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Bell Laboratories RECORD

A Tester for the Nike Missile Systems
Personal Signaling in Columbus, Ohio
Optical Microscopy
A New Coin Telephone
A Barrier-Grid Tube Memory

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Cover

E. S. Greiner observes rod of boron powder being melted by floating-zone refining. This technique has produced boron crystals as large as 0.1 inch across (see p. 476).

Much time and technical effort lies between an engineer's initial idea and the eventual equipment or system he hopes to produce. A way to hasten the process of engineering development is to simulate some of the steps. For the Nike Missile Systems, Bell Laboratories has applied this technique with a device called the Nike System Tester.

A Tester for the N

V. M. Cousins

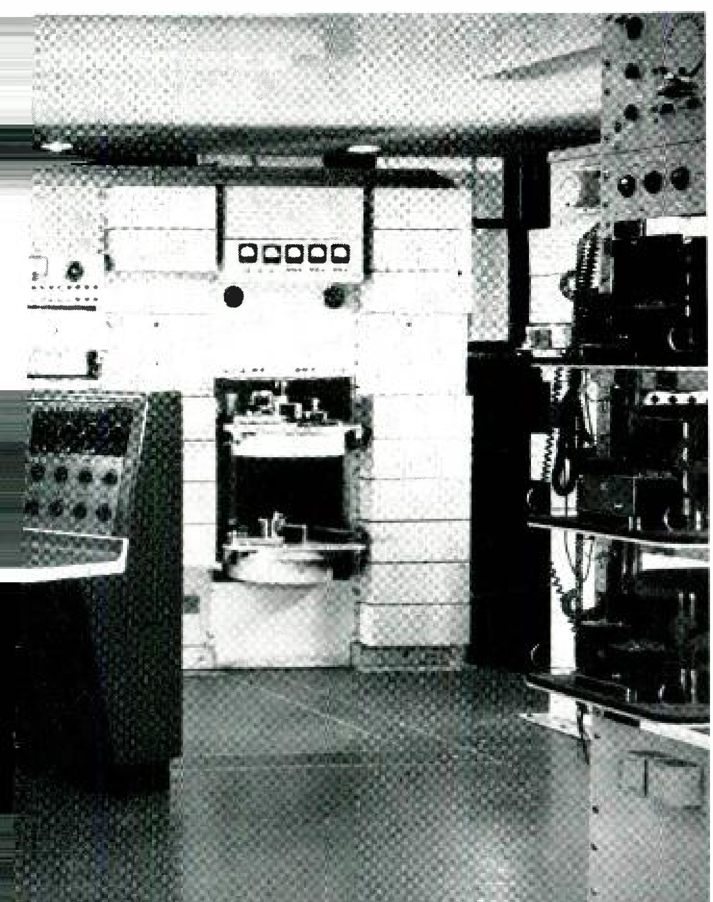
ssile Systems

SIMULATION holds an important place among the many techniques contributing to the design and ultimate effectiveness of modern military systems. This technique is used, for example, in grounded flight trainers where student pilots, through simulation, learn the conditions and sensations occurring in actual flight. Another example is the simulated flight conditions found in a wind tunnel, where engineers study the aerodynamic forces on aircraft and missile structures.

In the case of the Nike guided missile systems (RECORD, *February*, 1959), a large number of actual field tests have been performed. For this program, however, there are limitations, both physical and financial, that prevent engineers from completing a large number of intercepts under the same conditions. By simulation, they can "perform," quickly and cheaply, enough engagements between simulated missiles and targets to get conclusive results. Thus evolved the Nike system tester, used to simulate the various Nike guided missile systems over the past ten years. During this period the tester has carried out more than 70,000 realistic engagements.

Over the years, engineers have found a good correlation between the results of the actual intercepts and the simulated engagements for similar conditions. Such agreement, of course, helps them to trust the results of the simulation of other factors, such as targets of the future. Simulation also permits controlled testing situations where a whole series of engagements are carried out under precisely the same conditions. The value of a single parameter can be changed between successive tests so that the effect of that factor only can be evaluated. This, of course, would be impossible in a real operating system.

Like most other major military developments, the Nike guided missile systems employ simulation in a variety of forms. General and special-purpose digital and analog computers at the Laboratories, the White Sands Missile Range in New Mexico and the Douglas Aircraft Company in Santa Monica, California, have been in continuous use solving problems peculiar to the missile, the radars, and the guidance, as well as



Simulation equipment room at the Whippany, New Jersey, location of the Laboratories. Part of guidance computer can be seen on left wall. Across front, B. R. Burrell, left, and D. L. Castner make adjustments to target and radar portion of simulator. J. N. Wright sits at console where initial conditions of a simulated engagement are set into the system. To right of area shown in picture is the missile portion of simulator.

combinations of these major components. When the characteristics of the components are incorporated in a complete system simulator, such as in the Nike system tester, designers can make an over-all evaluation of the system by simulation in the laboratory, well in advance of system tests in the field.

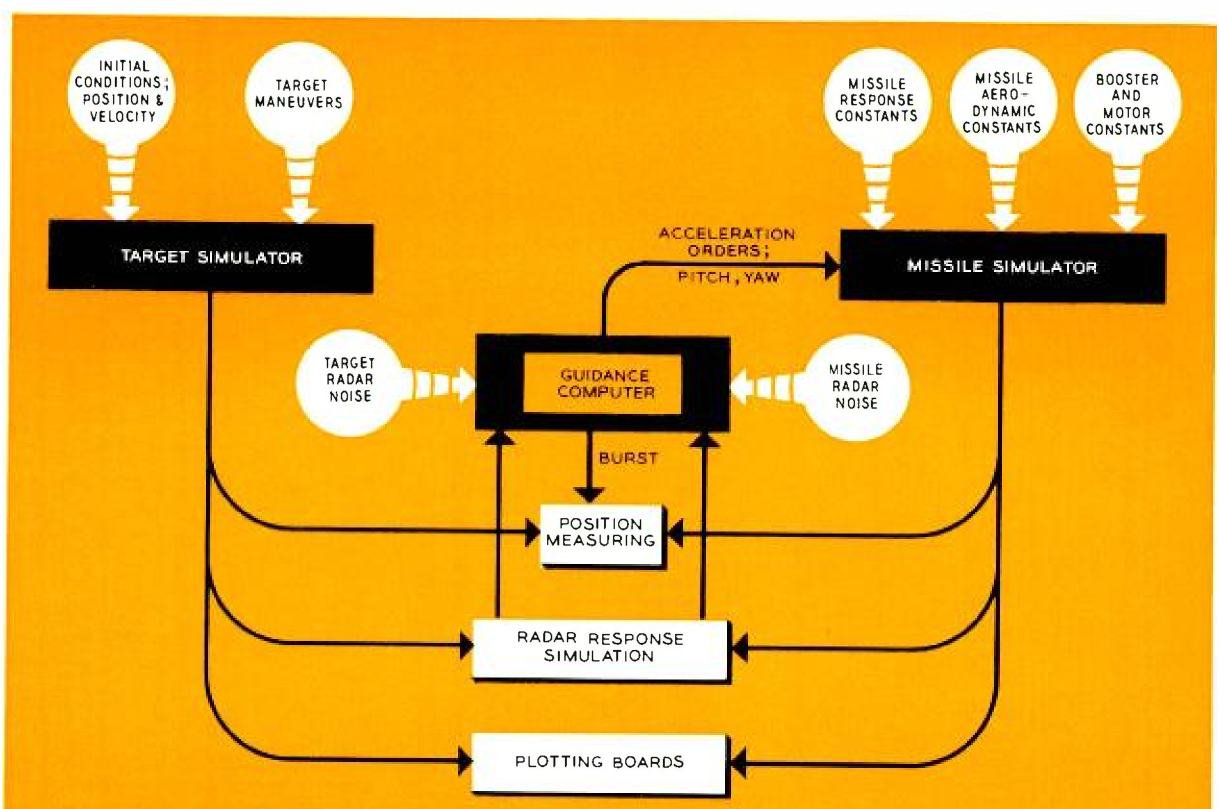
To understand how it can help insure the success of a military weapon, perhaps we should first recall what simulation is. Simulation may be defined as a representation of a physical device by any means that generates an equivalent result. A well-known example is the use of electrical networks to study or measure mechanical systems. Here, engineers use the analogy between mechanical and electrical systems to transform the physical quantities of one system into those of the other.

Simulation may contain some components actually used in the physical system as well as some simulated components. On the other hand, all components may be simulated — a type usually referred to as mathematical simulation. A device of this type is, in reality, an equation solver. The best known of these are the digital computers which solve equations describing a physical system and generate answers a physical system would produce.

What are the reasons for using simulation in the development of military systems, as well as in civilian activities? First of all, the complicated nature of many components and the system they comprise make it impractical and at times impossible to compute, by normal calculating methods, their performance characteristics and to study the effects of various parameters.

Component Variations

For example, during the early stages of the development of a weapon system it may not be possible to predict accurately the characteristics desired of various components, although their general characteristics and limitations may be known. Circuits which smooth radar tracking data, for instance, can suppress spurious fluctuations in the data, but at the expense of introducing a time lag in transmitting the data. By including such circuits, either in physical or simulated form, in a system simulator, engineers can study the effect of component variations on



Set-up of Nike system tester is quite similar to that of a regular weapon system. Target, missile and computer are tied together by radar signals. Computer system functions on "real" time.

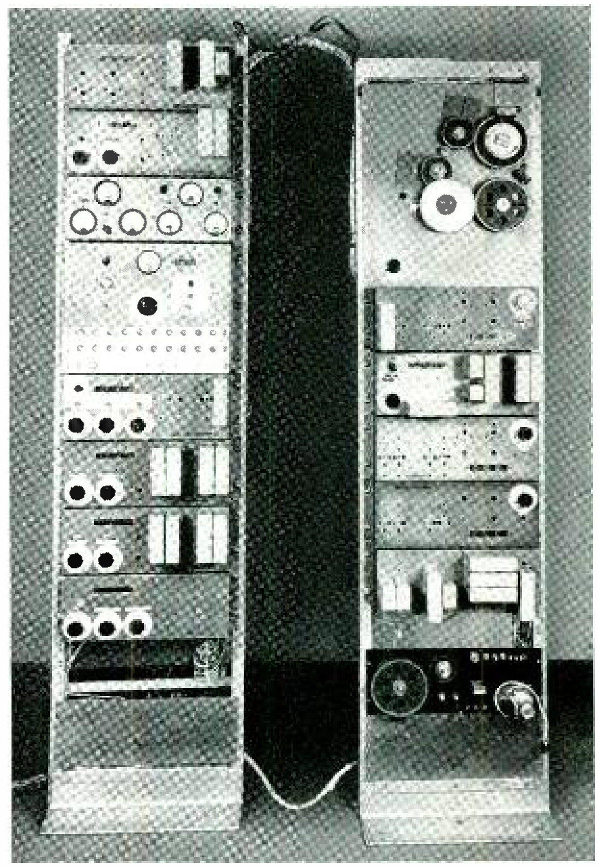
system performance. Simulation for this purpose may be considered as a design tool.

The philosophy for the family of Nike guided missile systems is to employ a "command type" of missile control — orders to steer the missile to intercept the target are generated by ground equipment and transmitted to the missile. Furthermore, insofar as possible it employs proven, or reasonable extensions of, available techniques. By this procedure, development time is minimized and the expendable part of the system — the missile — is kept as simple as possible.

A Nike system was first simulated with a so-called "computer analyzer" — a simple, two-dimensional electronic simulator containing many approximations to the final Nike system. Bell Laboratories engineers used the computer analyzer to confirm the analytically derived method of operation for Nike, and to establish optimum values of some of the important constants of the system. The value of simulation such as this, even if simplified, is illustrated by the fact that subsequent field operations and more complete simulation have not modified the basic conclusions derived from the computer analyzer.

The computer analyzer was a forerunner of the Nike system tester, a three-dimensional device which has been in operation at the Whippany, New Jersey, location of Bell Laboratories for about ten years. This special-purpose, large-scale simulator for Nike systems employs analog computing equipment to simulate the characteristics of major components significantly affecting the performance of the system.

The Nike system tester performs both the design-tool and evaluation functions mentioned previously. Its major sections include the guidance computer and simulation of the missile, radars, and, of course, a target.



The "computer analyzer"—simple two-dimensional electronic simulator — forerunner of Nike tester.

Field System Computer

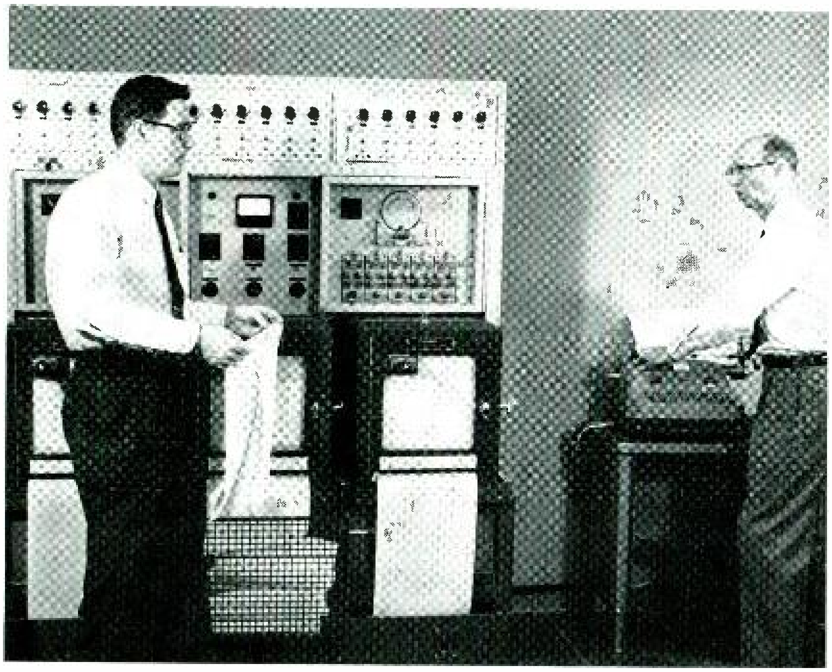
The only major component not simulated in the tester is the guidance computer. This is a physical component that operates as part of a field system. The arrangement is such that the computer doesn't know whether the problem it's solving is a real or a simulated one, and thus performs in an identical manner in either case. For this reason, the tester operates on a "real time" basis.

However, the target, missile, and radar sections employ mathematical simulation since their input-output characteristics need only *reproduce* the performance of physical components. This is justified, because in studying the performance of a system it is not necessary to simulate the actual internal mechanisms of a component, but only a duplication of its input-output characteristics.

In the study of a component, however, engineers would normally simulate the internal mechanism when they study the component itself. Douglas Aircraft Company engineers, for example, simulate the Nike missiles and their internal control systems, including the effects of aerodynamic reactions on the missiles and their control surfaces.

In undertaking simulated engagements, the Nike system tester goes through the same operational sequences as would a field system. The target is started on its course, and at the proper time the missile is launched. The missile proceeds through its normal boost and motor-burning phases and the guidance system automatically guides it to intercept the target.

At the start of the engagement, the initial conditions of the target and missile — their position, heading and speed — are pre-set into the simulator. In the case of the missile these conditions are the position of the launcher on the ground, its attitude in the launcher and zero velocity. Thereafter, the system continuously computes



R. M. Hangley, left, and V. M. Cousins with the data recording machines. The continuous pen recorder, behind Mr. Hangley, keeps track of such functions as steering orders to the missile and "time to intercept."

positions in space by adding to these initial positions the integrated velocities and accelerations as they occur during the engagement.

The accelerations that produce speed changes, in either target or missile, are the result of longitudinal thrust and drag forces. On the other hand, transverse accelerations produce course changes and these accelerations are usually considered as target or missile maneuvers. These quantities of position, velocity, acceleration and many others are represented in the simulator by accurately and properly scaled voltages.

The missile and target sections of the simulator are normally used as part of the closed loop system in which the missile is automatically steered by the guidance computer. The missile and target simulator sections, however, may be operated independently as trajectory calculators without automatic guidance. They also may operate either with or without programmed accelerations applied during flight.

As indicated in the block diagram on page 448, the section representing the target can produce the characteristics and maneuvers of both aircraft and ICBM type targets. The maneuvers — simulated changes in course and speed — may continuously vary or may be introduced discretely in steps. Two sources of the "stepping" maneuvers are an integral part of the system. One is a programmer in which 38 separate maneuvers in each of two channels may be stored to be applied to the target selectively during its "flight." The other is a function generator that uses teletypewriter tape to store maneuvers. This can produce an unlimited number of discrete orders in each of three control channels at a rate of five per second.

The missile section of the simulator continuously computes the effects of thrust, drag and lift forces as a function of the environment the missile encounters during flight. This includes the effects of variation of the mass of the missile as its fuel is consumed and the variation of its response to steering orders as a function of such things as changes in speed and altitude.

