEETING-IN-MINIATURE, South Orange, N. J.

Ballman, A. A., *The Growth and Properties of Doped Quartz.*

Gieniewski, C., *Polyethylene Chemically Cross-Linked with Di-Tertiary-Butyl Perioxide.*

Hellman, M. Y., *The Polydispersity of Polymers by Viscometry.*

Kuebler, N. A., and Nelson, L. S., *Kinetic Absorption Spectra Recorded Through Flash Heated Grids.*

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

AMERICAN CRYSTALLOGRAPHIC ASSOCIATION, Washington, D. C.

Abrahams, S. C., *Liquid Helium Goniometer-Mounted Cryostat for a Single Crystal Automatic Neutron Diffractometer.*

Geller, S., *Refinement of the Structure of $LiMnPO_4$.*

A.I.E.E., WINTER GENERAL MEETING, N. Y. C.

Baker, A. N., *High-Speed Silicon p-n-p-n Diodes.*

Dunbar, F. C., *A Delay Distortion Simulation Set.*

Hagelbarger, D. W., *Error-Detection Using Recurrent Codes.*

Hochgraf, L., *E6 Voice Repeater—Background and Theory of Operation.*

Lang, W. Y., *Advances in the Printing Telegraph Art During 1959.*

Munk, P. R., *Tentative Proposed Standard for Low-Power Wide-Band Transformers.*

Pedersen, L., *E6 Telephone Repeater—Packaging Design.*

Pike, V. B., *Corrosion Considerations Connected with Grounding Metallic Sheath Communication Cables.*

Smethurst, J. O., *E6 Voice Frequency Telephone Repeater—Description and Testing.*

Ulrich, W., *Automatic Maintenance Operations in an Electronic Telephone Central Office.*

AMERICAN PHYSICAL SOCIETY MEETING, N. Y. C.

Frisch, H. L., and Lebowitz, J. L., *Singlet and Pair Distributions in a Fluid.*

Hrostowski, H. J. Kaiser, W., and Thurmond, C. D., *Electrical and Optical Effects of Oxygen in Germanium.*

Kaiser, W., see Hrostowski, H J.

Lax, M., *Fluctuations from the Non-Equilibrium Steady State.*

Lebowitz, J. L., see Frisch, H. L.

Thurmond, C. D., see Hrostowski, H. J.

Weinreich, G., *Valley-Orbit Splitting in Germanium from Strain-Induced Shift of Lyman Spectrum.*

1960 INTERNATIONAL SOLID-STATE CIRCUITS CONFERENCE, Philadelphia, Pa.

Bittmann, C. A., Davis, R. E., Kirkpatrick, R. J., and Saari, V. R., *Circuit Applications of a Coaxially Encapsulated Microwave Transistor.*

Davis, R. E., see Bittmann, C. A.

Early, J. M., *High Frequency Amplification and Generation.*

Franks, L. E., and Witt, F. J., *Sampled-Data Bandpass Filters.*

Kirkpatrick, R. J., see Bittmann, C. A.

Ross, I. M., *Microelectronics.*

Saari, V. R., see Bittmann, C. A.

Witt, F. J., see Franks, L. E.

OTHER TALKS

Ahearn, A. J., *Mass Spectographic Studies of Bulk Impurities and Surface Contaminants of Metals, Semiconductors and Insulators*, Western Electric Co., Allentown, Pa.

Allen, F. G., *p-Type Films and Surface Measurements on Silicon in High Vacuum*, Cornell University, Ithaca, N. Y.

Anderson, O. L., *The Adhesion of Metals in Air at Room Temperature*, Minnesota Mining and Manufacturing Co., Research Laboratory, St. Paul, Minn.

Chapin, D. M., *Making Solar Cells in the High School Laboratory*, Newburgh Free Academy, Newburgh, N. Y.

Cutler, C. C., *Engineering Background for Communication in Space*, I.R.E. Third Annual Symposium on Modern Communications, Philadelphia, Pa.

D'Asaro, L. A., *Esaki Diodes*, Cornell University, Ithaca, N. Y.

