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Bell Laboratories
RECORD

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Bell Laboratories **RECORD**

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Contents

Cover *R. S. Engelbrecht with four stage amplifier using semiconductor diodes as active elements.* *See story on page 250.*

People frequently ask whether certain potential communications services would be useful to the customer. Answers to such questions should be determined at the earliest possible stage—preferably even before equipment is built. The Human Factors Engineering group at Bell Laboratories has developed techniques for simulating services and for testing user reactions.

R. R. Riesz and H. D. Irvin

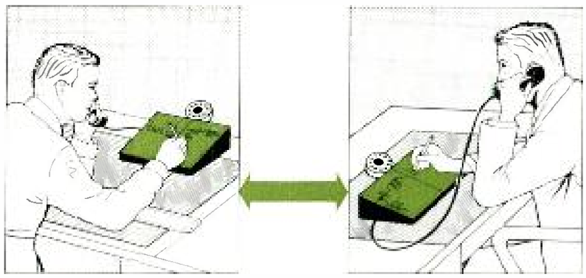
Simulation in Engineering

The Bell System has a constant obligation to consider the needs and preferences of the user in designing communication services and devices. Special efforts are made, for example, to keep the users' preferences in mind as research and development programs are considered. Field trials of new systems are conducted; careful consideration is given to customers' suggestions and complaints; and periodic nationwide surveys of telephone customer opinion are made.

In this field of human factors studies, problems encountered in the research and development activities at Bell Laboratories are becoming more numerous and more complex. This is particularly true as we look ahead toward intriguing future services which technological progress is making potentially available to the Bell System customer. This cornucopia of future possibilities for the telephone user is so full that it would be too costly and too slow to build them all so that field trials could be made. Thus, the Human Factors Engineering group is doing research to discover improved techniques (short of actual development), for evaluating reliably *now* the preferences of users for these possible *future* communication services.

The solution of a user-preference problem usually involves getting answers to two questions: (1) Will a proposed communication service or device be something the user will really want and need? (2) How shall the new service or device be designed so that the user will find it convenient and adequate? To get reliable answers to such questions, it is necessary to use considerable caution. For instance, a commonly used way to discover what groups of people think about something is to conduct a poll. The questions that can be asked are of two classes: (1) The "post mortem" type — questions about past experiences, such as "How *did* you like so and so?" (2) The "crystal ball" type — questions about future experiences, such as "How do you think you *will* like so and so?"

Both of these classes of questions can provide useful information if adequate safeguards are taken regarding the limitations of human behavior. When a person answers a "post mortem" question, he is post-judging something from memory. Although the reliability of memory in certain cases is fairly good, it is often not so for the quantitative details of a prior experience. On the other hand, the "crystal ball" question demands that the person pre-judge something which he has never experienced. The value of answers to this class of questions will depend greatly on the novelty of the situation being judged: the further it is from his experience, the less reliable will be his answer. And, even at best, a human being will respond differently to situations merely



If a "telewriting" system becomes economically practicable in the future, specifically what type of service are users of such systems likely to prefer?

described to him as opposed to conditions that are actually experienced.

In either case, more reliable answers to these questions can be obtained by providing people with the actual experience and by observing how they behave in the given situation. This is the reason for field trials, of course, yet field trials require a device or service that has already been designed and built. User-preference evaluations would be most valuable if they were made at an early stage of development, perhaps even before there was a laboratory model. Here is a paradox. On the one hand, a user evaluation of a communication device or service is needed before the system has been developed, but on the other hand, the system itself is needed to make the evaluation. One way of resolving this paradox is by simulating the system.

Simulating Communication Systems

A simulation presents to a user all the relevant features of a particular device from the viewpoint of "human factors," even though the simulation does not have the physical reality of the device itself. Simulation is not a new technique, of course, but has been used in many situations. Ancient man used simulation (camouflage) for survival; the legitimate theater, the motion picture and the television play simulate human situations for the purpose of entertainment. At the present time, in certain phases of the training of flight crews for aircraft, the use of simulators has become well established as a reliable and economical substitute for training in actual flight.

The success of simulation in user-preference studies is based on two simple ideas: (1) "People can't look ahead, so make them look backwards." This says that the crystal ball difficulty can be overcome by giving people actual experience with a new device. (2) "People's attitudes toward a new device or service depend on what they *think* it is — not on what it *actually* is." This says that if people can't tell the simulation from the real thing, they are getting the actual experience they need to make a reliable evaluation.

How is this concept of simulation applied to human factors research? The question is best answered by giving a few illustrative examples. Consider the problem of evaluating the human factors governing the technical design requirements of a "telewriting" channel which might be considered for use as an adjunct to a speech communication channel. Such a channel, as shown in the drawing on this page would in effect give to each person at opposite ends of a telephone connection a pad on which he could write or draw sketches — this information being reproduced at the distant pad as it was set down. Such a system contemplates a narrow frequency band so that television techniques would not be used. To determine the engineering requirements needed to develop such a system, it is necessary to determine the user's attitude toward such factors as the size of writing pad, the need for a permanent record, the ability to erase and make changes, and the ability to write and talk simultaneously or alternately.