Variety of Characteristics

In addition to pre-setting initial engagement conditions, operators can simulate a wide range of missile types, or variations of a given missile characteristic. They do this by setting simple potentiometers by hand to establish such characteristics as the mass of a missile, its wing area, and the magnitude and duration of its booster and motor thrust. This arrangement is an important design tool because with it, engineers can determine by successive trials the best value of a given characteristic. The effects of many such characterstics defy normal types of analysis.

In a field system, the radar data transmitted to the computer, which define the apparent positions in space of the target and missile, would contain unavoidable errors. These come from the dynamic characteristics of the radars, and spurious fluctuations in the radar data called "tracking noise." In the Nike system tester, however, the position data produced by the target and missile simulator sections are, by definition, the true positions of target and missile in space, and as such are error free.

To simulate the effect of radar errors, the true-position data to the computer are passed through networks that simulate the dynamic errors of the radars. Also, simulated noise errors are generated and fed to the computer along with the radar data. The computer then operates as though the primary radar data contained the radar errors. However, the true target- and missile-position data are free of errors for the measurement of their true positions in space.

Probably the most important data obtained from an engagement, either actual or simulated, is the magnitude of the "miss distance" — the positions of target and missile in space at the instant the warhead explodes. The tester obtains the miss distance by accurately measuring the positions of target and missile at the instant the computer generates the burst signal.

A considerable amount of additional data is recorded during each simulated engagement. An automatic data recording system converts from analog to digital form voltages representing 25 of these important quantities and automatically types the data on a form sheet.

A bank of continuous pen recorders makes records of 42 quantities of a similar nature. Furthermore, two plotting boards record the trajectories of the target and missile throughout each engagement, one giving the ground projection of the paths, and the other a view in the vertical plane. Although the continuous pen recorders are only moderately accurate, the data they record gives an excellent qualitative picture of the situation existing during each engagement. These data are also valuable in indicating and locating equipment troubles.

Although a valuable tool, simulation has certain inherent deficiencies which would be present in anything short of a complete physical system operating under field conditions. Simulation does not, for example, shed much light on the reliability of the field equipment, since the Nike system tester includes a limited amount of equipment identical to that used in the field system. Furthermore, any such equipment contained in the simulator is maintained and operated by Bell System specialists under controlled conditions.

On the other hand, simulation contains its own class of errors, such as mistakes made by the operators as well as the designers, and possible equipment troubles. A burden is thereby imposed on the simulator designers. They have to ensure that the characteristics of the physical system, including all discernible sources of error, are properly simulated, and that spurious errors generated by the simulator itself are minimal.

A good measure of the adequacy of a system simulator is obtained by duplicating the firings of a physical system, and comparing the results in detail. This method has been employed through field test programs involving the firing of a considerable number of Nike missiles. Some of the simulated firings duplicated those of the field system and demonstrated very good correlation of results. For this reason, engineers are highly confident in the results they have obtained from the simulator under conditions they could not attain at a missile proving ground.

One of the important assets of the Nike tester type of simulation is its ability to obtain a measure of the performance of the missile system while it is still in a conceptual stage. After simulating its proposed characteristics, and those of the targets, engineers conducted tests to show up required changes early in development.

The Nike system tester employs standard analog computer techniques. The major electronic elements include operational amplifiers that perform the mathematical operations of adding, integrating and differentiating and a number of special devices such as function-generators and multipliers. Electromechanical servomechanisms use precision wire-wound potentiometers RECORD, *May*, 1954) to generate highly accurate voltages as functions of other voltages. The tester contains 270 operational amplifiers and 28 servos.

Insofar as possible, the Nike system tester uses standard computer components, at times modified, and special equipment only where the standard equipment is not suitable. The tester is a special-purpose device with a relatively fixed arrangement of its circuits. This presents an advantage in design whereby those areas requiring high accuracy justify a large amount of time and effort to achieve the required accuracy; in the areas requiring less accuracy, design effort is minimized. The various parts of the simulator are thus tailored to meet specific requirements, and vary in accuracy from one in 20,000 to one in 20.

The age of electronics is now actually invading our coat pockets. New and improved equipment has recently been installed by Ohio Bell Telephone Company, assisted by Bell Laboratories, to offer a personal signaling service. This service, in effect, enables a customer to carry his telephone bell around with him wherever he goes.

Newton Monk

PERSONAL SIGNALING IN COLUMBUS, OHIO

A previous article outlined a new type of telephone service, called "Personal Signaling," and described a trial installation in the Allentown-Bethlehem area of the Bell Telephone Company of Pennsylvania (RECORD, *January*, 1958). Since that article appeared, further study has been given to this type of service and on May 1, 1958, a new and improved installation was placed in operation by the Ohio Bell Telephone Company in Columbus, Ohio.

Personal Signaling is essentially an extension of the bell on a customer's telephone. It operates in such a manner that any customer to the service absent from his phone can be signaled "selectively" to indicate that he is wanted. That is, of the customers using the service, he alone hears the signal. He may then go to the nearest telephone and call a predetermined number to obtain the message. For this service, a radio transmitter sends coded signals corresponding to the customer's number. These signals are picked up by pocket-size radio receivers carried by the customer. Each receiver is responsive to a particular code, which when received, causes an audible signal to sound and alert the customer.

The Columbus installation, in contrast to the earlier installation in Pennsylvania, permits calls to be handled directly from the telephone switchboard using substantially standard operating techniques. It is also arranged to operate on and share the same radio channel with a general mobile-telephone system. With the present limited frequency spectrum available to the common-carrier mobile telephone services, such dual operation of two services on a single radio channel will be of considerable advantage.

The Personal Signaling system installed in Columbus is indicated in the first block schematic. Shown in this figure are both the Personal Signaling system and the mobile-telephone system with which it is integrated. This mobile-telephone system operates from the switchboard through a control terminal, a base-station transmitter, and several base-station receivers. Personal Signaling service operates from the same switchboard through a signaling control terminal and a separate radio transmitter. An interlock-control circuit, shown in the center of the diagram, interconnects the mobile-telephone and personal-signaling systems.

Both systems operate in the 30 to 44 mc band, and the signaling system uses the same frequency as that transmitted from the mobile-telephone transmitter — namely, 35.42 mc. Though it would be desirable to use the same transmitter for both services, this was not possible in Columbus. The reason is that the mobile-telephone service uses frequency modulation and the available pocket receivers were designed for amplitude modulation. Thus, it was necessary to use a separate AM radio transmitter for the signaling service.

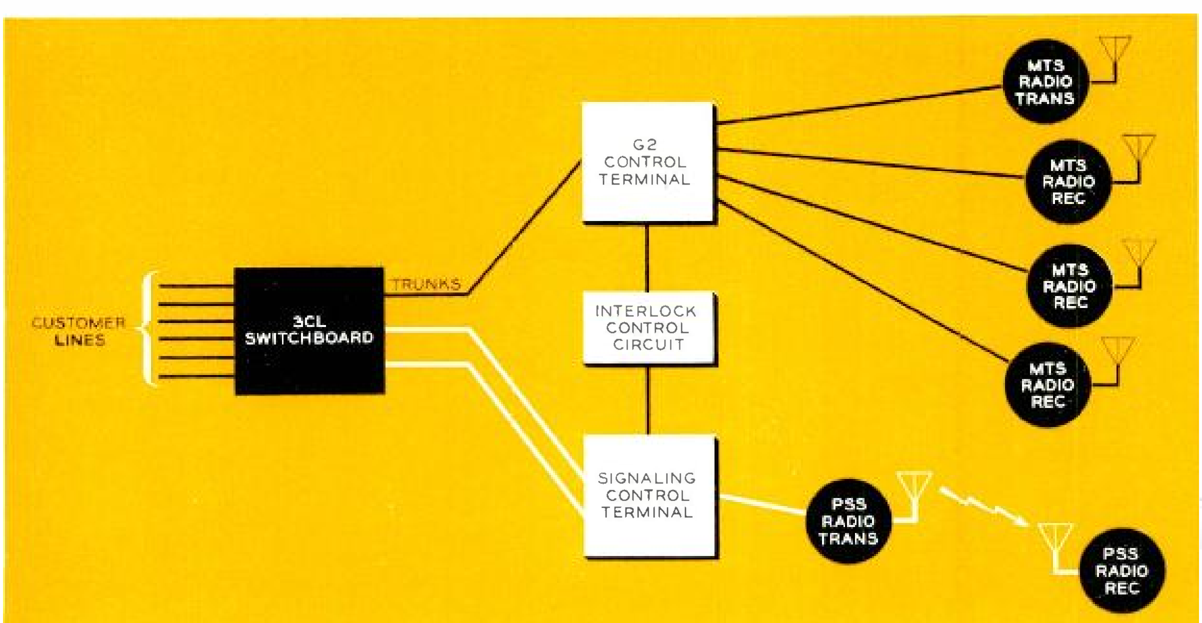
The equipment is arranged to transmit personal signals whenever the radio channel is not in use for mobile telephone service. This is achieved with an interlock control circuit. This circuit accepts a request for the radio channel from the signaling control terminal and assigns the signaling transmitter to it if there are no mobile telephone calls in progress. When the channel is busy, transmission is delayed until the end of the existing mobile-telephone call. If personal signals are being transmitted, the interlock circuit also prevents completion of a mobile-telephone call until the signaling call in progress is completed. When the channel is required for both services, telephone and personal signaling calls are transmitted alternately. Since a signaling call is always of very short duration, this in effect gives priority to the mobile telephone service.

Each signaling code is made up of four tones transmitted sequentially. These are chosen from nine available tones in the frequency range from about 160 to 300 cycles per second, each of which corresponds to a digit between one and nine. Aside from certain unusable codes, the maximum number of codes available is approximately 3500.

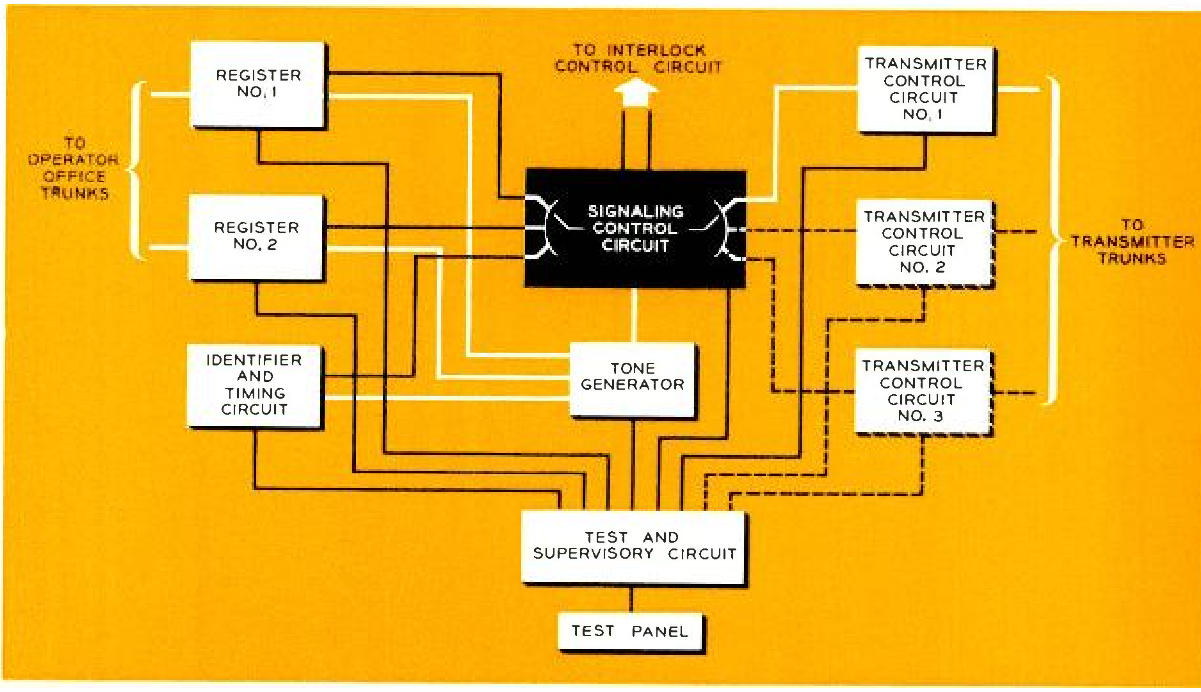
System Timing

The total time required to transmit a code is 1.4 seconds. To insure reception of the signal, each code is transmitted three times with an interval between codes of approximately 2.5 seconds. Thus, the time required to transmit a complete signal is about 9 to 10 seconds. Since another period of about 2.5 seconds is required between signals, the system can handle up to about 300 calls per hour — assuming that the radio channel is not in use during any of that time for mobile-telephone service.

We note in the first diagram that the Personal Signaling service is operated from a switchboard over either of two standard operator



Block schematic of the Personal Signaling system. The circuits include both the personal signaling system (PSS) and general mobile-telephone service (MTS). All circuits are fully integrated.



Signaling control terminal used for personal signaling service. Incoming signals from the switchboard, in the form of dial pulses, are translated to tone signals and passed on to the radio transmitter.

trunks which terminate in the control terminal. A block schematic of this terminal is shown in the second diagram. The equipment is mounted on a standard channel-type relay rack *(right side of photograph opposite)* and is located beside the control terminal.

As seen in the diagram above, after a call is stored in a register, the signaling control circuit gives an indication to the interlock circuit. If the radio channel is idle, or as soon as it becomes available, this latter circuit returns an indication to the signaling control circuit to start the transmission of signals. After assurance that the radio transmitter is radiating its carrier, the stored pulses in the register are translated to the four-tone signal. The four tones obtained from the tone generator are transmitted through the transmitter control circuit and over a trunk to the radio transmitter. After the four-tone signal is sent out three times, it is removed from the register. If another code is stored in the second register or, when one is received from the switchboard, the interlock circuit is interrogated, and the new signal is transmitted as soon as the radio channel becomes idle.

Only one transmitter control circuit is used for the Columbus installation, since in this case only one radio transmitter is employed for the signaling system. However, the control terminal has been designed to function on an optional basis with a number of transmitters or groups of transmitters. These may be energized in turn to prevent false signaling of receivers which might otherwise be located in areas of overlapping transmitter coverage.

Identifier, Timing and Test Circuits

To meet FCC requirements, the signaling control terminal contains a station identifier and timing circuit. This circuit functions with the other equipment to connect identifying tone signals — consisting of the call letters of the radio station in international Morse code — to the transmitter trunk 30 minutes after the first personal signal is sent out, or as soon thereafter as the radio channel becomes available. The identification signal is also radiated three times. Following the next transmission of a signaling code, a new timing cycle is started. The station identification signal is thus repeated about every 30 minutes as long as the signaling system is in operation.

The signaling control terminal also includes a test and supervisory circuit containing circuitry for supervising, monitoring and testing the entire system. These functions are aided with a test panel which contains a dial and handset, together with a number of keys and supervisory or trouble lamps.

Personal signals pass from the signaling control terminal over a short cable circuit to the radio transmitter. This circuit is arranged to give two dc paths for controlling and supervising the transmitter remotely.

Transmitter and Receivers

The AM transmitter has a power output of 250 watts, and is located on the 42nd floor of a tall building in the central part of Columbus. The antenna system is also placed on this building. It includes two antennas (half-wave coaxial dipole types) mounted on diagonally opposite corners on building offsets in such a manner that the tips of the antennas are approximately 480 feet above street level, but about 70 feet lower than the top of the building tower. The antennas are energized simultaneously and in phase to reduce distortion because of the shielding and reflection effects of the tower.