David, E. E., Jr., *The Relevance of Cerebral Mechanisms to Communications Research*, Conference on Cerebral Systems and Computer Logic, California Institute of Technology, Pasadena, Calif.

Downing, H. L., *Electron Tubes, Elementary Theory and Applications*, Notre Dame High School, Easton, Pa.

Garn, P. D., and Kessler, J. E., *Thermogravimetry in Self-Generated Atmospheres*, A.C.S. Meeting-in-Miniature, Newark, N. J.

Garrett, C. G. B., *Organic Semiconductors*, Merck, Sharp and Dohme, Rahway, N. J.

Geils, J. W., *Research in Industry Today*, Industrial Management Clubs, Camden, N. J.

Germer, L. H., *Electrical Breakdown Between Close Electrons in Air*, Gaseous Electronics Conf., N. Y. C.

Gordon, J. P., *The Maser*, Rensselaer Polytechnic Institute Electrical Engineering Department Colloquium, Troy, N. Y.

Hogg, D. C., *Low-Noise Antennas*, I.R.E., Garden City, N. Y.

Hogg, D. C., *Millimeter-Wave Transmission Problem*, I.R.E., Washington, D. C.

Hopfield, J. J., *Edge Emission Phenomena in CdS, ZnS, and ZnO*, Westinghouse Electric Co., Pittsburgh, Pa.

Ingram, S. B., *Our Future Scientific and Engineering Manpower Problem*, University School of Journalism, Ardsley, N. Y.

Irvin, H. D., *Man-Machine Systems*, Polytechnic Institute of Brooklyn, Conf. on Solving Industrial Engineering Problems by Simulating Techniques, Brooklyn, N. Y.

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

Kohman, G. T., *Hydrothermal Growth of Quartz Crystals*, Seventh International Congress of Pure and Applied Chemistry, Munich, Germany.

Koontz, D. E., *Cleaning of Metals for Use in Electronic Tubes and Semiconductors*, A.S.M. Golden Gate Conf., San Francisco, Calif.

Kostkos, H. J., *New Horizons in Communications*, Southern New England Telephone and Telegraph Company, New Haven, Conn., Feb. 17, 1960; Electrical Society of Montreal, Montreal, Canada, Mar. 9, 1960.

Leamer, F. D., *Maturity: A Useful Criterion in Professional Salary Administration*, Northern Ohio Personnel and Executive Conf., Cleveland, Ohio.

Lebert, A. W., *Armored Ocean Telephone Cable*, Board of Education of the Montclair School System, Montclair, N. J.

Lewis, W. D., *Coordinated Broadband Mobile Telephone System*, I.R.E. Tenth National Conf., Prof. Gp. on Vehicular Communications, St. Petersburg, Fla.

Lewis, W. D., *Modern Communications*, Vail-Dean School, Elizabeth, N. J.

Ligenza, J. R., and Spitzer, W. G., *The Mechanisms for Silicon Oxidation in Steam and Oxygen*, Second Conf. on Semiconductor Surfaces, U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Md.

Morin, F. J., *Transition Metal Oxides*, Merck, Sharp and Dohme Research Laboratories, Rahway, N. J.

Mumford, W. W., *Microwave Noise Figures*, I.R.E., Stratford Avenue School, Garden City, N. Y.

Mumford, W. W., *Technical Aspects of Microwave Radition Hazards*, I. R. E., San Diego, Calif.

Pierce, J. R., *Satellite Systems for Commercial Communications*, Twenty-Eighth Annual Meeting of Institute of Aeronautical Sciences, N. Y. C., Jan. 26, 1960; I.R.E. Prof. Gp. on Military Electronics, Los Angeles, Calif., Feb. 3, 1960.

Pollak, H. O., *Uncertainty*, Conrad Hilton Hotel, Chicago, Ill.

Schulz-Du Bois, E. O., *The Present Status of Solid-State Maser Development*, Technical University of Karlsruhe, University of Frankfurt, Technical University of West Berlin, Germany.

Slepian, D., *On Prolate Spheroidal Wave Functions, Fourier Analysis and Uncertainty*, Society for Industrial and Applied Mathematics, Chicago, Ill.