"Telewriting" Simulator

A simulator used for investigating these human factors was constructed at Bell Laboratories. Users, on opposite sides of a wall, can converse only over a normal telephone path. On a table before him, each user has a sheet of translucent paper on which he can write or sketch. By means of a system of mirrors, each person sees through a transparent glass panel a right-side-up reflection of what his partner has written. This image is projected from the rear of the sheet on which it was written.

By communicating over such a dual transmission system, users can get experience with such design features as those mentioned above. Fine wires leading to a switch in each pen indicate when each person is writing. Voice-operated switches indicate when each person is speaking. This arrangement permits measurements to be made of the percentage of time each user talks or writes as well as the percentage of time he talks and writes simultaneously. By means of lockout switches, it is possible to evaluate a "telewriter" system with which a user can either talk or write at any time but cannot do both simultaneously. The simulator has been used to determine many of the human design requirements which must be satisfied by any operating telewriter used as an adjunct to a speech communication channel.

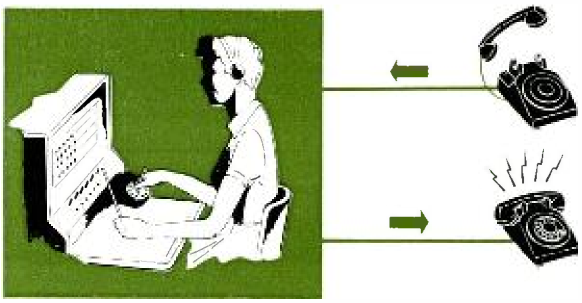
It is often convenient and economical to use a human being as one of the control mechanisms in a simulator. An example of this is the simulator devised to study user reaction to voice dialing. To initiate a telephone call by this method, a user would speak the desired telephone number into his handset, and a machine in the central office would recognize the spoken digits and complete the connection. Would people prefer voice dialing to finger dialing? A universally reliable voice dialing machine has not yet been developed. The preference information would help decide whether or not to sponsor a research project aimed toward developing the machine.

To get this information, people had to be able to try dialing numbers by talking to a machine, and they had to do so without knowing that there was no real voice dialing machine in existence. As shown in the illustration (*right*) tests were made by using a human in the simulator. A silent operator listened to the number spoken and then dialed it on a speeded-up finger dial. The operator was instructed to obey the same rules of operation that might be built into the future machine. She was not allowed to use her intelligence to do things that the machine would not be designed to do. This simulator had great flexibility since it was possible to try out changes in design simply by changing the rules of operation. Privacy was assured by automatically disconnecting the operator's receiver as soon as the ringing signal started.

Information on how people used voice dialing was obtained by making tape recording of the signals going to the operator's receiver. When people first began to use voice dialing, they often accompanied their spoken telephone number with incidental remarks such as, "Please" or "Connect me with________." As they became used to talking to a "machine," these verbal habits carried over from manual telephony stopped and they spoke the desired telephone number only. Since speech defects must be considered in the design of any voice-dialing machine, several stutterers were included in the panel of users. As these people gained experience with the voice dialing simulator, their stuttering during voice dialing tended to disappear.

Voice Dialing Preferred

This was a striking finding which tended to confound preconceived notions of many engineers about the difficulties stutterers would have with voice dialing. It is a good illustration that preference tests often contradict initial opinions about the human factors associated with new devices or services. The tests with the simulator showed that the panel of users generally preferred voice dialing either to finger dialing or to the speaking of telephone numbers to a manual switchboard.



SILENT OPERATOR LISTENS TO SPOKEN NUMBERS ONLY

Sometimes a human being can simulate a possible future service: operator uses predetermined rules in testing user reaction to voice dialing.

To make a reliable prediction of the usefulness of a new telephone service or device, tests of the service should be made under realistic conditions of use. If a trial user is brought to a test laboratory to try out a new service, the experiments are well controlled but the conditions of use are somewhat artificial. Simulation, however, enables the tests to be made under the more natural conditions of the home or office. An example of this consideration is the simulation designed to study the effectiveness of auditory signals to tell the telephone user that there is an incoming call for him to answer.

Many Signals Tested

As shown in the drawing on the next page for each incoming call the ringing current from the central office, instead of ringing a bell, automatically connects the receiver of the user's handset to the output of a tape recorder. By the use of different tape recordings, the effectiveness and acceptability of a wide variety of subscriber calling signals could be studied.