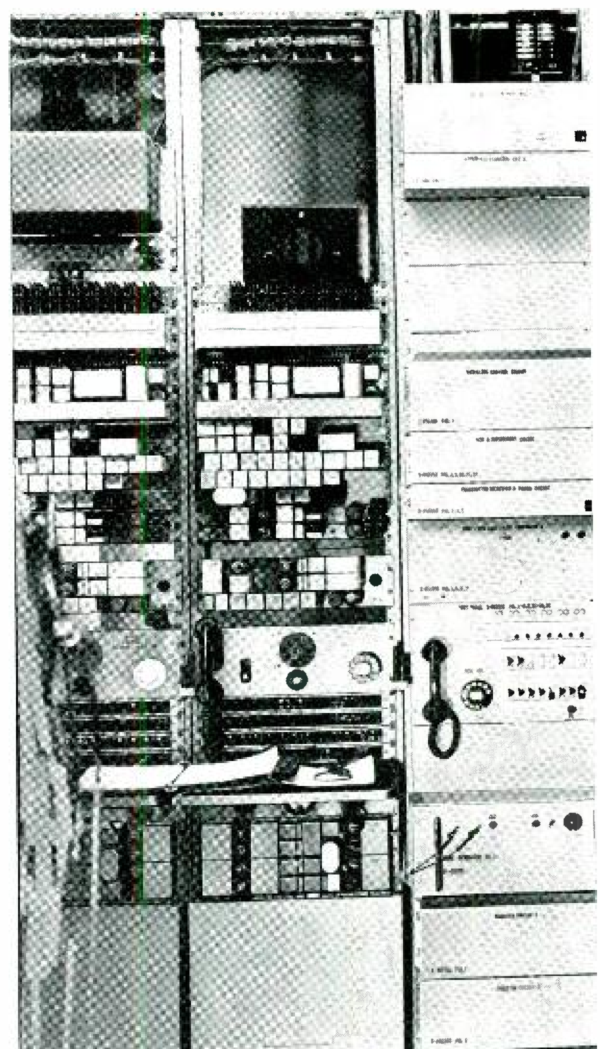
Pocket radio receivers used in the Columbus system are the same as those employed in the Allentown installation. Each is a self-contained, completely transistorized unit which measures 1-$\frac{1}{4}$ by 2-$\frac{3}{8}$ by 5-$\frac{7}{8}$ inches and weighs about 8 ounces. The receiver is powered by replaceable mercury cells capable of operating it for approximately 750 hours.

A super-regenerative type of receiver is used. The audio-frequency part of the circuit includes four tuned reeds operating in the frequency range from 160 to 300 cycles per second. When these reeds vibrate in proper sequence in response to an incoming signal, an audio-frequency oscillating circuit is energized. The output of this circuit is connected to a minature loudspeaker which operates to alert the customer until he presses a button on the receiver.

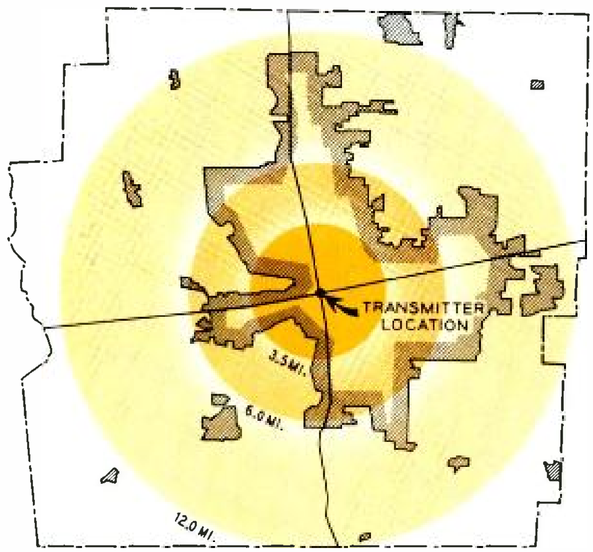
Because of the inefficient, internally contained antennas necessarily employed with pocket receivers, the radio signal required to operate them is some 20 to 30 db higher than that required for satisfactory operation of a mobile telephone installation on a vechicle. Consequently the area over which personal signals can be received from a given transmitter is considerably less than that ordinarily expected in a vehicular communication system. In addition, this area is further restricted when the customers are in shielded areas such as automobiles or buildings.

The territory in and around Columbus is relatively flat, and a favorable location for the antenna system was available on a tall building. The accompanying map indicates the area over which signals can be received when customers are in automobiles or on streets. The circle with a radius of 3.5 miles from the transmitter outlines the boundary for the reception of signals when customers are in automobiles, when they are carrying receivers on their persons, and when the receivers are of just acceptable sensitivity. Some receivers, however are somewhat more sensitive. The circle having a 6.0 mile radius indicates the signaling area for customers, in automobiles, with receivers that have maximum sensitivity.

Much greater range is possible when the customers are in the open. This is indicated by the 12-mile circle within which customers using receivers of minimum required sensitivity can be signaled when they are on city streets. On the



Signaling control terminal is mounted on a standard channel-type relay rack (right), and is located beside the control terminal (left), which is in turn associated with the mobile-telephone system.



Map showing the transmitter location in downtown Columbus, Ohio. Circles indicate areas within which customers in automobiles and on the city streets can receive the radio-beamed signals.

other hand, our tests have indicated that, under favorable circumstances, persons in the open with receivers having maximum sensitivity can be signaled up to distances as great as 17 miles.

The signaling range in buildings has not been thoroughly investigated in Columbus, but data obtained from this and other locations indicate that under these circumstances, ranges from about 0.5 to 8 or 9 miles may be obtained, depending on the type of building.

Determining the effects of sharing a radio channel with mobile-telephone services was an important task at Columbus. The primary advantage of such operation is, of course, more efficient usage of the radio spectrum. On the other hand, operating the two services on the same channel has its disadvantages.

One important disadvantage is that when channel time is shared, the number of customers which can be served by the signaling system is considerably reduced. Small delays for calls of both types are also encountered. In addition, there is a possibility that mobile customers may be confused as they attempt to place calls when the signaling system is busy, since they will hear the signaling tones.

The personal signaling system was placed in operation in Columbus on May 1, 1958, with some 40 pocket receivers in service. After four months, the number of receivers in use had increased to about 120. During this period, there was an average of 85 mobile-telephone units using the radio channel. For each business week from 8:00 a.m. to 5:00 p.m., Monday through Friday, the radio channel was used by these units for mobile-telephone service about 38 per cent of the time. The delays on these 'mobile calls' are extremely short.

However, to assist in determining the effects of sharing the radio channel by the two services, the significant delays experienced by the 'signaling calls' during the initial service period have been recorded and analyzed. For the four-month period, no delay was experienced by 57 per cent of the signaling calls. The average delay for the other 43 per cent was 1.6 minutes, and less than 6.5 per cent of all the calls were delayed more than 3 minutes.

Further information of this type — along with other plant, traffic and commercial studies — will be required to determine the performance of the integrated signaling system. However, experience in Columbus indicates good public acceptance of the service. We now know that operation of a signaling system on the same radio channel with a mobile-telephone system is both feasible and desirable.

Author wearing in vest one of the pocket receivers used in the Columbus system. Each receiver is a self-contained unit weighing about eight ounces. It is powered by replaceable mercury-cell batteries that last about 750 hours.

The optical microscope serves the metallurgist in three important ways: in the development of new materials; in showing changes in the structure of metals with time; and in furthering man's research into a fundamental understanding of the nature of metals and alloys.

E. E. Thomas

OPTICAL MICROSCOPY

A Key to Metallurgical Progress

Not so long ago, metallurgy might have been defined as "the art of extracting metals from their ores and preparing them, alone, or in the form of alloys, for the service of man." From Tubal Cain, the worker in brass mentioned in the Old Testament, and beyond, the history of the art is a long one, and may be said to parallel closely the later course of man's own history.

Metallurgy began to change from an art to a science about 100 years ago. It was then that the Englishman, H. C. Sorby, applied the optical microscope to the study of the structures of steel. Sorby and his successors laid the groundwork of what is now physical metallurgy. Other valuable tools for the study of metals have been developed in recent years. But the optical microscope, now often an elaborate instrument equipped with many helpful accessories, still remains among the most useful and indispensable tools of the metallurgist.

The first great triumph of Sorby and his immediate followers was an approach to an understanding of the reasons why carbon steels of identical chemical composition could be given widely varying physical properties by changes in heat treatment. In addition to arriving at a clearer understanding of the practical aspects of making steel of high quality, these pioneer microscopists made important collateral strides in metallurgical theory. To do this, they borrowed ideas from studies of chemical equilibria and applied them to metallurgical equilibria.

An important basic concept transferred was that of "phase" — as used in the area of physical chemistry then being studied by the American, J. Willard Gibbs (1839-1903), and the Hollander, Bakhuis Roozeboom (1854-1907). By applying this concept, the study of alloys has been systematized. The results of these studies have been made readily accessible in the form of "constitutional," "phase" or "equilibrium" diagrams. Such a diagram represents the phases, liquid and solid, which form in alloys under different conditions of concentration of components and of temperature. They also show limits of existence of the phases under certain ideal circumstances. Together, these ideal circumstances make up a state formally described as "thermodynamic equilibrium," and they derive from established laws of chemistry. Gibbs' Phase Rule, which describes the conditions for thermodynamic equilibrium, is one of the most important of these laws.

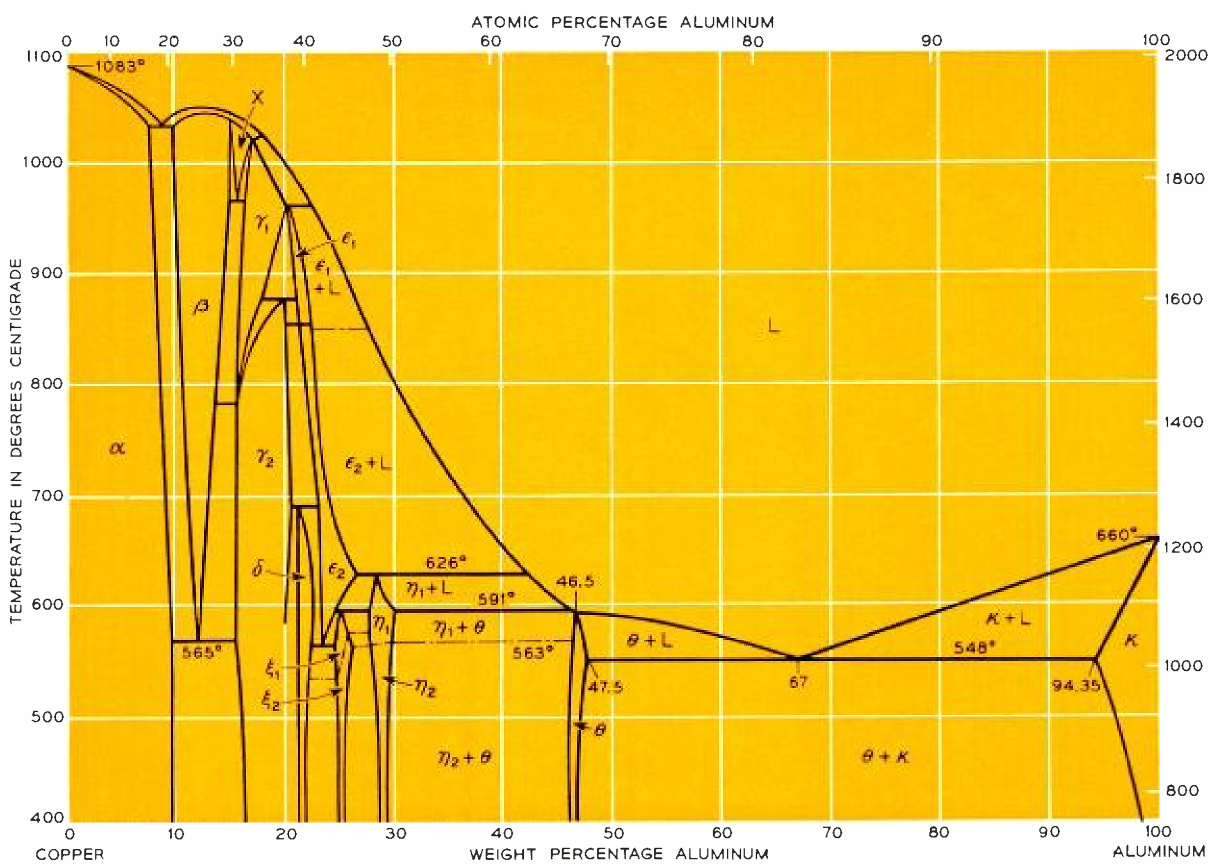
The Importance of "Phase"

The importance of the phase concept to metallurgy lies in the fact that the kinds of phases present and their form and distribution are responsible for many of the differences in the physical properties of alloys. The era of rapid progress in the science of metallurgy which followed the adoption of the phase concept found the optical microscope in increasingly greater use.

In practical alloying, true thermodynamic equilibrium is seldom achieved — for good reasons. Sometimes, it takes too critical processing or too long a time. In other cases, a state of incomplete equilibrium may be deliberately sought to obtain some especially desired physical property, such as great hardness. However, the constitutional diagram still has immense value in tailoring an alloy to a particular need.

All metals, when melted together, influence each other's "personality," even if they only interact to the extent of dissolving one in the other. This solution-forming tendency may, and usually does, persist into the solid state. Several solid solutions may be possible, and even exist simultaneously in an alloy system. Other phases that may form are those akin to intermetallic compounds, or solutions of these.

A familiar example of a simple solid solution is cartridge brass, often termed "alpha brass." This alloy contains about 30 per cent zinc dis-



Constitutional diagram of the binary alloy system of aluminum-copper. As the very small and very irregular areas in certain portions of the plot show, even a binary alloy can produce many and complex phases. As some of the area designations indicate, certain portions of the alloy are made up of two phases. This diagram was taken, with minor changes, from the Metals Handbook, 1948 Edition.

solved in 70 per cent copper. If the alloy has been subjected to suitable mechanical and heat treatments, the zinc will be uniformly distributed through the copper, diluting its red color to the familiar yellow of brass. A plane section, properly polished and etched, looks the same under the microscope as all elementary metals and homogeneous solid solutions.

The metal's "landscape" will be featureless except for a network of lines, which are called "grain boundaries." In three dimensions, the surfaces corresponding to these lines enclose the grains — the building blocks of the gross metal structure. Grains are occasionally called "crystal grains" or "crystallites," reminding us that while they do not possess the plane faces and sharp edges of the familiar concept of crystals, they are nevertheless internally crystalline and are composed of atoms sited in orderly array.

While most elementary metals and simple solid solutions possess relatively simple internal structures, some solid solutions may have internal structures of considerable complexity. Consequently, their "space lattices" — a characteristic described in detail later — have a low order of symmetry so that these complex structures possess a low degree of "give" under stress and are brittle. The presence of one or more brittle phases can make an alloy commercially useless. Examples of brittle compositions exist even in the brasses and in the copper-tin system — the bronzes.

To illustrate the complexities in phase-interrelationship and the possibilities of structural inhomogeneity which may result even in a binary, or two-metal, system, let us consider aluminum-copper. The constitutional diagram for this system is shown at the left. The complexities indicated in the diagram may be still further compounded by a condition of incomplete equilibrium. In the diagram, the letter "L" represents the liquid phase while the Greek letters denote the different solid phases, and the lines bound the regions of their existence and co-existence.

To the experienced metallographer, the complex of phases present in an alloy, similar to those indicated by the phase diagram, are apparent from microscopic investigation. For example, the low-power micrograph (a) at the top of page 460 shows a section of a bead formed by first twisting together a copper and an aluminum wire and then melting the twisted ends with a spark. The time for interaction between the metals was thus very short. The phases formed were of varying degrees of brittleness, and at the slightest pull the wires tended to break off from the bead. In many similar samples, the stress set up by cooling in the different phases was sufficient to cause rupture, because each phase has a characteristic rate of thermal contraction.