Slichter, W. P., *X-Ray Diffraction in Polymer Research*, A.C.S., Staten Island, N. Y.

Smith, G. E., *Electron-Spin Resonance in Bismuth and Antimony*, IBM Watson Laboratories, N.Y.C.

Snoke, L. R., *Biology at Work in Communications Engineering*, Livingston High School, Livingston, N. J.

Spitzer, W. G., see Ligenza, J. R.

Tebo, J. D., *Bell Laboratories Place in the Bell System*, Bell Telephone Company of Pa., Pittsburgh, Pa.

Tebo, J. D., *The Nike-Hercules Guided Missile System*, A.I.E.E., Mellon Institute, Pittsburgh, Pa.

Thomas, D. G., *Excitons in ZnO and CdS*, Wright-Patterson Air Force Base, Dayton, Ohio.

PATENTS

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

Abbott, G. F., Jr. — *Error Detection Circuit* — 2,926,334.

Ashkin, A. — *Traveling Wave Tube* — 2,926,281.

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Daniel H. Wenny, Jr. ("New Dimensions in Metallurgy") was born in East Orange, N. J. and received the degree of Metallurgical Engineer from Lehigh University in 1929. After working for a year in a steel mill, he joined the metallurgical research group of the Laboratories. His first assignment was the study of methods for preparing molybdenum Permalloy powders for loading-coil cores. He then conducted research in magnetic materials until 1942, when he was put in charge of the Metals Processing Laboratory. Here he was concerned with the development of new specialty alloys of base and precious metals for communication apparatus, and the processing, and heat-treating techniques that control their structure and properties. Mr. Wenny holds several patents on the melting, refining, and processing of magnetic materials. He is a member of the American Society for Metals.

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William B. Cagle is from Hollis, Oklahoma. He joined the Laboratories in 1953 immediately after graduation from the University of Oklahoma with a B.S. in Electrical Engineering and completed the three-year Communications Development Training Program at the Laboratories in 1956. Mr. Cagle was concerned with the design of semiconductor logic circuits—the subject of his article in this issue —for the experimental ESS and the Morris, Illinois, field-trial ESS. He is presently supervising a group doing transistor circuit design and logical design for the central control of Electronic Switching System No. 1. He is a member of Tau Beta Pi, Eta Kappa Nu, Sigma Tau, Phi Eta Sigma, and the I.R.E.

R. L. Robbins

Robert L. Robbins, a long-time resident of Allendale, New Jersey, received his bachelor of electrical engineering degree from R.P.I. in 1929. After a year with Westinghouse Electric, he joined the Laboratories in 1930, first working on quartz crystals for aircraft radio transmitters. In 1938 he joined what is now the Systems Engineering Department to work on shortwave circuits, the lineless handset and a special longwave transmitter located at Rocky Point, Long Island.

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During World War II, Mr. Robbins acted as technical observer on communications for the Air Force and the Army in Europe. After the war, he returned to the Laboratories and began studies on mobile radio service for New York City. He has also worked on the TD-2 microwave radio-relay system and is presently concerned with radar interference studies (the subject of his article in this issue) and the problems of commercial suppliers of microwave equipment.

Some of this work has required him to take field trips—a fact responsible for one telephone man being alive today. In September, 1954 Mr. Robbins was instrumental in saving the life of a near-victim of electrocution during field tests in Charleston, South Carolina. For this act he received the Vail Medal in 1955.

W. J. Brown

W. J. Brown was born in Paterson, New Jersey. He received the B.S. degree from Yale University in 1928, and joined Electrical Research Products, Inc. (a subsidiary of the Western Electric Company) in 1929. There he engaged in the development of amplifiers and loudspeakers for sound motion pictures and sound evaluation equipment. He also acted as consultant with architects and industry in general on sound-control problems. Mr. Brown transferred to the Laboratories in 1943 and since then has been engaged in similar work, plus the development of recording equipment for telephone-answering and announcement systems. He is a member of the Yale Engineering Society and Sigma Xi. Mr. Brown is author of "A New Fluttermeter" in this issue.