The relative attention-arresting power and the pleasantness of combinations of tones, sequences of tones, duty cycles, musical passages, and so on could be assessed under realistic conditions of use. At the central control position, the time to answer each call was measured, enabling the influence of signal level and character of signal on answering time to be determined. As a base line, each user's answering time for the regular telephone bell was first measured. Subsequent interviews enabled the user's judgment of the pleasantness of each calling signal to be obtained. One interesting result of these tests was that most of the trial users in office locations preferred a calling signal that began at a low level and increased to its final loud level in about 10 seconds.

Such signals were answered as quickly as signals that began at the higher level. Also, most trial users preferred certain tone calling signals to the usual telephone bell, and these signals were answered as quickly as was the bell signal.

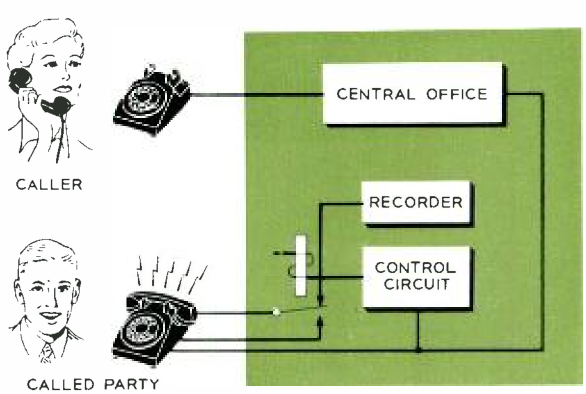
New Simulation Laboratory

The development of simulation as a reliable scientific technique is an active part of the work of the Human Factors Engineering group. This activity includes the development of "Sibyl"—a simulation laboratory which will be equipped to handle many different kinds of experiments in this area. (Sibyl gets its name from the Sibylline oracles who were credited by the Romans with being able to foresee the future.) Currently, experiments are conducted within the Laboratories with Laboratories' personnel as trial telephone users, but it is expected that simulation will be developed to the point where it can be used under field conditions.

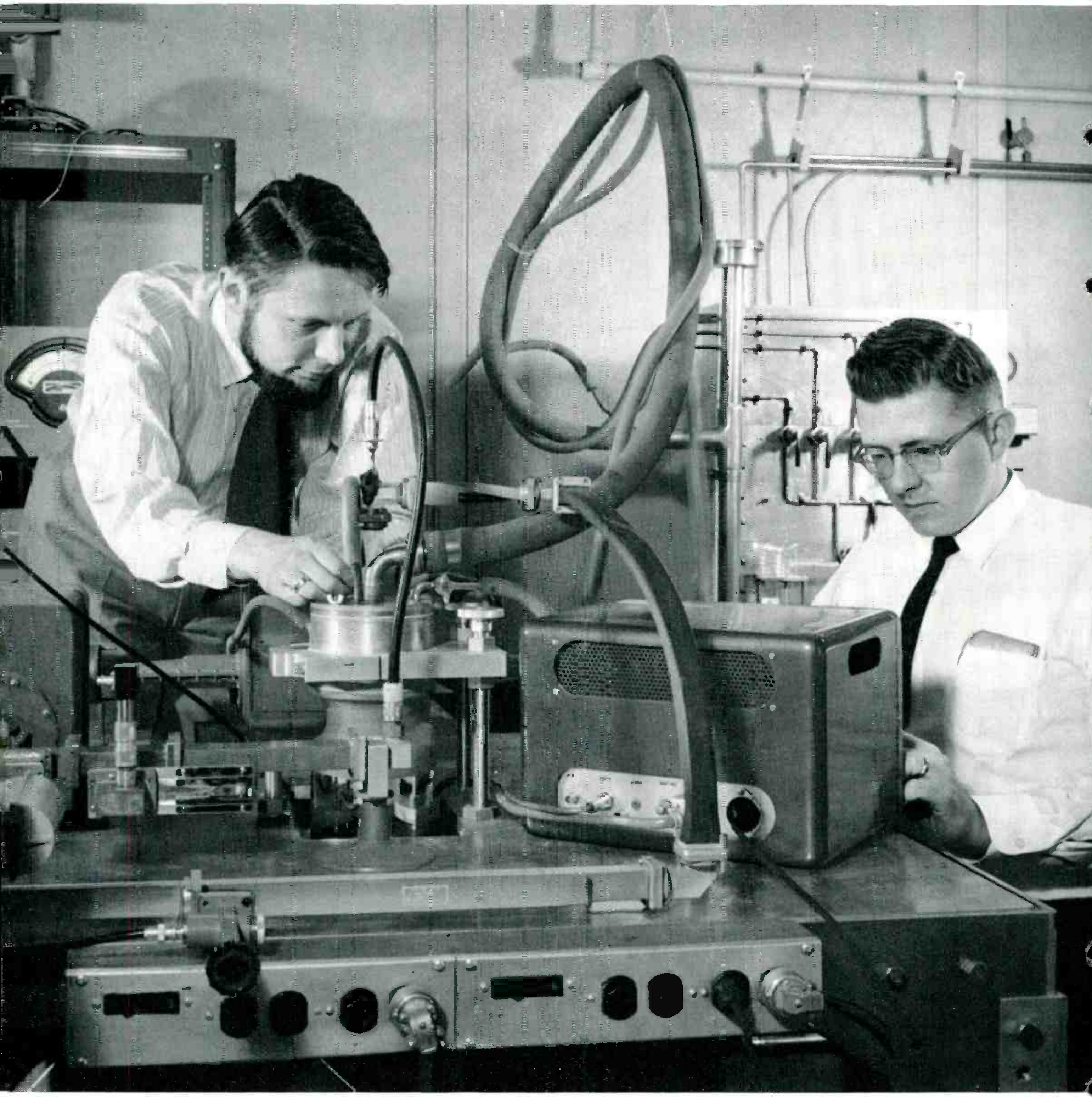
Experiments conducted within the Laboratories are also useful in developing testing techniques for Human Factors research. For example, the importance of conditions of use can be studied by comparing (1) results obtained in test rooms to which users of a device can be brought with (2) results obtained at users' desks or other usual work locations. Samples of users selected from Laboratories' personnel can be used for developing test methods, but for field studies, other test groups would be chosen. For methods studies, users can be selected who, because of the nature of their work, have a *real need* for a device under test. Also, the value of questionnaires for collecting objective data can be studied, since Sibyl is being instrumented for recording automatically a wide variety of objective information on what users *did* with a particular simulated service. This information can be compared with what the same users later *say* they did when using the service. It is anticipated that simulation will ultimately prove itself a valuable addition to the methods already in use to ensure that the Bell System is adequately satisfying the communication wants of the user.