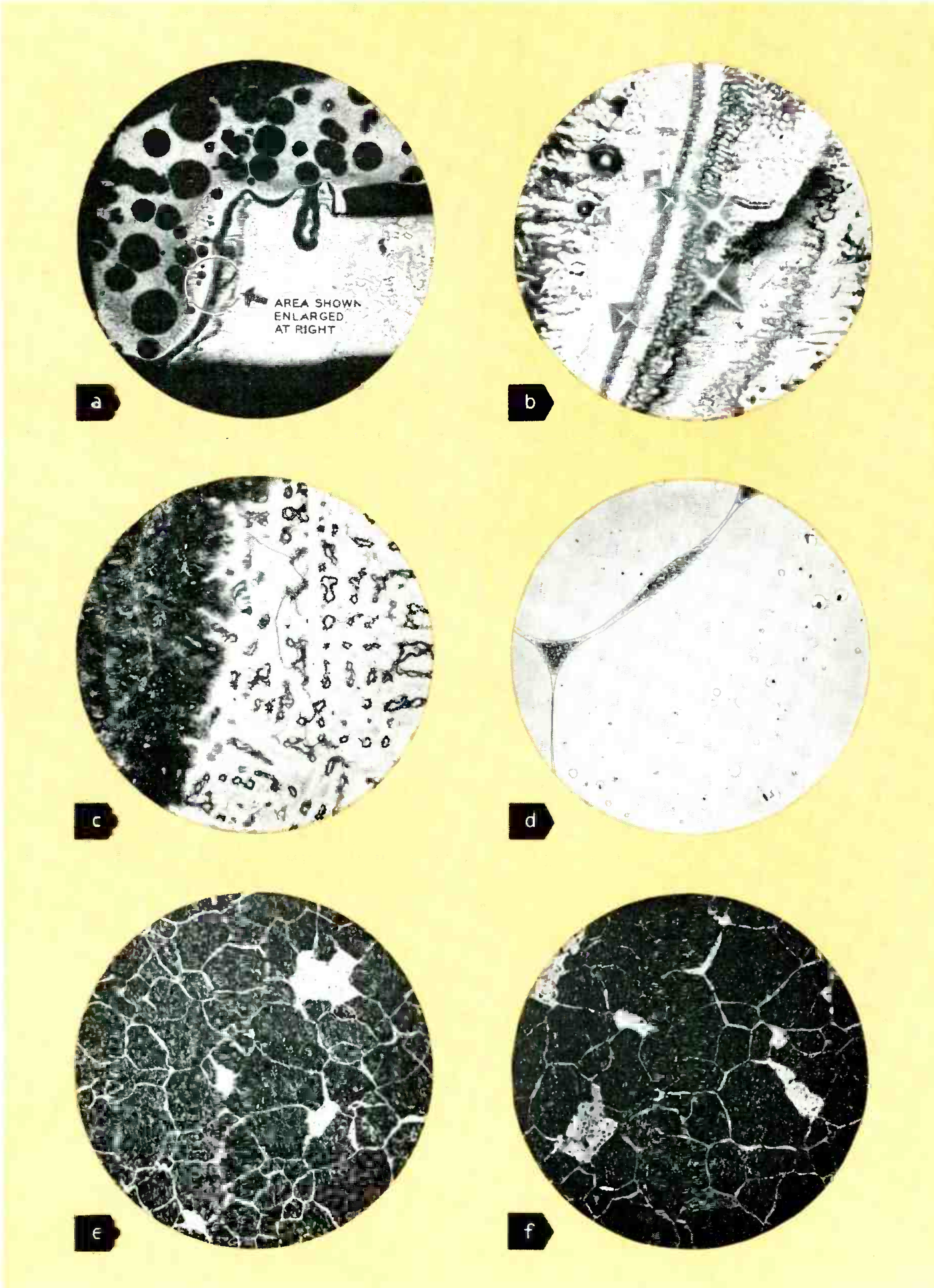
This sectional area of the bead shows that several phases, indicated by differences in reactivity to chemical etchant, had formed in succession. At the extreme lower right is the structure of the copper of the unmelted wire. The next area, toward the left, is copper which has rapidly melted and re-solidified. Then follows a series of aluminum-copper phases successively richer in aluminum, ending with the large area of highly aluminum-rich material at the left and above. The dark formations here are gas holes.

Details of a portion of the area in this micrograph are given in the companion illustration (b), taken at appreciably higher magnification. Here, the different phases are more clearly delineated. This micrograph was taken after hardness tests of different parts of the multi-phase area had been made, which accounts for the different-sized square markings with diagonals. Each of these squares corresponds to an indentation made by a diamond penetrator, each time loaded to the same degree. From the areas of the squares, the relative hardness of the individual phases can be computed. The smaller squares of course correspond to the harder phases. This micro-hardness technique, an auxiliary to metallurgical microscopy, is becoming increasingly useful in the study of the micro-constituents of structure.

The Role of the Microscope

The optical microscope, therefore, clearly associated the physical behavior of the beads of aluminum-copper alloy with the complexities of phase formation characteristic of the system. These complexities were increased by the lack of time available to attain some reasonable degree of thermodynamic equilibrium. This and other difficulties temporarily prevented the development of what appeared to be a simple, effective and economical method of joining copper wires to aluminum wires in the Bell System telephone plant. A different approach later solved the problem.

An equally graphic illustration of the profound structural differences possible within an alloy, still of only two metals, is shown by the two micrographs (c and d) in the middle of page 460. The alloy is copper — 2 per cent beryllium, slight modifications of which find increasing and important application in present-day engineering. The two samples represented were cut from adjoining areas of the same ingot, and were suitably polished and then chemically etched to bring out surface detail.


AREA SHOWN ENLARGED AT RIGHT
a
b
c
d
e
f

The complex structure at left (c) is of the alloy in the "as cast," or nonequilibrium, condition. Three phases are present. The predominant light phase is the background, or "matrix," phase which consists of a solid solution of beryllium in copper. As one might guess from its appearance, this solid solution is not here homogeneous. The alloy is generally not used in the form shown because its properties are correspondingly non-homogeneous. The accompanying micrograph (d) shows the same alloy after it was subjected to a single heat treatment: heating for some hours at 800°C and quenching or cooling rapidly. This treated alloy is still generally undesirable commercially because of the presence of the white, beta phase. The dark phase is called gamma. Hence, the microscope shows directly and graphically, and in a way that is easy to interpret and explain, the ineffectiveness of a particular heat treatment.

The properties of copper — 2 per cent beryllium can be improved, however, because this alloy is of a class called "age-hardenable." Desirable physical properties are obtained by carefully controlled heat treatments, usually two. The exact temperatures and times of these must be worked out experimentally.

Heat Treatments

Briefly, the alloy is first heated at an elevated temperature to insure a complete solid solution of the beryllium in copper. It is then quenched to room temperature. It is now supersaturated with respect to beryllium and will remain so because at this temperature the rate of precipitation of dissolved material is exceedingly slow. Therefore, a second heat treatment, at an intermediate temperature, is required to precipitate out the excess of dissolved beryllium. This precipitate is not elementary beryllium itself but the gamma

Micrograph (a), taken at low power (40x), is of a section of a metal bead formed in joining a copper wire to an aluminum wire by a spark. Micrograph at higher power (265x) (b), illustrates hardness of various areas measured by a diamond penetrator. In the center are photomicrographs (135x) of an alloy of copper and 2 per cent beryllium. Complex structure (c) is the material in the "as-cast" condition, and the more homogeneous structure (d) is the same material after heat treatment. Bottom pair of micrographs (67x) show cable sheath believed to be of Western Electric manufacture (e) compared to known, standard Western lead-antimony sheath (f), used throughout the Bell System. When further compared, the two proved to be of the same origin. These micrographs and those on pages 462 and 463 were taken by the author. Magnifications are approximate.

phase already mentioned. The separation takes place in somewhat the same way as ice particles appear during the cooling of regions of the upper atmosphere. Some mechanical treatment may be added to facilitate the first heat treatment.

Most of the metallurgical work done with the microscope is far removed from the romanticism of scientists in white coats pontificating over deadly microbes. Occasionally, however, one's detective instinct may find some expression in working back from a microstructure to the cause of some apparent oddity of behavior of a metal. This might be done by tying that behavior in turn to some departure from best practice in fabrication.

Also, since so many alloys look superficially alike, it may be necessary to obtain not only positive identification of some material but some idea of its history. For example, the micrograph (e) at the bottom left of the group opposite represents the structure of a lot of lead-alloy cable sheathing which had strayed illegally from Telephone Company possession and whose identity was important to establish beyond doubt. The structure was thoroughly familiar to the microscopist as that of Bell System cable-sheathing alloy, lead — 1 per cent antimony, with certain characteristics ascribable to a service life of some years. It corresponded almost exactly with the structure of a sample taken from service elsewhere, shown adjacent (f). The identification was further confirmed by spectrochemical analysis and by certain structural features associated with Western Electric methods of fabrication.

Another interesting problem in "practical" metallurgy, solved with the help of the microscope, concerns the metal "cards" for the card translator in the No. 4A toll switching system (RECORD, *March*, 1955; *May*, 1955; *August*, 1955). The card translator, which is an automatic card file of available alternate routes for direct-distance-dialed toll calls, contains about 1000 cards made of strip steel, hard-rolled. Over the steel there is a protective plating of nickel, over which is "flashed" a thinner coat of chromium.

In normal operation, the cards are pulled up by magnets and dropped very rapidly — up to several times per second. To make them flat enough to do this smoothly, a stress-relief anneal was necessary. In some cases, however, the annealing, though it made the card generally flatter, increased (up to 30 per cent) rather than decreased the interface friction.

A look at sections of some lots of the translator cards under the microscope revealed that the increased roughness was due to "cannibalistic" growth of some of the crystal grains of the nickel plate at the expense of others. In the series of micrographs below, the untreated card metal, as received from the supplier, is shown on the left. The middle one shows a satisfactorily annealed strip with the columnar grain structure of the nickel recrystallized but without unduly large grains. The right-hand micrograph shows the large cannibalistic grains that resulted in the nickel layer from annealing at too high a temperature. This, in turn, resulted in a corresponding localized roughness in the chromium layer.

Crystal grains of metals, when studied microscopically, can thus tell the metallurgist a great deal about the surface of the metal. But the fundamental significance of grains and boundaries goes much deeper. Some reference has already been made to the internal structure of elementary metal grains and of simple homogeneous solid solutions. These structures consist of atoms in orderly array. If we were to join these individual atom sites, whose distance apart and arrangement are now well known through X-ray studies, by imaginary lines, we would obtain "lattice" structures repetitive in three dimensions throughout the grains.

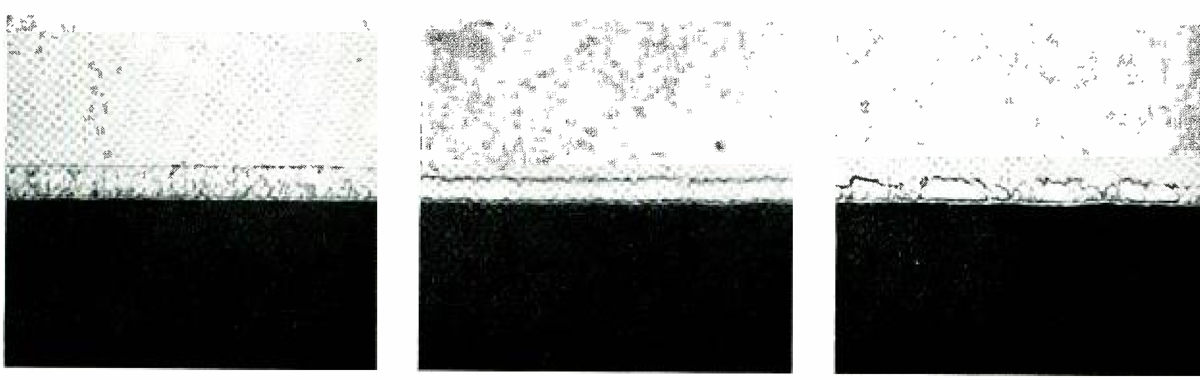
The various forms of lattices for the elementary metals are few, are fairly simple, and possess high orders of symmetry. One of the most valuable properties of metals — the capacity to be usefully shaped by deformative processes — derives partly from this lattice symmetry. Metals can be bent, spun, extruded or otherwise formed because a relatively large number of atom-plane systems are available for slipping or sliding past one another, as in a deck of cards, while still retaining a high degree of adherence to each other.

The theory involved in this simple assumption is insufficient to account for the whole story of metallic behavior, however. For example, calculations of the strengths of metals made on the basis of lattice perfection give values up to a thousand times greater than the actual measured values. Other facts concerning metal structures, difficult to explain on such simple grounds, are the details of plastic deformation and the equally complex details concerning the growth of crystals.

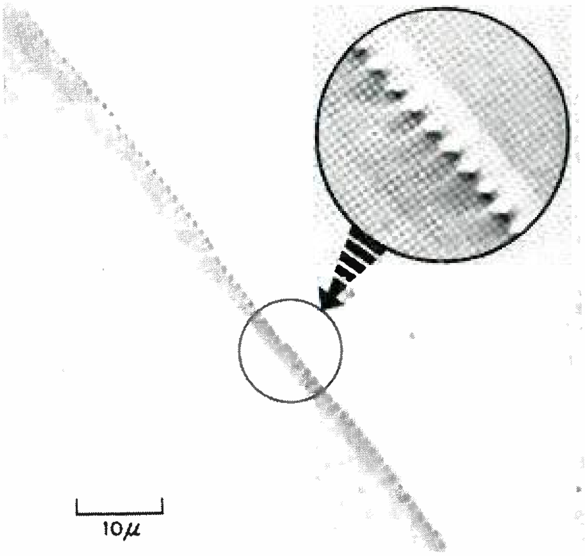
In an attempt to explain the mechanical behavior of metals, many theories concerning lattice defects have been postulated over the last twenty years. One class of lattice imperfections is called "dislocations," and important contributions to Dislocation Theory have been made at Bell Laboratories by W. Shockley, W. T. Read, Jr., F. L. Vogel and others (RECORD, *March*, 1955; *August*, 1955; *April*, 1956).

Dislocation Theory has made a number of successful predictions. One was the existence of a certain type of dislocation, the so-called "edge dislocation." The more specific corollary prediction was that a "boundary" between two very slightly misoriented, neighboring regions in an otherwise perfect single crystal should be made up of a linear array of edge dislocations, equally spaced.

"Etch pits," frequently seen in metals, have long been associated with the presence of either particles of impurity or of otherwise highly localized areas of high potential energy. Such special



Photomicrographs of cross-section of three different cards, shown here at about 1000. The light area at the top is steel, the slightly irregular area immediately below the steel is nickel, and the fine light line below this is the outside chromium layer. Black area at bottom is a bakelite block used to mount cards for photography. Card on left is as received from supplier, with no heat treatment. Middle card has been satisfactorily stress-annealed without appreciable grain growth in the nickel. The card at the right has also been annealed, but at too high a temperature, so that fewer and larger grains have developed in the nickel layer and these have distorted the very thin surface layer of chromium.



Etch pits in germanium. Such microstructures indicate the existence of edge dislocations.

regions tend to etch chemically at rates faster than their immediate surroundings, and pitting results. Occurrence of arrays of discrete, equally spaced pits might then correspond to equally spaced linear arrays of edge dislocations.

Were there to be such a correspondence, discreteness of the pits — that is, a sufficient degree of optically visible separateness under the microscope at reasonable magnification — would be obtainable if the degree of misorientation were small enough and the etching carefully controlled. The first micrograph of a series of etch pits definitely identified with a corresponding array of edge dislocations is shown in the micrograph above. The small but accurately determinable value of angular misorientation of the two adjacent portions of crystal, calculated from direct optical measurement of the pit spacing, was compared with that found by x-ray measurement. Agreement was very close.

The high-purity, single-crystal material used in this experiment was germanium, which had been previously examined in the course of inspecting similar samples for use in transistors. Many subsequent experiments of the same type, with different materials, have gained wide acceptance for the reality of edge dislocations. This in turn has given added credence to other aspects of general dislocation theory.

The microscope work of the Metallurgical Research Department thus ranges from problems that arise in alloy development or are associated with details of fabrication by Western, to those of basic research into the structure of metals.

Dr. Fisk again Heading U. S. Group for Nuclear Test Talks at Geneva

Dr. J. B. Fisk — President of the Laboratories — has again been named to serve as chairman of a group of U. S. scientists currently participating in nuclear test talks with Soviet scientists. According to Secretary of State Christian A. Herter, the new talks concern the latest scientific data applicable to detection of underground nuclear tests. The meetings again are being held in Geneva.

The earlier talks, held during the summer of 1958, were also on the technical aspects of policing a nuclear test ban. The new talks began the week of November 23. The U. S. group includes severa. members of the original 1958 technical conference.

In addition to his career at Bell Laboratories, Dr. Fisk also served as Director of Research of the Atomic Energy Commission for two years. During that time he also was Gordon McKay Professor of Applied Physics at Harvard University. He is currently a member of The President's Science Advisory Committee and a member of the General Advisory Committee of the Atomic Energy Commission.

Dr. J. B. Fisk

The "phone away from home" is now being subjected to an intensive program of studies. New coin mechanisms and modern techniques promise to make the well known public telephone an even more attractive, efficient and useful instrument.

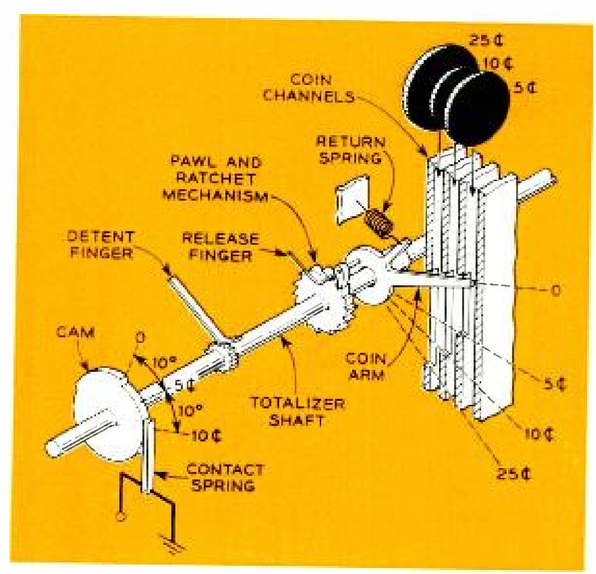
W. Pferd

A New Coin Telephone

Some time during the coming year the total number of public telephones in the Bell System will reach one million. This millionth coin-operated telephone may be installed in an outdoor booth, a "drive-up" booth, an indoor unit, or on the wall of a business or public establishment. It will symbolize the great extent of this type of service, which, except for the war years, has been growing continuously. This growth record is evidence that public telephones serve the American public well and produce sufficient revenue for the Operating Companies to warrant continued studies directed toward further improvements in service.