The examples given above illustrate that simulation is a useful engineering technique for investigating user preference questions. Moreover, simulation can help determine the human factors setting design requirements of equipment. As an engineering tool, simulation is economical, versatile and powerful: economical because future systems can be evaluated long before their final development; versatile because proposed systems and their modifications can be evaluated rapidly; powerful because systems even beyond present technological knowledge can be evaluated now.

At Bell Laboratories location used for tests of simulated systems, O. O. Gruenz takes data at control station. Careful procedure during tests assures maximum reliability of the conclusions.



In place of the usual ringing signal, tape recorder in experimental equipment supplies many different types to test the reactions of users.



A Bell Laboratories experimental MASER. E. O. Schulz-Du Bois, left, adjusts well of refrigerant into which the waveguide and cavity are inserted as R. W. DeGrasse takes data on operation.

Noise is the enemy of all transmission systems, and it is especially troublesome because it can never be reduced below a minimum determined by the temperature of electronic amplifiers. New MASER amplifiers, however, have theoretical operating noise temperatures as low as the temperatures of the coldest refrigerants.

H. E. D. Scovil

A THREE-LEVEL SOLID-STATE MASER

Any research and development organization concerned with communications is of course interested in all types of amplifiers — electron tubes, transistors and magnetic amplifiers, to name the chief types in use today. Thus, Bell Laboratories is looking carefully at new types that may be used in the future, and the amplifier we are concerned with in this article is the MASER — a coined word standing for "Microwave Amplification by Stimulated Emission of Radiation." In particular, we shall describe a MASER of the "three-level" type — a concept that will be discussed later, after a brief review of some of the background and some of the principles of this area of development.

Several years ago, Professor C. H. Townes of Columbia University suggested the concept of a "two-level," gas MASER—a device that uses ammonia gas, which can be caused to emit radiation when gas molecules drop from a high-energy state to a lower-energy state. A number of these devices have been built. Then, in 1955 the Russian physicists N. G. Basov and A. M. Prokhorov proposed the application of a "three-level" principle in a gas-type MASER. A next step was the possibility of achieving the three-level type of amplification in a solid-state device, a suggestion first published by Professor N. Bloembergen of Harvard University.

At Bell Laboratories, two three-level, solid-state MASERS have been built. Each includes a crystal salt placed in a magnetic field in a resonant cavity. The cavity is kept at a very low temperature by refrigeration with liquid helium.

In simplest terms, the idea is to subject the crystal salt to a source of electromagnetic energy called the "pump". Energy is absorbed from the pump, thus stimulating the crystal into an active condition so that it may amplify or oscillate. The MASER can operate regeneratively with only the pump input and the output — that is, as an oscillator — or a signal can be introduced to control the output, in which case the MASER functions as an amplifier.

The first MASER designed at Bell Laboratories was arranged as an oscillator, and it was the earliest demonstration that a solid-state MASER could in fact be built. This first device used a pumping frequency of 17,500 mc, and the output frequency was 9,000 mc. A magnetic field of 2,200 oersteds was employed.

More recently, an amplifying MASER has been built at the Laboratories, operating on a pumping frequency of 11,500 mc and an output of 6,000 mc. This device has shown a gain of 20 db with a bandwidth of 100 kc. With improvements, however, potential bandwidths can be much greater in amplifying structures of this type.

Since a refrigerant is used, it is apparent that a MASER is a complex structure compared with more conventional amplifiers. Why, then, are we interested in it? First of all, of course, when something new is introduced into the field of communications, it is thoroughly studied with no immediate concern for its ultimate application. Much of the interest derives, however, from the fact that MASERs may introduce very little noise into a signal.

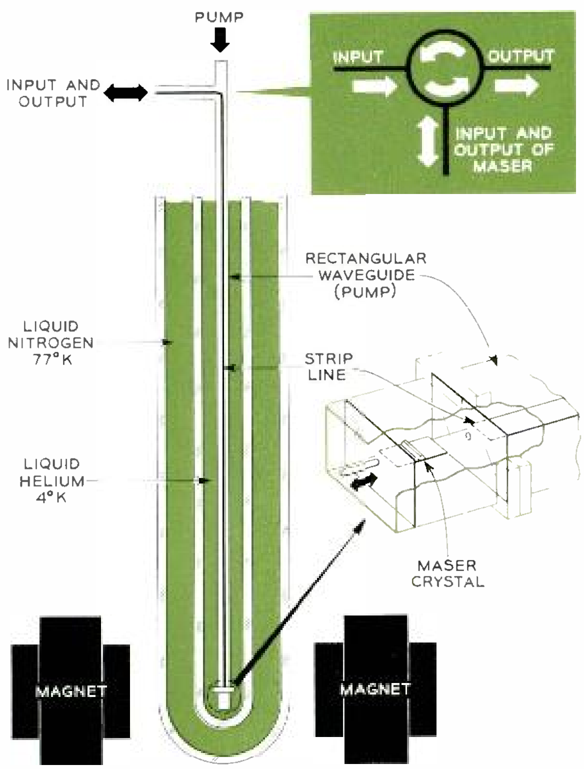
Low Thermal Noise

It is commonly known, as a result of work at Bell Laboratories by J. B. Johnson, that there is no such thing as a noiseless amplifier. Some noise is always present, and the minimum amount that can be present is often called "thermal noise," because it is directly related to temperature of operation. In theory we can reduce this noise by lowering the operating temperature, but this process cannot be carried very far with conventional amplifiers. Conventional amplifiers may have effective noise temperatures of 290° Kelvin (room temperature) or higher. By comparison, the entire 6,000 mc amplifier has an effective measured noise temperature of 150°K, and the actual MASER structure has a noise temperature of less than 35°K, compared with a theoretical value of less than 4°K.

Such an extremely low noise figure of course raises many interesting possibilities for communications. It could mean that microwave repeaters can be placed farther apart, or, alternatively, operate at lower signal levels over the present distances. The MASER also promises a greatly increased range for radio astronomy — weak signals now obscured by noise in the receiving circuits may in the future be detected at good signal-to-noise ratios. The MASER also has obvious applications in radar.

Thermal noise has been mentioned in connection with conventional types of amplifiers. Another common type is that termed "shot noise." Without going into the mechanisms of these noise sources, we merely note that they derive from the motion of free conducting electrons — a motion basic to electrical conductivity. One of the fundamental characteristics of the MASER is that it does not depend upon free electrons for its operation.

Rather, a solid-state MASER operates by bringing about changes in energy levels of atomic "spins." The crystal salt used in the Bell Laboratories MASERs is lanthanum ethyl sulfate with ½ per cent of gadolinium added. The gadolinium is the active element — distributed throughout the crystal so that in a magnetic field, the magnetic dipole or "spin" associated with each atom of gadolinium has little interaction with the dipoles of neighboring gadolinium atoms. That is, the structure is paramagnetic.