The first major post-war improvement in coin telephones was a new coin chute, introduced in 1947. This new chute was given a high priority when it became evident that rapidly rising costs would require higher basic rates for coin service. Other changes in the familiar design included a push button for clearing out coins, and a "pull-bucket" arrangement for the refund opening.

It was long recognized that other improvements should be introduced in the coin telephone. The basic instrument and circuit had its origin in the early days of telephony, and many of the mechanisms and circuits were designed for methods of manufacture and operation existent at that time. The post-war development effort perforce was directed toward necessary immediate modification of the existing plant, and did not satisfy the need for an over-all new design. More



Details of the "read-in" portion of the new coin totalizer. Basic operation is to rotate totalizer shaft in proportion to amount of deposit. Rate can be adjusted by repositioning cam at left.

The author demonstrating an appearance model of the new design coin telephone. External appearance of coin unit was styled by Henry Dreyfuss.

recently, therefore, a complete re-evaluation of all parts of coin telephone apparatus and operation has been undertaken.

The systems, transmission and apparatus problems of providing public telephone service have now been studied intensively. This effort resulted in the development and construction of laboratory models of coin telephone apparatus containing many new features. These devices and circuits were assembled in an exploratory coin telephone and were placed on trial for study in Woodbridge, New Jersey, during the summer of 1958. The units, installed for public use on a test basis, gave the necessary opportunity to observe use of the equipment by customers and operators. The results of this study of the new features were favorable. The coin telephones tried at Woodbridge were the forerunners of an entirely new coin set presently being designed for production at the Indianapolis location of Bell Laboratories. An appearance model of the new design, styled by Henry Dreyfuss, is shown in the accompanying photograph (*left*).

The procedures for placing a call from a public telephone are so well known that a requirement for any new design is to leave them unchanged so far as possible. For local calls, prepay service would be continued, with dial tone withheld until after the correct deposit is made.

A second requirement in the new design is more flexible control of the basic rate—that is, the amount the user must deposit to get dial tone and dial his call without the assistance of an operator. Convenience of adjusting local rates is one advantage, of course, but another consequence of flexible rate control is new possibilities for automatic dialing of multi-unit calls. One application, for example, is the placing of special coin telephones along highways so that travelers can directly dial a considerable distance into the next large city.

For this purpose, a new "coin totalizer" device was developed. This is an electromechanical mechanism assembled on the lower section of the coin chute. It can be adjusted in 5-cent steps for any basic rate up to 25 cents merely by changing the position of a cam, or, depending upon the exact design, by using different cams. In the drawing opposite a cam can be seen mounted on the left part of a shaft included in the mechanism.

This illustration shows some of the details of the "read-in" portion of the totalizer. Coin channels *(right in drawing)* guide the nickels, dimes and quarters to strike a coin arm which protrudes into an opening in the channel plates. The falling coin causes rotation of the arm assembly about the totalizer shaft. After a small initial rotation, a ratchet mechanism is engaged, and the arm assembly and totalizer shaft rotate together. Then, after the coin leaves the arm, the arm assembly returns to the start position, drawn by the return spring. The totalizer shaft, however, remains in the rotated position, held by the "detent finger" seen beside the cam. The angle through which the shaft advances is equivalent to 10° for a nickel deposit, 20° for a dime and 50° for a quarter.

In this particular drawing, the cam is arranged to close a set of contacts after 20° of rotation, or 10 cents. At this point, the problem is to "count" the amount deposited by resetting the totalizer shaft — that is, by rotating it back to its original position. For this purpose, a self-stepping relay *(not shown in the drawing)* is brought into play. In stepping the totalizer shaft back to its start position, this relay operates once for each 10° (5 cents) of rotation. The customer

This arrangement demonstrates how trial models of new coin-telephone work. The author, left, holds handset that is comparable to operator's headset, and L. A. Strommen holds new coin-signal network in his right hand.

hears dial tone only after the shaft reaches the start position.

A third requirement for the exploratory development is to improve the coin signals. Instead of using the traditional "gong and chime" type sounds to identify nickels, dimes and quarters, it was desirable to develop a system that would be more adaptable to automatic methods. In the new set, a transistor oscillator is switched on briefly each time the stepping relay operates.

Tone Signals

For example, suppose a user has deposited 10 cents (either two nickels or a dime). In "erasing" this amount, the stepping relay operates twice; thus, it triggers the oscillator twice and sends two "beeps" to the central office. Thereafter, if an operator helps establish a longer-distance call, she hears one "beep" for a nickel, two for a dime, and five for a quarter. These signals are electrically more discrete than the older gongs and chimes, and therefore are more easily incorporated into systems of direct distance dialing from coin telephones, where no operator would be required.

The next drawing *(right, below)* is a block diagram of the trial coin-telephone circuit. The rate cam is designated T_1, and T_2 is a totalizer contact that short-circuits the telephone set whenever the totalizer is storing information on coin deposits. If two nickels are used to start a local call, T_1 and T_2 first advance to their 5-cent positions, and the coin-relay contact (*bottom part of the diagram*) closes. At this point the central office places battery and dial tone on the line, but this tone cannot be heard in the receiver and the number cannot be dialed. When the second nickel is deposited, however, short circuits are removed from the telephone set and from the stepping relay. The rate relay (*center of the diagram*) operates and the totalizer shaft is reset. The rate relay then remains operated for the duration of the call and permits the totalizer to be reset immediately after any subsequent deposit of coins. Each time the stepping relay operates, the coin-signal network is energized to produce a pulse of tone.

The coin-signal network is also shown in schematic form on the next page. The transistor is arranged in the common-emitter configuration with a tuned collector circuit. Inductors L_1, L_2 and L_3 are wound on a common core. When a voltage is applied across the telephone line, the oscillator is triggered, and feedback from L_1 to L_2 sustains oscillation. The output appears across L_3 in the line. Components were mounted on an etched-wire board and encased in epoxide resin.

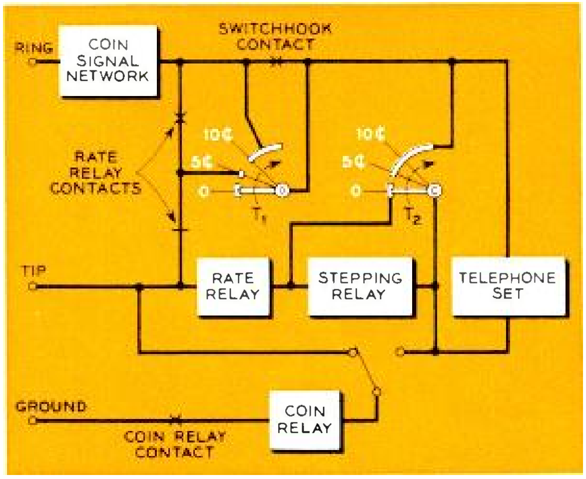
Laboratory and Woodbridge tests were conducted to find acceptable values for the coin signals. A tone of 1016 cps was used, with each pulse lasting about 50 milliseconds. The signals were easily recognizable at pulse rates of 10 to 15 per second. Studies are continuing to determine the optimum signal.

A fourth major improvement was the development of coin mechanisms that would reject a high percentage of slugs and spurious coins. In the exploratory unit, the upper section of the coin chute contains such mechanisms, and has a single opening for accepting nickels, dimes and quarters.

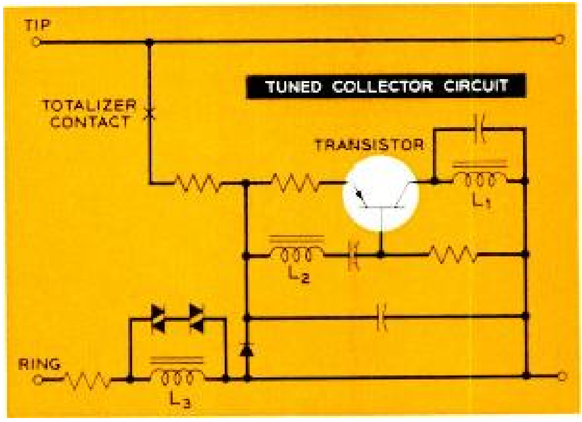
All inserted pieces are tested to detect washers and to determine weight, thickness, maximum diameter, minimum diameter and ferromagnetic properties. Another coin chute under development will also test for eddy-current properties and will give additional protection against fraud.

The new design introduces a clear-out feature whereby the customer operates a bar to have coins returned. In existing coin telephones, rejected pieces drop right through to the refund receptacle, but in the new design, such pieces are trapped in the chute until the customer presses the bar. This new procedure permits better rejection techniques, a saving of space, and more effective clearout of slugs.

A fifth objective — improved coin disposal — is now possible becaues of a new coin relay developed at the Indianapolis Laboratory (RECORD, *November,* 1959). This relay provides a replacement mechanism for existing coin telephones, and preliminary models were used in the equipment for the Woodbridge trial. It permits operation of a coin telephone at a greater distance



Block diagram of trial circuit. Contacts T_1 and T_2 add amount deposited; stepping relay "counts" the amount by stepping totalizer shaft back to its original position and sending out tone signals.



Schematic of coin signal network. Transistor oscillator generates pulse ("5 cents") whenever voltage is applied to line, left, by coin deposit.

from the central office, and is both more reliable and more economical than the coin-disposal unit it replaces.

The functions of storing coins after they are collected, and of tranferring them to the refund opening, were also considered in the studies. A larger and more secure cash compartment was tested in the laboratory, along with a more tamper-proof device covering the refund opening. These were new, untried designs, however, and have been reserved for future field testing.

Twelve exploratory models were used in the Woodbridge trial. In brief, they indicated that the new operating method, with a single slot for all coins, was practicable. The need to operate the "coin-return bar" to retrieve rejected coins did not appear to be objectionable. Reaction to the new coin tones was generally favorable, with indications that the new type signals would be increasingly satisfactory with larger percentages of the station plant operating on that basis. Subsequent to this trial, the Indianapolis group began further development work aimed at refining the components and designing an entirely new enclosure. This phase of the work will consider the security aspects of coin-set design required to minimize loss through theft, damage and fraudulent operation.

For the more distant future, the Laboratories, in cooperation with the Customer Products group of the American Telephone and Telegraph Company, is studying many new ideas for further improvements in public telephone service. Among these are credit-card operation, change-making devices, and more efficient and comfortable booth facilities. In this way, we intend to continue the fine record of offering excellent service at the "phone away from home."

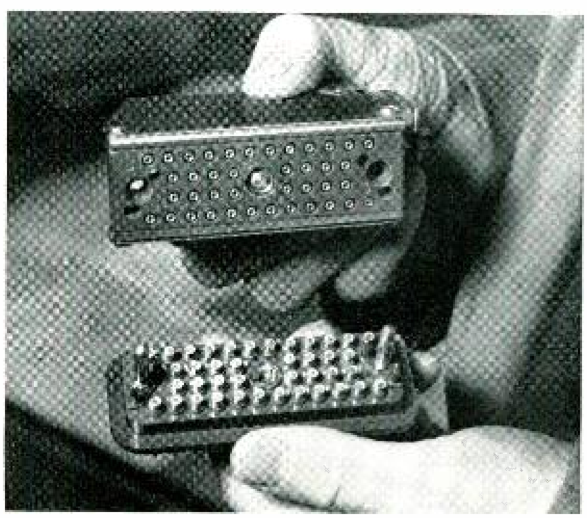
Printed-circuit designs place many extra demands on traditional contact connectors. A new multicontact connector promises to speed designs requiring low insertion and withdrawal forces, and to improve greatly the connector as a circuit element.

A New Multicontact Connector

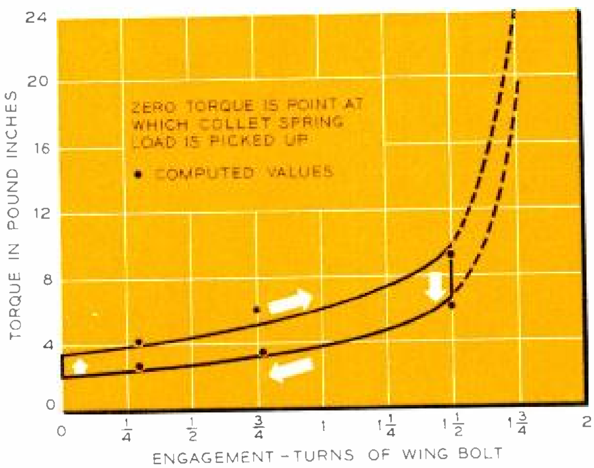
In the design of military electronic systems, it is desirable for reasons of manufacture, maintenance and testing to break such systems down into a number of subassemblies. During operation, these units are electrically connected by wiring that is terminated in connectors. The use of printed circuits and of automation tends to accentuate this philosophy of design — thus increasing the number of units and the number of connectors required. Much consideration, therefore, needs to be given to the design of the connector as a circuit element.

With earlier designs, connectors left much to be desired. In particular, the electrical continuity between individual plug and jack elements was often unsatisfactory. Also, the insulation between elements was apt to be inadequate. More recent designs reveal many improvements; but a report by the Assistant Secretary of Defense, issued in October 18, 1955, listed connectors as the second most frequent source of trouble in a total of 36,000 component failures.

One of the most prevalent design limitations for connectors today is the high force required to engage and to disengage the plug and jack members. For example, a typical 30-circuit connector often requires from fifty to sixty pounds of force for engagement or disengagement. Such forces applied manually — often under conditions of human stress — may result in misalignment and breakage of the connector or associated apparatus. On some jobs, connector breakage is said to have run as high as 50 per cent during system development testing. Connectors are often disengaged by pulling on the connecting wiring. This, of course, may produce even more trouble. The connector shown was developed



Picture shows detail of a 40-contact chuck-type connector. The forty collet-type chucks are loosely held in the upper insulation block to permit self-alignment of contacts. The two blocks of the plug assembly are held together by screws that serve as guide pins when plug and jack come together.



Graph shows average tightening torque, left, for forty-contact connector vs. engagement forces.

by Laboratories' engineers, and it overcomes need for high insertion and withdrawal forces.

The jack member of this new connector has a collet-type chuck (that is, a metal ring chuck) which grips tightly the pin or plug member, thereby establishing good electrical connection. A collet adapter, operated by its own individual collet spring in the plug member, accomplishes the gripping action. These collet springs are energized by tightening a bolt and nut common to the complete connector. Within limits, this arrangement of chuck, adapter, and spring can be duplicated any number of times in the connector. At present, only two connectors of this type are in production. One of these has forty contacts and the other has forty-eight.

If we look at the 40-contact connector, we see that the jack assembly contains forty collet-type chucks. These chucks are loosely held in the insulating block, and the looseness allows for self-alignment of the contacts. Forty mating pins are molded into the plug assembly to permit pressure sealing, so that when the unit is mounted, no gases or dust can leak through the connector. This is an important consideration for some military applications. Collet adapters and their springs are located in recesses in the outer block of the plug assembly, and two blocks of the plug assembly are held together by screws that also serve as guide pins when the plug and jack assemblies are brought together. A wing bolt projects through the jack assembly and engages a nut in the plug assembly when the two are brought together.

This arrangement provides a connector for which relatively low forces are required to turn the wing bolt and bring the connector assemblies together. Thus we have accomplished the major objective of this connector design. Let us now examine its other features.

Merely obtaining low insertion and withdrawal forces is not enough. We must also have reliability and low contact resistance. This connector achieves both to a high degree.

The contacting surfaces of the chucks and the pins are gold plated for protection against tarnish and other corrosion effects. When the surfaces mate, sliding action between the chuck and pin prevents the lodging of dirt between the contact parts. Each chuck member is divided by saw slots to provide four independent jaws — each of which presses against the pin. Thus, for each contact there are four parallel paths. While this principle is old in the art of electrical communications, it is probably carried to a higher degree of perfection in this connector than in other connector designs.

This use of gold plating and parallel paths reduces contact resistance to a negligible value. Measurement of the over-all resistance of each chuck and pin connection of a 40-contact connector after 0, 10, 100, 300, and 1000 insertions showed the use factor to be negligible. The average over-all resistance was 0.0032 ohm for each contact — of which the contact resistance is probably less than 5 per cent of this value.

Tests of insulation resistance and ability to withstand shock, vibration and pressurization more than met the requirements of the pertinent military specification. Five of these connectors were each engaged and disengaged 1000 times — for a total of 200,000 circuit-continuity tests — without a single failure. The probability is that a system having up to 5000 chuck-type connectors — with a maximum of 500 insertions each — will have no circuit discontinuities in the connectors. The graph illustrates their high performance.

High insulation resistance between contacts is gained by using Orlon-filled diallyl phthalate resin. The results obtained from temperature, humidity and pressure tests satisfactorily met all requirements.

Development of this connector was undertaken to meet a specific need for which no suitable connector existed. In the time that it has been available it has proved satisfactory, and many connectors of this type have been manufactured.

R. H. Ricker
Electro-Mechanical Development

Memory is the warehouse of intelligence for machines as well as for human beings. This is one reason why Laboratories engineers have devoted so much effort to memory devices for the Electronic Switching System. For temporary storage of information they developed the barrier-grid store—a high-speed memory that can store up to as many as 16,000 bits of information.

T. S. Greenwood

A Barrier-Grid Tube Memory

To operate successfully, a telephone switching system must be able to store large amounts of information. This information may come from many sources, varying from the digits each customer dials, to the operating details specified by the designers. Very little of this information, however, can be used at the instant it becomes available. For this reason, it must be stored in some form such that it can be released to the system when needed.

The length of time information is stored can vary over extremely wide limits for different systems or even different parts of the same system. For example, the frequency of current needed to ring a certain party line is information used over and over again; it must be stored indefinitely. On the other hand, dialed information may be stored for only a few seconds. And some information generated within the system may even be stored for only a very small fraction of a second.

This wide range of storage intervals means systems designers must apply a wide range of techniques and devices to perform the storage function. But in general, the storage of information in telephone switching systems can be divided into two major categories — temporary and semi-permanent.

Consider a manual switching system wherein an operator, orally given a telephone number, mentally stores it while she seeks the proper jack. Once she has made the connection, she no longer needs the stored information. So she immediately forgets it and re-uses her memory for the next customer. This use of memory falls into the class of "temporary" storage.

In quite a different class is the information stored in the telephone directory. This information is used over and over, and furthermore, it seldom changes. Its memory form is classed as "semi-permanent." Because of their large capacity requirements, most semi-permanent memories are "non-human," even in manual telephone systems.

Automatic telephone switching systems have entirely analogous storage needs. Therefore, the experimental Electronic Switching System (ESS) developed at Bell Laboratories (RECORD, *October*, 1958) uses two new large memories — one temporary and one semi-permanent. ESS is based on the concept of minimization of equipment needs through the use of high-speed electronics. So these memories must be faster-acting than any previously developed.

The semi-permanent memory must have very large capacity and very high reading, or information obtaining, speeds. But, due to the infrequent changes in content, it may have relatively slower writing, or information depositing, speeds. This memory is called the flying-spot store (RECORD, *October*, 1959). The temporary memory, although large, has considerably smaller capacity, but both reading and writing must be done at high speed. This storage system is called the barrier-grid store because its storage device is a barrier-grid tube.

Basically, a barrier-grid tube consists of a beam-forming electron gun and a non-conducting target the beam must strike. The gun is similar to that found in a cathode ray tube. The target, however, instead of being a phosphor-coated face plate, is of special construction. It is built like a sandwich, having: (1) a fine-mesh grid through which the beam must pass (the barrier grid), (2) a mica plate which the beam strikes, and (3) a metal plate (the back plate).

Information is stored in the form of electric charges on the mica plate. Imagine the mica to be divided into discrete areas about the size of the diameter of the electron beam. Each of these areas may be charged to a positive or negative potential, and since the mica is a non-conductor, these potentials will remain essentially unchanged as long as the beam is turned off. Thus each area will store a single binary digit or "bit" of information. Because the beam is small there may be as many as 16,000 such areas and each tube can thus store 16,000 bits of information.

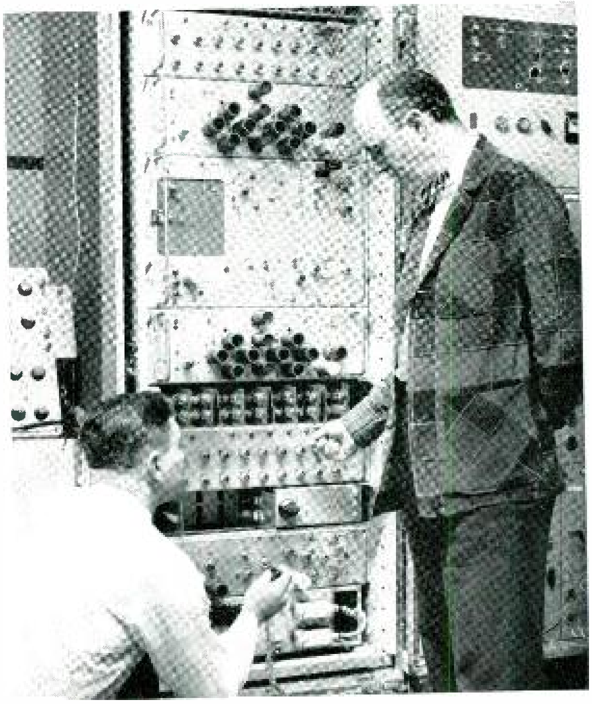
The ESS requires the barrier-grid store to be able to select any one of these areas and read or change it in microseconds. This is done by changing the deflecting potentials while the beam is off so that when turned on, it will strike only the desired area. Because the sequence of areas selected by ESS is completely arbitrary, this is known as a "random access" store. One of the principal circuit problems associated with the store is that of changing the deflecting voltages from one precise value to another in less than a microsecond.

When the beam strikes a selected area, secondary electrons are emitted. These secondary electrons may fall back to the area or may flow to the barrier grid, depending on the relative potentials. This means that if the mica area is more positive than the barrier grid, secondary electrons will return to the area. If the area is more negative than the grid, the electrons will go to the grid. Since the barrier-grid potential is held at a fixed value, the mica potential must adjust itself until the number of electrons leaving the area just balances the beam electrons arriving. This equilibrium potential of the mica is very nearly equal to the potential of the barrier grid and, because of the small area of the spots, is reached quite rapidly — under a microsecond. This high speed permits a short cycle time in the barrier-grid store.

Equilibrium potential of an area represents a bit of information, a binary 0, while a potential 20 volts more negative than this represents a binary 1. The system uses the process of charging an area to an equilibrium potential both in reading and writing.

For instance, to write a 0, the area is selected and the beam turned on. After a microsecond, the area is at equilibrium potential — it represents a 0. From observation of the current flowing to the barrier grid during this interval, it may be determined whether the area was previously a 1 or a 0. No pulse of charging current will be needed to reach equilibrium if the area was already at equilibrium, or was a 0.

Note that this process of reading is destructive in the sense that by the time the original state of the spot is determined it is at equilibrium poten-



B. A. Ackerman, left, and T. S. Greenwood with model of barrier-grid store. Tube is located in tall panel of upper-middle portion of cabinet. All circuitry is on removable chassis. Complete power supply is in adjacent cabinet (behind author).

tial and thus always represents a 0. For this reason, if a 1 is present and the system desires to continue to store this 1, it must be rewritten. This is done by first raising the backplate above its normal potential and again turning the beam on. The act of raising the backplate potential places a positive charge on the area, but the beam removes this charge in the process of charging the area to equilibrium. Once at equilibrium the beam is turned off, and then the backplate is restored to normal potential. This final action places a negative charge on the area and leaves it more negative than the barrier grid — a stored 1.

The tube operates on a basic cycle of three phases. During the first phase — DEFLECT — the beam is off, while the voltages on the deflecing plates are being changed from some previous value to one that will direct the beam to the desired spot. Immediately following this, the beam is turned on and the stored information is read — the READ phase. The final, or WRITE, phase consists of writing the area, or spot, to its next potential.

These three phases take approximately equal times of 0.7 microsecond and, allowing time for circuit recovery, the cycle may be repeated every 2.5 microseconds. The switching system initiates each cycle by supplying an address in pulsed form, plus a "start" pulse. The start pulse may appear on any one of four leads, depending on what is to be done during the WRITE phase. The four options are:

(a) Write a 1,
(b) Write a 0,
(c) Rewrite the original information (REGENERATE).
(d) Write the opposite of the original information (REVERSE).

The use of a barrier-grid tube in ESS thus requires appropriate circuitry to generate the reading and writing actions as well as to deflect the beam to the desired spot. This assemblage of tube and circuits is what constitutes the "store."

The barrier-grid store has four major divisions — the addressing or deflecting system, the tube and its direct control circuits, a sequential control section, and a readout section. A basic block diagram of the store shown on page 473 indicates the four circuits needed. The store receives each deflecting address in the form of parallel digital pulses. In other words, several signals arrive simultaneously on several leads. The deflection circuitry then must convert this digital input into the two voltages necessary to deflect the beam horizontally and vertically to the desired spot; it must do this rapidly and accurately.

The accuracy required permits the beam to deviate no more than a tenth of a spot diameter from its desired location. For a large change in spot position this means accuracies exceeding 0.1 per cent. Since the beam must be within this final error limit before completion of the 0.7 microsecond DEFLECT phase of the cycle, it must move at very high speed.

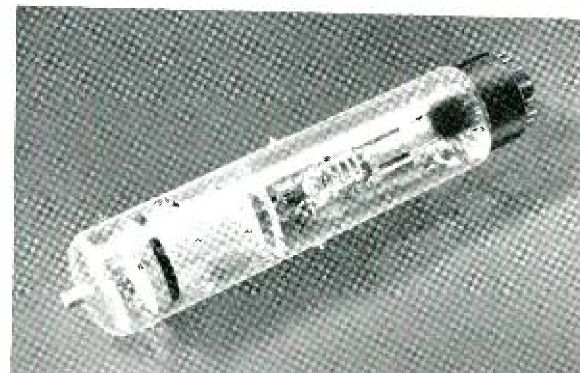
The sequence-control section of the store generates the train of pulses needed to carry out the cycle. It provides these pulses at the proper times to integrate the operations of the addressing, tube and readout sections. In this section the operations are digital and may be carried out by the repeated use of small functional circuits as is done in other digital systems.

The basic parts of the readout section include an amplifier to raise the output signals of the tube to working level and detection circuits to pulse the proper output cable. Although the signals from the store are low in amplitude initially, they are relatively noise free and thus present no basic reading problem.

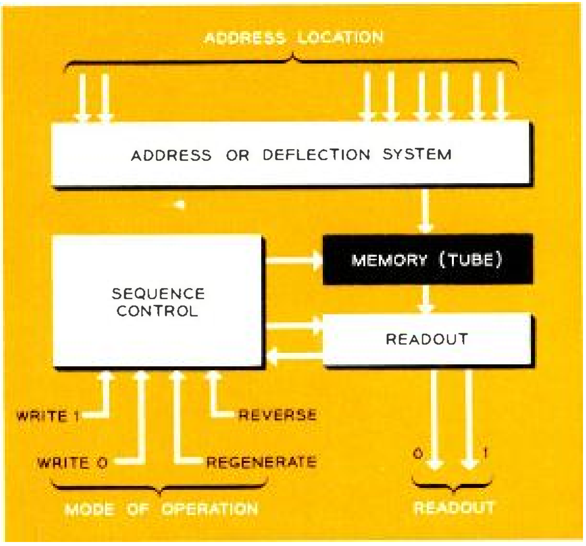
The barrier-grid store together with the required voltage-setting circuits, is reasonably compact. This entire store consists of one bay of circuits and one bay of power-supply equipment.

As part of a telephone system, the barrier-grid store can be primarily characterized by its 16,000-bit capacity and its 2.5-microsecond random access speed. There is, however, another very interesting characteristic, typical of electrostatic memories — the information-regeneration rate.

Although the information stored in a barrier-grid tube is very stable when the beam is turned off, in normal operation the low-level "spray" of electrons within the tube causes a gradual deterioration of stored charges. This effect is most severe adjacent to spots where the beam appears



Version of barrier-grid tube. Sixteen thousand bits of temporary information are stored here.



Four major divisions of the barrier-grid store, and the circuits that link them. Memory (the barrier-grid store) receives its instructions from both the deflection system and sequential control.

most often, but all spots must be periodically rewritten for long-time storage. How often this must be done is governed by a figure called the Read-Around-Number, or RAN.

The RAN indicates the largest number of times a given spot may be used before its immediate neighbors must be rewritten. In the present barrier-grid tubes, the RAN varies from spot to spot from a value of 150 to several times this value. To avoid interference between spots, the switching system is arranged to rewrite all the spots within one second and never let the usage ratio of adjacent spots exceed 150. Because writing is so rapid, these extra rewriting operations use less than 10 per cent of the system's time.

Since a high order of reliability is essential to telephone systems, the "error rate" of the barrier-grid store is also an important factor. Specific tests on present stores have indicated that the error rate is less than one in ten billion. This is a very low probability of error, but the high speed of the store permits this many operations in less than a day. Thus in actual systems two stores would normally be checked against each other. Under these conditions the probability of simultaneous errors is practically non-existent.

A number of barrier-grid stores have been built and operated for laboratory switching systems and for the laboratory trial of ESS. The accumulated experience with these stores has indicated that this form of memory can furnish highly reliable, high-speed storage at economical cost for future telephone switching systems.

Ten Bell System Men Named Fellows of the I.R.E.

Seven members of the Laboratories and three others from the Bell System have been named Fellows of the Institute of Radio Engineers. The grade of Fellow, the I.R.E.'s highest membership rank, is bestowed only by invitation on those who have made outstanding contributions to radio engineering or allied fields. I.R.E. Sections will present the awards in areas where the recipients live.

The new Fellows will be recognized at the annual banquet to be held on March 23 at the Waldorf-Astoria Hotel in New York City. Members of the Laboratories and their citations are:

A. C. DICKIESON — "For contributions to wire and radio communications." He is Director of Transmission Systems Development.

STEPHEN DOBA, JR. — "For contributions in the field of television signal transmission." He is Transmission Measurement Engineer in the Transmission Systems Development Department.

P. G. EDWARDS — "For contributions in the field of telephone communications systems." He is Director of Development, Merrimack Valley Laboratory.

W. H. C. HIGGINS — "For contributions to military electronics." He is Director of Military Electronics Development.

F. L. HOPPER — "For contributions in underwater sound search and sound recording." He is Military Development Engineer at the Winston-Salem, N. C., location of the Laboratories.

J. M. MANLEY — "For contributions to the theory of modulators and parametric amplifiers." He is in the Guided Wave Research Department.

DOREN MITCHELL — "For contributions to long-distance communications systems." He is Special Systems Engineer in the Special Systems Engineering Department.

Among others named Fellows are J. P. Molnar and J. H. Felker, formerly of Bell Laboratories, and H. R. Huntley, Chief Engineer of the A.T.&T. Company.

Mr. Molnar, a former Vice President of the Laboratories and President of Sandia Corporation, was selected for his "contributions to gaseous and solid-state electron devices." Mr. Felker, former Director of Special Systems Engineering and now Transmission Engineer at A.T.&T., was selected for his "contributions to computer technology." Mr. Huntley was named for "contributions to communications engineering."

Sources of Temporary Illumination

The Head Lamp is an important source of light when both hands must remain free. A diffusing lens creates a broad beam of light for close work.

People in outside-plant and installation departments of the Operating Companies often require temporary sources of light to facilitate their work. Typical of the dark places that they may encounter are underground cable areas and locations in certain equipment, such as the inside of a terminal box. Also, installers are often confronted with dark working areas in customer's homes. And, of course, many emergency situations arise during hours of darkness when quick and dependable light sources are vitally important.

The many uses for temporary lighting have resulted in standardizing several portable lighting devices for the Bell System. A device may use power from a building circuit or a portable generator, or may obtain power from batteries. Examples of lights that use generated power are the Portable Lamp and the B Floodlight. Types which operate on batteries include such items as the Dual-Battery Light, the work lamps and the Head Lamp.

The portable lamp operates on 120 volts and uses a 75-watt lampbulb fitted into a molded plastic handle. This device has a guard and reflector assembly, and a 25-foot cord which terminates in a three-wire grounded type of plug. The handle is equipped with a "convenience outlet" into which may be plugged a soldering iron or an electric drill. The B Floodlight receives its power from a 120-volt portable generator and uses a 150-watt lampbulb. This source furnishes general illumination around work areas and serves as a warning to traffic near highway working areas. It is designed to be mounted on a warning mast and is equipped with a friction joint so that the direction of the light beam may be adjusted.

The Dual-Battery Light is used in emergency work on aerial lines. This light has an adjustable feature which permits a beam of light to be directed upward in a vertical arc. A reflector on one end of the housing has an adjustment device that permits the light beam to be focused, while a reflector on the opposite end furnishes a pre-set flood beam. A toggle switch on the case enables the operator to select either beam. When the unit is placed on the ground, and when the focusing beam is directed upward to the work area, the flood beam on the opposite end can be used to illuminate the immediate area on the ground. Two dry batteries, mounted in the case, furnish the necessary power. Another battery-powered light is the Electric Hand Lantern. This is a general-purpose light, convenient to carry when walking and searching. It furnishes a large amount of illumination for its size and weight.