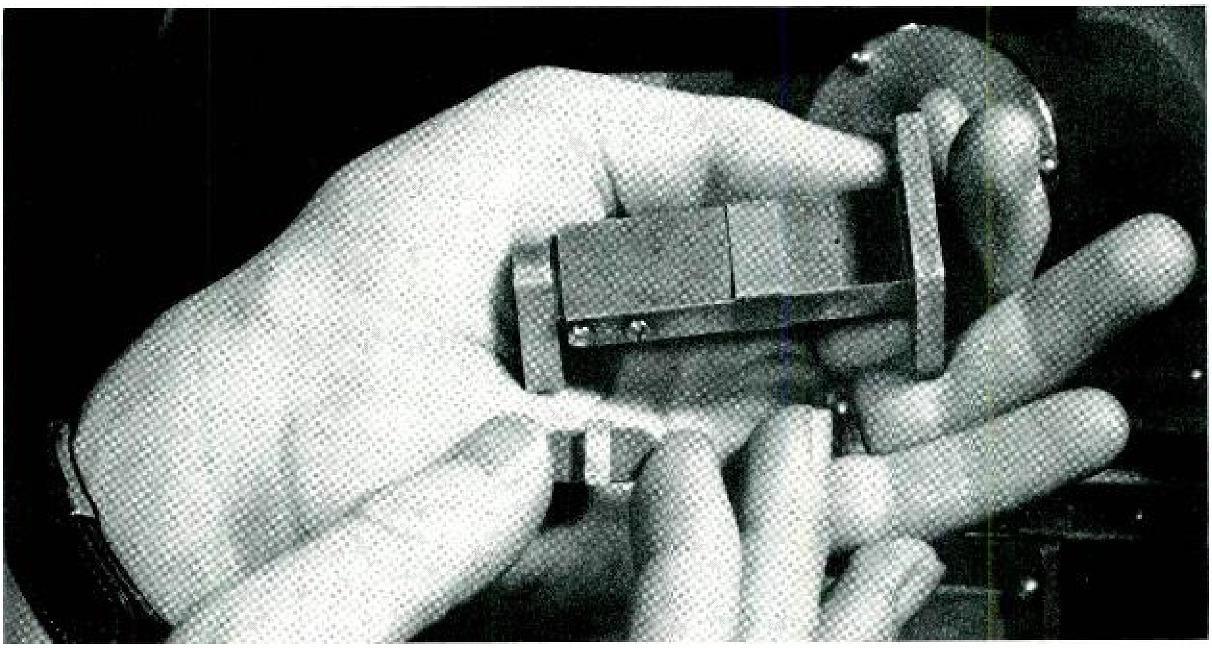


Representation of the chief elements of the MASER structure. The crystal is mounted in a resonant cavity and cooled to low temperature.

Eight Energy Levels

Now, the spin of electrons (bound electrons) in such active elements can assume a number of discrete orientations with respect to a magnetic field. In an ordinary bar magnet, the number of such discrete orientations is so very large that it virtually forms a 360° continuum, which is the point of view of classical mechanics. In certain materials, however, the allowed number of separate orientations can be relatively small, and for the salt used in the MASERs described here, the number is exactly eight — eight orientations with respect to the applied magnetic field with no possible intermediate states.

Further, these eight orientations correspond to eight energy levels that the atomic dipoles may assume. Let us number them according to their occurrence under normal conditions — that is, the



The resonant cavity structure (above) and the mounted crystal (below) of an experimental Bell Laboratories MASER. Representation of these parts can be seen in drawing on previous page.

largest number of atomic spins will normally occur at the lowest energy level 1, a lesser number at the next higher energy level 2, an even smaller number at 3, and so on.

Consider now the crystal salt at room temperature. Thermal agitation will raise some of the dipoles out of energy level 1 into levels 2, 3 and higher, but normally level 1 will be the more densely "populated." If we then lower the temperature, many of the levels 2, 3 and higher dipoles will lose energy, dropping toward level 1 to make it even more densely populated.

Basically, the idea of the three-level MASER is to take advantage of the first three energy levels in such a way that, contrary to the normal condition, level 2 is maintained as the most densely populated region, so that when the atomic spins are caused to drop from level 2 to level 1, energy in the form of output radiation is emitted. The pumping frequency is chosen so that it has just the right energy to raise spins from level 1 to level 3, and an impurity is introduced into the crystal to permit the efficient transfer of spins from level 3 to level 2, the cumulative result being the desired heavy population of level 2.

The introduction of the impurity (cerium, about 1 part per 500) proved to be useful in the development of the solid-state, three-level MASERs built at Bell Laboratories. The energy difference between levels 2 and 3 is critical, and without proper choice of the impurity element and its proper distribution throughout the crystal, these MASERs could not operate efficiently. With some other crystal salts, however, added impurities are not necessary.

Finally, with the establishment of an over-population in level 2, the output is obtained when a signal stimulates a large number of spins to drop to level 1. By contrast with certain other solid-state amplifiers, however, the process is continuous. Level 2 is continuously replenished, and a continuous signal frequency produces a continuous output. The MASER will oscillate if the internal and external (load) losses are sufficiently small, since it is equivalent to a negative-resistance amplifier.

Mechanical Analogy

This concept of MASER operation can perhaps be made a little more pictorial by resorting to a mechanical analogy. Consider that we have a large tank of water at ground level; this is level 1 of the atomic spins. Suspended above the tank at, say, a distance of 20 feet, we have a very large number of buckets (level 2) capable of holding, in all, more water than the tank does. Each bucket has a tap by which, with a sudden flip of its lever, the contents of the bucket can be dumped back into the tank. At a greater distance above the tank, say 30 feet, we have another group of buckets (level 3) whose contents can be drained to the lower group of buckets.