A portion of the cable-splicing operations carried out by construction and maintenance men takes place at night and also in dark locations such as manholes. Illumination for these situations comes from "work lamps." One of these lamps uses a 6-volt storage battery, and consists of an aluminum reflector, a lamp, a plastic lens, a 25-foot cord, and a mounting bracket which can be "telescoped." The bracket is equipped with a swivel to facilitate directing the light, a hook to engage cable racks, and a clamp to secure the unit to the cable-supporting strand.

A second type of work lamp uses two 45-volt dry batteries. It consists of a 6-watt fluorescent lamp enclosed in an aluminum reflector, a 25-foot cord, a telescoping mounting bracket, and a steel carrying case. The case has three compartments — one serves as a housing for the batteries, another for a spare lamp, and the third for space to store the light fixture and the cord. The starting switch, fuse, and current-limiting resistors are mounted on a control panel inside the case. This lamp operates for approximately 100 hours of intermittent use on one set of batteries.

The Head Lamp is a useful device for directing light on a work area while the hands remain free. A typical application is in terminal work on telephone poles. This lamp is held on the head by an elastic band and may be adjusted up or down by means of the bracket support that connects the elastic band to the lamp housing. The housing is equipped with a diffusing lens that projects a broad beam of light on work at arm's length. The diffusing lens may be removed to throw a sharper beam of light for a greater distance. The power source consists of four "D" size batteries contained in a case that fits in the workmen's pocket or clips to his belt. A four-foot, two-conductor cord connects the case and the lamp housing.

Even the common flashlight is an important way to provide temporary light for workmen when they are moving about and performing various tasks. About 100,000 flashlights are supplied annually to the Bell System construction, installation and repair forces. Most of these are of the "angle" type and are powered by two, 1½-volt dry batteries. In use, the light may be placed on end on a flat surface or clipped to the belt if it is desired to free both hands for work.

This work lamp is a versatile device which can be fastened to a strand or a cable rack and whose beam of light can be pointed in any direction.

The Dual-Battery Light can either direct a beam of light upward or flood the area behind it, according to which type of illumination is needed.

An important feature of the latest standard flashlight is an improved slide type on-off switch. This consists of a plastic switch body and a strip assembly made of phosphor bronze that completes the circuit when moved toward the head, or lens end, of the light. Since this new switch construction is rugged, it is not likely to be damaged when the flashlight is dropped or struck with other tools.

Another recent development on the angle light is a unique arrangement of lens and reflector. The safety glass lens is held in place across the face of the reflector with a rubber channel gasket that fits over the edge of the lens and the lip of the reflector. The lamp is secured at the rear of the lens and reflector assembly by a plastic retainer which may be unscrewed to replace the lamp. This arrangement keeps the reflecting surfaces free from dirt and fingerprints.

W. R. SPENNINGER
Outside Plant Development

NEWS

Bigger Boron Crystals Produced By Floating Zone Melting Method And New 'Pressed-Bar' Technique

A technique for producing relatively large crystals of boron — a semiconductor — was described last month by E. S. Greiner, of the Metallurgical Research Department, at a meeting of the Metallurgical Society of the A.I.M.E. Used in basic research on boron, these crystals can now be made from 'pressed' rods of powdered boron. Consequently, they can be purified by the method of floating-zone refining (RECORD, *September*, 1957).

Because of its physical properties, boron does not ordinarily lend itself to floating-zone refining, since it is not possible to form the powder into a suitable shape by pressure alone. The pressed forms are so friable, so easily crumbled, that they fall to pieces as soon as they are removed from their forming dies.

In one step of the new technique, boron powder is placed in boiling boric-acid solution, and the mixture boiled to dryness. This coats the boron granules with boric acid, permitting the powder to be pressed into forms that can be handled without breaking.

The formed bars, or 'compacts,' are heated in two stages in a vacuum for one hour, at temperatures of 300 to 600 degrees C to decompose the boric acid into boron oxide. This compound forms a liquid coating on the boron particles. When the compact is cooled, this liquid hardens, bonding the powder into a strong bar.

For the zone-refining process, the bar of boron powder is mounted vertically. To melt a narrow band, or zone, of the material, a high-frequency induction coil surrounds the bar. The molten zone is moved down the rod by raising the bar through the coil, while the melted boron freezes or crystallizes above the coil. During this operation, the 'binder' of boron oxide sublimes — becomes a gas directly — before the melting point of boron (about 2000°C) is reached. The method has produced crystals as large as 0.1 inch, many of which exist as twins.

Before mounting the compact, the corners of the square bar are ground off to minimize the 'cage' effect, in which the corners do not melt. The resistivity of the boron must be lowered so that it can be heated and melted by high-frequency induction. This is done by heating a graphite cup adjacent to the top end of the bar.

The apparatus used in the floating-zone refining is similar to that used in the treatment of other materials, except that the rod of boron is enclosed by two concentric, transparent quartz tubes. When the subliming boron oxide covers the tubes enough to restrict vision, the inner tube, which is slotted, can be rotated to give a clear field. This modification to the equipment has previously been used at the Laboratories in the floating-zone melting of gallium arsenide by J. M. Whelan and G. H. Wheatley, of the Semiconductor Research Department.

Mammoth Navy Antenna Will Aid Radio Astronomy Studies

The U. S. Navy is erecting what will be the largest radio telescope in the world on a 1,500-acre site in Sugar Grove, West Virginia. The $79,000,000 structure is being designed by Grad, Urbahn and Seelye, New York architects-engineers. The Bureau of Yards and Docks, acting for the Naval Research Laboratory, is the contracting agency. NRL scientists formed the basic specifications and other criteria after years of intensive research.

The concept of radio astronomy originated in the work of Karl Jansky in 1932. Working at the Holmdel, New Jersey, location of the Laboratories, he built what was to become the first radio telescope. Using a spiral antenna array to study static disturbances, he discovered that some of the sources of radio noise are in the center of the earth's galaxy.

Signal Range Extended

After scheduled completion in 1962, the Navy's 20,000-ton facility, to be known officially as "Naval Radio Research Station," will be the world's most powerful "ear to the universe." It will enable NRL scientists to tune in on radio signals emitted by astral bodies as far as 38 billion light years out in space — 19 times the distance probed by the 200-inch optical telescope at Mount Palomar, California.

The instrument's aluminum-mesh reflector dish will have a 600-foot diameter, and an area exceeding seven acres. Rotation of huge wheels supporting the dish complex will elevate the reflector in any direction between horizons. Rotation of the entire structure on rollers riding circular tracks on the ground will turn the instrument to any point in azimuth. Thus, the dish can be aimed at any point in the sky above the horizon. The telescope will be electronically controlled from a laboratory - operations building near-by.

G. N. Thayer

J. E. Dingman

S. B. Cousins

Thayer, Dingman, Cousins Named A.T.&T. V.P.'s

G. N. Thayer, formerly vice president — operations of the Ohio Bell Telephone Company, was recently elected vice president of the A.T.&T. Company, in charge of the Marketing Department.

Mr. Thayer joined the technical staff of Bell Laboratories in 1930. He was appointed Director of Transmission Development in 1951, and was elected vice president of the Laboratories in 1952, in charge of Military Development. Before he left the Laboratories to go to A.T.&T. as chief engineer in 1955, Mr. Thayer was vice president in charge of switching and transmission development. Two years later, in 1957, he went to Ohio Bell as vice president — operations.

Mr. Thayer replaces J. W. Cook, who was named vice president — public relations of A.T.&T. Mr. Cook in turn succeeds S. B. Cousins in the public relations post.

Mr. Cousins, formerly vice president and general manager of Bell Laboratories, was appointed vice president — personnel, succeeding H. Randolph Maddox, who will retire at his own request effective December 31 of this year.

Effective December 1, J. E. Dingman was elected vice president and appointed Chief Engineer of A.T.&T. He replaces H. R. Huntley, who is retiring at the end of this year.

Mr. Dingman began his Bell System career with the Western Electric Company in 1921 and is a former vice president of Bell of Pennsylvania. He was vice president and general manager of Bell Laboratories from 1952 to 1956. Mr. Dingman has been Director of Operations at Long Lines for the past three years.

Laying Operations Begin for U. S. to Puerto Rico Cable

The cable ship *Monarch* left San Juan, Puerto Rico, on November 4 for the Florida coast, where it began laying the new telephone cable between the United States and Puerto Rico. This will be the world's deepest telephone cable. The $17,000,000 project is a joint undertaking of the Long Lines Department of the A.T.&T. Company and Radio Corporation of Puerto Rico, a subsidiary of International Telephone & Telegraph Corp.

Twin cables — one for each direction of speech — will make up the entire system. One end will be at West Palm Beach, Florida. From there, the cables will dip into the intra-coastal waterway and go underground across Palm Beach. Then they will enter the sea, run 20-30 miles apart, and emerge 1,250 miles away on the shores of San Juan. About 75 miles northwest of Puerto Rico, the cables will drop to a depth of five miles into the Puerto Rican "trench," the deepest point in the Atlantic Ocean.

T. F. Gleichmann of the Transmission Systems Development Department is at West Palm Beach, and R. M. Riley of the Outside Plant Development Department is aboard the *Monarch*.

The new twin cables, scheduled for service early in 1960, will be able to handle 48 simultaneous conversations. This capacity will help to meet the rapidly growing demand for service between the United States and Puerto Rico.

New Arrangement for Distortionless Mobile Radio

A way to circumvent automatically a certain type of distortion of radio signals in turnpike patrol cars has been devised at Bell Laboratories recently. This distortion is encountered whenever the vehicle is in a location on the highway where the effective areas of two transmitters overlap.

The phenomena, called "co-channel" interference, results when signals from two or more stations, transmitting the same intelligence on the same frequency, are received at similar intensities. Equipment developed at the Laboratories several years ago precluded this distortion by an arrangement that reversed the directivity of a bi-directional receiver antenna located atop the car (RECORD, *November*, 1956).

Automatic Operation

This arrangement, however, was mechanical — a switch had to be operated to reverse the antenna pattern. Since police officers often must patrol their routes at high speeds and operate a variety of other equipment, they are not always in a position to operate this switch. For this reason, the Laboratories designed a system to do this automatically. This development, however, has not been carried to the point where circuits and equipment are available.

Basically, the switching is actuated by two different tones, at a low frequency, sent out from alternate transmitters located along the road. So long as a car's receiver hears only one of these tones, the antenna is not affected. But as soon as the receiver notes a second tone — when the car is in a overlapping coverage area — resonant and flip-flop circuits in the system actuate a mechanism that rotates the antenna pattern 180 degrees.

Unique Colonial Home At Holmdel Presented to Historical Association

The Monmouth County Historical Association has accepted the gift of the historic Hendrick Hendrickson house in Holmdel, New Jersey, through arrangements made by the Bell Laboratories. The structure, a unique example of Colonial architecture dating from about 1730, is situated on the site of the new Holmdel laboratory being built for Bell Laboratories (RECORD, *May*, 1959).

The Association intends to restore the house to its original condition on another site, and to furnish the house in the manner in which it might have appeared in Colonial times. Upon completion of the restoration, the home will be open to the public.

Nike-Zeus Missile Tested at White Sands

A test model of the Army's Nike-Zeus Anti-Missile Missile performed successfully in an experimental test firing at the White Sands Missile Range on October 14. Although the flight terminated (during the coasting phase) short of the planned trajectory, it yielded the desired technical data. The booster motor and sustainer motor were fired during the test. Both performed successfully.

The Nike-Zeus booster, the missile's first stage, is composed of a single unit using a solid propellent. It is the most powerful rocket motor of its type ever known to be fired, developing more than 400,000 pounds of thrust at launch. The engine was devised by the Thiokol Chemical Corporation, Redstone Arsenal, Alabama.

Grand Central Rocket Company, Redlands, California, developed the sustainer engine which will make up the second stage of the Nike-Zeus.

Purpose of the test flight was to obtain information on flight and propulsion characteristics of the missile. Nike-Zeus is being developed by Bell Laboratories for the U. S. Army Ordnance Corps to defend the nation against intercontinental ballistic missiles. The Western Electric Company is the prime contractor.

The experimental test firing was conducted by Bell Laboratories and Douglas Aircraft Company personnel stationed at the missile range.

Contents of November 1959 Bell System Technical Journal

The November 1959 BELL SYSTEM TECHNICAL JOURNAL contains the following articles:

An Experimental Transistorized Artificial Larynx, by H. L. Barney, F E. Haworth and H. K. Dunn.

Ideal Binary Pulse Transmission by AM and FM, by E. D. Sunde.

Gyromagnetic Modes in Waveguide Partially Loaded with Ferrite, by H. Seidel and R. C. Fletcher.

Waveguide Bending Design Analysis, by F. J. Fuchs, Jr.

Error-Correcting Codes — A Linear Programming Approach, by E. J. McCluskey, Jr.

The Analysis of Valve-Controlled Hydraulic Servomechanisms, by R. G. Rausch.

Design Considerations for High-Frequency Transistor Amplifiers, by D. E. Thomas.

Effects of Tamping and Pavement Breaking on Round Conduit, by G. F. Weissmann and D. M. Mitchel.

TALKS

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

AMERICAN CHEMICAL SOCIETY NATIONAL MEETING, Atlantic City, N. J.

Ballman, A. A., and Laudise, R. A. *Hydrothermal Crystallization.*

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

Wasserman, E., *The Structure of the Thermochromic Form of Bianthrone.*

A.S.A./A.S.Q.C. CONFERENCE ON MATHEMATICS AND STATISTICS FOR RELIABILITY PROBLEMS, New York, N. Y.

Drenick, R. F., *Statistical Aspects of the Reliability Problem.*

Gupta, S. S., *Order Statistics from Gamma Distribution and Their Applications to Life-Test and Reliability Problems.*

Levenbach, G. J., *Exploring the Basic Mechanism of a New Device—A Non-Linear Estimation Problem.*

Tischendorf, J. A., *Sequential Life Testing to Establish Reliability.*

SHEFFIELD CONFERENCE ON MAGNETISM, Sheffield, England

Bozorth, R. M., *Ferromagnetism of Some New Compounds: Superconductors and Substituted Garnets.*

Bozorth, R. M., *New Varieties of Magnetic Material.*

Shulman, R. G., *NMR and Antiferromagnetism in* NiF_2.

THIRD INTERNATIONAL CONGRESS ON ACOUSTICS, Stuttgart, Germany

David, E. E., Jr., Guttman, N., and van Bergeijk, W. A., *Binaural Interaction of Impulsive Stimuli.*

David, E. E., Jr., *Comment on the Precedence Effect.*

David, E. E., Jr., Mathews, M. V. and Miller, J., *Monaural Phase Effects in Speech Perception.*

David, E. E., Jr., Mathews, M. V. and Vyssotsky, V. A., *Recognition of Voicing, Voice Pitch and Formant Frequencies with a Digital Computer.*

David, E. E., Jr., see Mathews, M. V.

David, E. E., Jr., see Schodder, G. R.

David, E. E., Jr., see van Bergeijk, W. A.

Flanagan, J. L., *A Resonance-Vocoder and Baseband System for Speech Transmission.*

Guttman, N., see David, E. E., Jr.

Mason, W. P., *Phonon Viscosity and Its Effect on Acoustic Wave Attenuation and Dislocation Motions.*

Mathews, M. V., David, E. E., Jr., and McDonald, H. S., *Digital Computer Simulation as a Tool in Speech Research.*

Mathews, M. V., see David, E. E., Jr.

McDonald, H. S., see Mathews, M. V.

Miller, J., see David, E. E., Jr.

Schodder, G. R. and David, E. E., Jr., *Pitch Discrimination of Complex Sounds.*

Schroeder, M. R., *Improvement of Acoustic Feedback Stability in Public Address Systems.*

Schroeder, M. R., *A New Automatic Method for Measuring the Reverberation Time and the State of Diffusion of a Room.*

Schroeder, M. R., *Recent Progress in Speech Coding at Bell Telephone Laboratories.*

van Bergeijk, W. A. and David, E. E., Jr., *Simulation of the External Spiral Innervation of the Cochlea.*

van Bergeijk, W. A., see David, E. E., Jr.

Vyssotsky, V. A., see David, E. E., Jr.

OTHER TALKS

Ahearn, A. J., *Mass Spectrographic Studies of Impurities on Surfaces*, American Vacuum Society Symposium, Philadelphia, Pa.

Baker, A. N., *Stored Charge Analysis of Transistor Operation*, Graduate Seminar in Electrical Engineering, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

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

Bozorth, R. M., *Magnetic Properties of Ferromagnetic Superconductors*, Gordon Research Conference, New Hampton, N. H.

Brattain, W. H., *Development of Concepts in the Understanding of Semiconductors*, Science Faculty Colloquia, Rensselaer Polytechnic Institute, Troy, N. Y.

Carbrey, R. L., *Video Transmission Over Telephone Cable by Pulse Code Modulation*, Fifth National Communications Symposium, Utica, N. Y.

Danylchuk, I., *Magnetic Amplifier Binary-to-Analog Conversion*, Special Technical Conference on Non-linear Magnetics and Magnetic Amplifying, Washington, D. C.

David, E. E., Jr., *Digital Simulation in Perceptual Research*, National Electronics Conference, Chicago, Ill.

David, E. E., Jr., *Some Problems in Speech Recognition*, Seminar on Speech Compression and Processing, Air Force Cambridge Research Center, Cambridge, Mass.

Deutsch, M., *Experiments on Social Perception*, Psychology Club of Brooklyn College, N. Y.

Eastwood, D. E., *Macro Modification of SAP*, SHARE Meeting, Seattle, Wash.

Ellis, W. C., *Mechanisms of Growth and Properties of Whisker Crystals*, Seminar Department of Metallurgy and Material Science, Northwestern University, Evanston, Ill.

Ferrell, E. B., *Fundamental Concepts of Statistical Analysis*, Utica-Rome Chapter, A.S.Q.C., Utica, N. Y.

Ferrell, E. B., *Statistical Methods in Engineering Design*, Boston

Section, A.S.Q.C., Boston, Mass.

Fuller, C. S., *Chemical Equilibria and Reactions in Semiconductors*, International Union of Pure and Applied Chemistry, Munich, Germany.

Germer, L. H., *Diffraction of Low Energy Electrons*, Cornell University, Ithaca, N. Y.

Geusic, J. E., *Evaluation of Maser Action in Ruby in the Frequency Range 500-9000 mc*, Seventeenth Annual Conference on Electron Tube Research, Mexico City, Mexico.

Geusic, J. E., *The Paramagnetic Resonance Spectrum of Cobalt Doped A_2O_3 at 1.6°K*, Meeting of the American Physical Society, Washington, D. C.

Graham, R. E., *A Noise-Stripping Process for Picture Signals*, Eighty-Sixth Convention of the Society of Motion Picture and Television Engineers, N. Y. C.

Greiner, E. S., *The Floating Zone Melting of Boron and the Properties of Boron and Its Alloys*, Conference on Boron, United States Army Signal Research and Development Laboratory, Asbury Park, N. J.

Guldner, W. G., *Applications of Vacuum Techniques to Analytical Problems*, Western Electric Training Course, Allentown, Pa.

Guldner, W. G., and Beach, A. L., *The Effect of Evaporated Films on the Recovery of Gases during Vacuum Fusion Analyses*, Analytical Chemistry Symposium on Gases in Metals, Pitt., Pa.

Hagelbarger, D. W., *Burst Correcting Codes*, Columbia University, N. Y. C.

Hagner, D. R., *Ballistic Missile Guidance*, Joint Meeting of I.R.E., A.I.E.E. and A.S.M.E., Panama City, Fla.

Hamming, R. W., *Current and Future Trends in Digital Computing*, Long Island Chapter A.C.M., Garden City, N. Y.

Hamming, R. W., *Summer Course on Frontier Research in Digital Computers*, University of North Carolina, Chapel Hill, N. C.

Helmke, G. E., see Pondy, P. R.

Hopfield, J. J., *Exciton Fine Structure in ZnO and CdS*, General Electric Laboratory, Schenectady, N. Y.

Hopfeld, J. J., *Observable Properties of Longitudinal Exciton*, IBM Research Laboratory, Poughkeepsie, N. Y.

Jaccarino, V., *Nuclear Magnetic Resonance in Magnetic Crystals*, National Institute of Health, Bethesda, Md.

Landau, H. J. and Pollak, H. O., *Energy Relations between Functions and Their Fourier Transforms*, American Mathematical Society Meeting, Salt Lake City, Utah.

Lee, C. A., *The Preparation and Electrical Properties of Alloyed P-N Junctions of InSb*, Semiconductor Symposium of the Electrochemical Society, Columbus, O.

Mardis, T. W., *Science or Fiction*, Aviation Club, Greensboro, N. C.

Mason, W. P. and Thurston, P. N., *A Compact Electromechanical Bandpass Filter for Frequencies Below 20 KC*, National Ultrasonic Symposium, Stanford University, Stanford, Calif.

Massey, R. P., *Transistor-Core Converter for High Input Voltages*, National Electronics Conference, Chicago, Ill.

Mendizza, A., *Plated Coatings for Electrical Contacts*, Joint Session of Newark-New York Branches of American Electroplaters Society, N. Y. C.

Miller, J. A., *Post-Graduate Training for the Engineer in Industry*, Eastern North Carolina Sub-section of A.S.M.E., Raleigh, N. C.

Miller, L. E., *Uniformity of Junctions in Diffused Silicon Devices*, A.I.M.E. Semiconductors Session, Boston, Mass.

Morrison, J., *The Behavior of Titanium in a High Vacuum*, American Vacuum Society Symposium, Philadelphia, Pa.

Och, H. G., *Functions of Management*, Ordnance Weapons Command Headquarters, Rock Island, Ill.

Pollak, H. O., *The Aims and Philosophy of the Ninth-Grade Committee of the School Mathematics Study Group*, Mathematics Teachers Meeting, Chicago, Ill.

Pollak, H. O., see Landau, H. J.

Pondy, P. R. and Helmke, G. E., *Measuring and Controlling Dust*, A.S.T.M. Symposium on Cleaning of Electronic Device Components and Materials, Phila., Pa.

Prescott, R. E., *Some Design Aspects of Molded Circuits*, Symposium on Printed Circuits, Bell Laboratories, Murray Hill, N. J.

Prim, R. C., *Some Minimax Problems for Labeled Graphs*, American Mathematical Society, Salt Lake City, Utah.

Purvis, M. B. and Staehler, R. E., *The Role of Photographic Storage in Electronic Telephone Switching Systems*, Society of Photographic Scientists and Engineers, N. Y. C.

Ruppel, A. E., *The Dew Line Story*, Fire Department, East Rockaway, N. Y.

Ruppel, A. E., *The Dew Line Story*, Hempstead Bay Power Squadrons, Hempstead, N. Y.

Schawlow, A. L., *Infrared and Optical Masers*, I.R.E., Princeton, N. J.

Schroeder, M. R., *New Results Concerning Monaural Phase Sensitivity*, Pavlov Institute of the U.S.S.R. Academy of Sciences, Leningrad, Russia.

Schroeder, M. R., *On the Steady State Sound Transmission in Rooms*, Acoustic Institute of the U.S.S.R. Academy of Sciences, Moscow, Russia.

Schroeder, M. R., *Vocoders for Military Use*, Air Force Research Center, Bedford, Mass.

Schulz-DuBois, E. O., *The Traveling Wave Maser*, University of Michigan, Ann Arbor, Mich.

Scovil, H. E. D., *Lecture Series on Masers*, White Sands Missile Proving Ground, Las Cruces, N. M.

Staehler, R. E., see Purvis, M. B.

Stone, H. A., Jr., *New Bedfellows*

in Electronics, Bell Laboratories-Western Electric Printed Wiring Symposium, Summit, N. J.

Suhl, H., *Ferromagnetism*, University of California, Berkeley, Calif.

Terry, M. E., *Modern Computers in Quality Control*, Eleventh Rutgers Conference on Quality Control and Statistics in Industry, New Brunswick, N. J.

Thurston, R. N., see Mason, W. P.

Walters, A. E., *Minority Carrier Lifetime in Neutron-Bombarded Germanium*, Second Conference on Nuclear Radiation Effects on Semiconductor Devices, Materials and Circuits, N. Y. C.

White, A. H., *Physics in the Communication Field*, Second Annual Corporate Associates Meeting, American Institute of Physics, Harriman, N. Y.

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

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Anderson, P. W., *The Knight Shift in Superconductors*, Phys. Rev. Letters, 3, pp. 325-326, Oct. 1, 1959.

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Birdsall, H. A., *Insulating Films*, Chapter IX, 1958 Digest of Literature on Dielectrics, 22, pp. 239-251, Oct., 1959.

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DeGrasse, R. W., see Geusic, J. E.

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Hardy, F., *Development of Special Lubricants and Lubrication Practices for Small Apparatus*, J. Am. Soc. Lubrication Engineers, 15, pp. 328-332, Aug., 1959.

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Li, Tingye, *A Study of Spherical Reflectors as Wide-Angle Scanning Antennas*, I.R.E. Trans., Prof. Gp. Antennas and Propagation, 7, pp. 223-226, July, 1959.

Logan, B. F. and Schroeder, M. R., *The Sound of Rain*, Frequenz, 13, pp. 229-234, Aug., 1959.

McCall, D. W., see Douglass, D. C.

Northover, W. R., see Flaschen, S. S.

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Roberts, S. W., *Control Chart Tests Based on Geometric Moving Ranges*, Technometrics, 1, pp. 239-250, Aug., 1959.

Samelson, H., see Allison. H. W.

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Schroeder, M. R., *Methoden zur Messung der Diffusitat in Hallraumen*, Acoustica, 9, pp. 256-264, July, 1959.

Schroeder, M. R,, see Logan, B. F.

Schulz-DuBois, E. O., see Geusic, J. E.

Scovil, H. E. D., see Geusic, J. E.

Sharpless, W. M., see DeLoach, B. C.

Spencer, E. G., see Clogston, A. M.

Uhlir, A. Jr., see Leenov, D.

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Wood, D. L., see Clogston, A. M.

Woodward, R. B., see Wasserman, E.

Wernick, J. H., *Semiconductor Metallurgy*, J. Metals, 11, p. 698, Oct., 1959.

PATENTS

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

Anderson, J. R. — *Ferroelectric Storage Circuit* — 2,907,984.

Bangert, J. T. — *Computer for Network Synthesis* — 2,910,241.

Becker, F. K. — *Two-Way Television Over Telephone Lines* — 2,909,600.

Blecher, F. H. — *Interlaced Feedback Amplifier* — 2,909,623.

Bogert, B. P. — *Automatic Phase Equalizer* — 2,908,873.

Buhrendorf, F. G. — *Clutch for Driving Apparatus* — 2,909,257.

Callaway, W. B. and Deltuvia, A. A. — *Telephone Traffic Data Processor* — 2,909,608.

Carbrey, R. L. — *Time Assignment Signal Interpolation System* — 2,907,829.

Caroselli, F. — *Microwave Impedance Branch* — 2,910,659.

Davis, J. L. and Rowen, J. H. — *Broadband Nonreciprocal Devices* — 2,909,738.

Deltuvia, A. A., see Callaway, W. B.

Edson, J. O. — *Bistable Frequency Divider* — 2,909,675.

Fleckenstein, W. O., Kretzmer, E. R. and Michel, W. S. — *Facsimile Communication System* —2,909,601.

Fthenakis, E. — *Current Supply Apparatus* — 2,909,720.

Graef, R. P. — *Mu-Beta Measurement in Feedback Systems* — 2,909,620.

Jensen, A. K. — *Transistor Control Circuits* — 2,909,678.

Kircher, R. J. — *Testing Apparatus* — 2,908,860.

Kretzmer, E. R., see Fleckenstein, W. O.

Mason, W. P. — *Apparatus for Eliminating Mechanical Vibrations in Aerial Cables* — 2,907,-811.

McKay, K. G. — *Negative Resistance Semiconductive Apparatus* — 2,908,871.

McKim, B. — *Magnetic Core Circuit* — 2,910,676.

Meacham, L. A. — *Party Line Identification System* — 2,908,-762.

Michel, W. S., see Fleckenstein, W. O.

Newby, N. D. — *Method of Making an Insulated Conductor* — 2,907,075.

Peek, R. L., Jr. — *Electrographic Transmitter* — 2,907,824.

Pierce, J. R. — *Automatic Phase Equalizer* — 2,908,874.

Pierce, J. R. — *High Frequency Amplifier* — 2,908,845.

Quate, C. F. — *Low Noise Traveling Wave Tubes* — 2,908,844.

Raisbeck, G. — *Measurement and Simulation of Transfer Parameters* — 2,907,950.

Raisbeck, G. — *Voice Pitch Determination* — 2,908,761.

Robertson, S. D. — *Finline Phase Shifter* — 2,907,959.

Rodgers, J. — *Locking Device for Straightedges* — 2,909,840.

Rowen, J. H., see Davis, J. L.

Schafer, J. P. — *Gyromagnetic Polarizing Device* — 2,907,964.

Simkins, Q. W. — *Transistor Current Limiter* — 2,909,677.

Soffel, R. O. — *Wide-Range Automatic Gain Control* — 2,910,550.

Taylor, R. L. — *Electrolytic Capacitors* — 2,908,849.

Thomas, L. C. — *Transistor Comparator Circuit for Analog to Digital Code Conversion* — 2,-909,676.

Thompson, Eugene, C. — *Transistor Binary Adders* — 2,908,828.

Timm, W. C. — *Transistor Gain-Bandwidth Test Circuit* — 2,-909,730.

Turner, E. H. — *Nonreciprocal Wave Transmission* — 2,909,-734.

Wennemer, G. P.—*Noise Compensated Tone Signaling System* — 2,909,606.

Wirsching, R. E. — *Solderless Connector* — 2,908,884

Wolfe, R. M. — *Electrical Circuits* — 2,910,670.

V. M. Cousins

V. M. Cousins joined Bell Laboratories in 1925, with a group designing sound systems. He was a member of the Special Products Development Department and its successors up to World War II, and since then has worked on military projects. He participated in the design of circuits for amplifiers and associated equipment for sound motion pictures and public address systems, and worked on Naval sonar and communications equipment between 1925 and 1940. Then he transferred to a group developing the research and development model of the M9 Anti-Aircraft Fire Control System. He was concerned with the development of computers for this and similar fire-control systems until the end of the war. In 1945 he took charge of a group responsible for the circuit design of the Nike research and development guidance computer. Since 1953, Mr. Cousins has headed a group which designs and operates the Nike System Tester, the subject of his article. A native of North Dakota, he received B.S.E.E. degree from the University of Minnesota in 1925.

Newton Monk, born in Stoughton, Mass., received the A.B. degree from Harvard College in 1920 and the B.S. degree from the Harvard Engineering School in 1922. He then joined the D.& R. Department of the A.T.&T. Co. where he worked on interference prevention and carrier development. This later activity was continued when he transferred to the Laboratories in 1934, and he was associated with early applications of carrier to railroad and other private communication systems. During World War II he was engaged in the development of military communications. Since the war he has been in charge of a group developing radio systems for railroads and airplanes and, more recently, personal signaling systems. He is a member of A.I.E.E.,

Newton Monk

a senior member of I.R.E., and served for two years as chairman of the Professional Group on Vehicular Communications of the latter organization. Mr. Monk is the author of the article on personal signaling in this issue.

Evan E. Thomas was born near Swansea, Wales, and attended the University of Wales and British Naval schools. After a period of navy teaching, he came to the United States in 1928, and joined Bell Laboratories almost immediately as a member of the then metallurgical group of the Chemical Department. Here, he became engaged in gas-metal studies and

Evan E. Thomas

then in lead-alloy studies for cable sheathing. Since 1931, he has specialized in optical microscopy, the subject of his article in this issue. His work has covered a wide range of metallic materials and semiconductors. Mr. Thomas is a member of Sigma Pi Sigma and the American Society for Metals. He received the M.S. degree from New York University in 1939.

William Pferd, who describes the exploratory coin telephone in this issue, was born in Elizabeth, New Jersey. After undergraduate training at Union Junior College and Purdue University, he entered the Armed Services in 1943. As an intelligence officer in

William Pferd

the Air Force he served with the 98th Bomb Group in Italy and subsequently received a B.S. in M.E. from Rutgers University in 1947 and his M.S. in mechanical engineering from Newark College of Engineering in 1951. He joined the Laboratories in 1947 and was first engaged in the development of the ringer and dial for the 500-type telephone. He was appointed a supervisor in charge of development of a new coin telephone in 1955, and is presently in charge of a group engaged in exploratory development of station apparatus including public telephones, signaling apparatus and station connectors.

T. S. Greenwood

T. S. Greenwood was born in Boston, Massachusetts. He received his B.S. degree in Electrical Engineering from Northeastern University in 1951 and his M.S. in Electrical Engineering from the Massachusetts Institute of Technology in 1953. While at M.I.T. he worked on storage devices for the Whirlwind computer, a forerunner of the SAGE computer. He joined the Laboratories in 1953 and has since been associated with the development of memory devices for the Electronic Switching System. Until this year he has worked on the barrier-grid store, the transient memory for the system. He is now in charge of a group developing its semi-permanent memory — the flying-spot store.