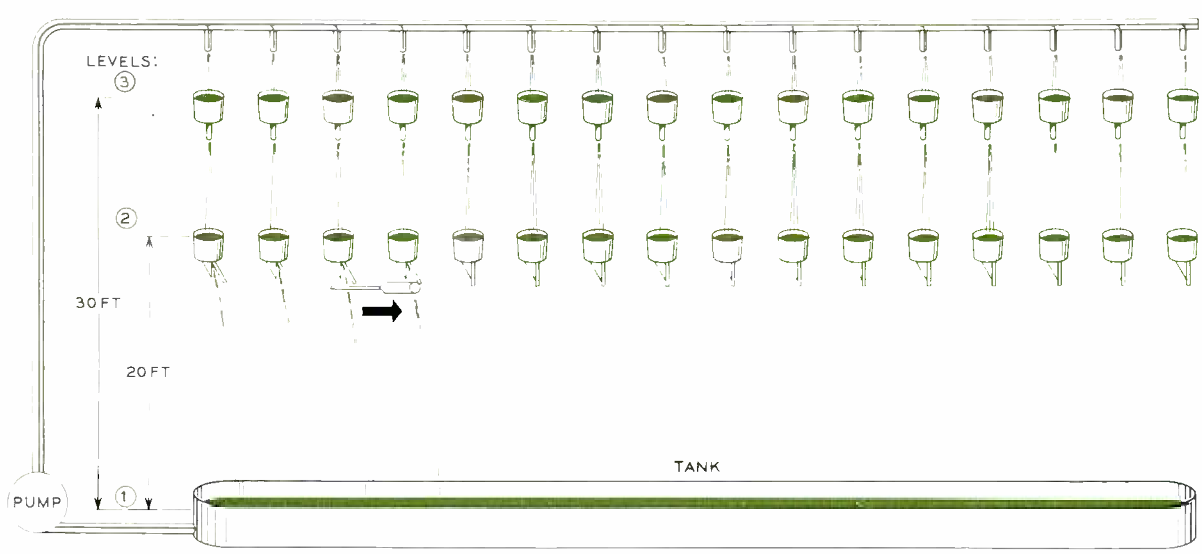
The peculiarities of our pumping system are such that although there is a small amount of transfer of water from the tank to the 20-foot high buckets, (and from the 20-foot high bucket to the 30-foot high buckets), the most effective way of filling the 20-foot high buckets is to pump water from the tanks to the top group, and to use a special valve (the cerium impurity) to drain water to the 20-foot height. Then, suddenly, a mechanical arm (the signal) sweeps along the group of 20-foot high buckets, tripping the levers and dumping the water into the tank. The signal strength is proportional to the number of levers tripped. The water dropping to the lowest level constitutes an expenditure of energy (the output). The total amount of water at the 20-foot height, however, remains constant because it is continuously replenished.

This constancy of the amount of water at the 20-foot height (constancy of spin population at level 2) introduces another reason why the MASER has a very low noise figure. Any fluctuation in the population at level 2 appears as a gain fluctuation, but the statistics of the MASER mechanisms work out so that this population is extremely stable.

Several final points will complete this brief discussion of the three-level, solid-state MASER, and will help to place it in proper comparison with other types of amplifiers. First, it has perhaps been noticed that one of the fundamental differences in the three-level MASER is its source of energy. In a conventional amplifier the energy source is a battery or some other dc supply, whereas the source for a three-level MASER is a supply of microwave energy at a frequency higher than the signal frequency. Second, practical considerations limit this type of amplification to the microwave range.

Isolation Required

Finally, a difficulty with the present structure should be mentioned. The MASER is a two-way amplifying device — once arranged for amplification of a signal traveling in a particular direction, it amplifies equally well for transmission in the opposite direction. This means that any reflection from the output circuitry, or any with the MASER proper, will be amplified and will tend to make the device oscillate. To date, this has limited the three-level, solid-state MASER to fairly modest values of amplification, but several possibilities for incorporating undirectional materials into the MASER structure or its associated circuitry are being investigated, and there is no reason to believe that this problem cannot be satisfactorily solved.



A mechanical analogy to the three-level principle: water spilling from the 20-ft height into tank is comparable to electron-spins dropping from level 2 to level 1 in the MASER amplifier.

A number of electrical protection devices are available to limit excessive voltages that are accidentally placed on telephone circuits. A recent Bell Laboratories development in this field provides electrical protection for transistorized telephone equipment. This is an unusual device in that it uses a semiconductor to protect other semiconductors.

J. W. Phelps

Electrical Protection for Transistorized Equipment

Telephone installations for Bell System customers frequently include protective devices that limit the voltage impressed on telephone equipment by diverting to ground excessive foreign currents. This protection is necessary to guard against the effects of dangerous lightning potentials and the effects of accidental contact between the telephone lines and electric power distribution circuits. The physical safeguarding both of customers and of service personnel is of primary importance. In addition the possibility of fire or other damage to property and also to equipment must be avoided.

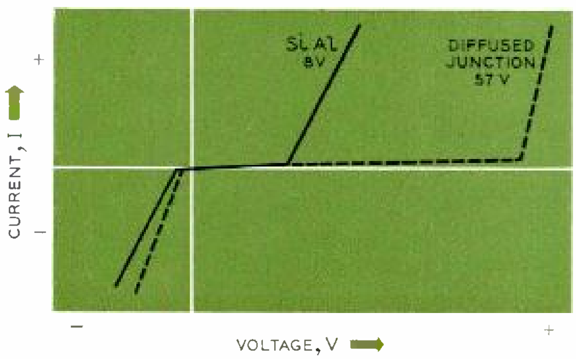
Let us consider some of the general facts about protection devices. A number of these are available and each is expressly tailored to do a specific job (RECORD, *August*, 1956). Most of them use an air discharge gap between two blocks of carbon. The blocks are connected between each side of the telephone circuit and ground. Because the foreign voltages impressed on telephone plant are voltages with respect to ground, they will, if large enough, cause the gap to "spark-over"—that is, cause an electric discharge through the air within the gap. The telephone plant is then, in effect, grounded for the duration of the transient voltage. The protective devices are inherently very rugged and will ordinarily restore themselves to their open-circuit condition after the transient voltage falls to a low value.

The potential at which the discharge gaps spark-over is primarily a function of the spacing between electrodes. Obviously, the least stress is put on the dielectric being protected when the spark-over potential is kept low. It is not feasible, however, to maintain gaps less than approximately 0.003 inch, because more closely spaced electrodes would then tend to become permanently shorted from low-magnitude transients.

Standard Gap

A 0.003-inch gap between carbon blocks is a practical spacing that results in a spark-over potential of approximately 500 volts peak. In the past, voltages of this magnitude have presented no great insulation problem to the apparatus designer and for this reason, the 0.003-inch discharge gap has long been used as a standard for protecting customers and equipment in homes and in central offices.

The unavoidable difference in spark-over potential between the two blocks is an important factor in the operation of protector blocks that are used in pairs on the two sides of a balanced circuit. Normal manufacturing variations result in spark-over potentials ranging from about 400 to about 600 volts peak. It is possible for a voltage surge in this range to be transmitted on both conductors of a telephone line and to cause only one of the two discharge gaps to spark over, momentarily grounding one side of the line. Currents will then



Typical characteristics of two diodes that are often used in devices for electrical protection. Parameter of interest is reverse breakdown voltage.

flow through any equipment terminating the line beyond the discharge gaps (a telephone set, for example), from the non-grounded, high-potential side to the grounded side.

By the very size and nature of normal non-miniaturized telephone apparatus, sufficient current-carrying capability and dielectric strength are fairly easy to obtain. The advent of the transistor and other semiconductor devices, however, and the equipment miniaturization which they make possible, has required certain changes in protection apparatus and circuitry. In general, it is possible to maintain sufficient dielectric strength in miniaturized equipment that insulation breakdown to ground is no problem. In such cases, conventional carbon blocks will protect these new devices against excessive voltages to ground; these are usually longitudinal voltages. The remaining problem, then, is to provide protection against the smaller metallic voltages that result from unsymmetrical block breakdown or from unbalances in the incoming transmission circuit. Even these voltages are sufficient to damage semiconductor devices in some circuits.

Second Protective Stage

Laboratories engineers recognized the possibility of such damage at an early point in the development of semiconductors and therefore began investigations to find a device capable of limiting voltages to much lower values. They concluded that it would be necessary to retain the conventional carbon blocks as protection against the relatively infrequent high-voltage transients. But the rather frequent surges in the range between the spark-over potentials of the two discharge gap pairs required a second stage of protection. For this second stage, semiconductor diodes have been found to do an excellent job when they are used in conjunction with series current-limiting resistors.

This diode is, in general, placed in parallel with the item to be protected. The voltage across the parallel network is then limited to the reverse breakdown voltage of the diode. The reverse breakdown voltage of a *semiconductor* diode is roughly analogous to the peak inverse-voltage rating of an *electron-tube* diode. An important exception is that the reverse breakdown voltage may be exceeded without damage to the semiconductor diode if the current is limited in magnitude and in time. A resistor is therefore placed in series with the line ahead of the diode to limit the current through the diode to less than what would be the destructive value.

Semiconductor diodes closely approximate the characteristics of a perfect protector. For voltages less than their reverse breakdown potentials, diodes present a very high impedance (act as a nearly open circuit). For voltages greater than their reverse breakdown potential, diodes are equivalent to a low-impedance battery with a voltage equal to the breakdown potential. In effect, they limit the potential rise across their own terminals. The curves on this page show typical characteristics of two diodes that have been used as protective devices.

Americus Trial

The first application of the two-stage, low-voltage protection network was made in the P-carrier field trial at Americus, Georgia (RECORD, *August*, 1956). This transmission system employs transistorized repeater and terminal equipment on open wire lines — notorious collectors of lightning surge-currents. The protection network used on this system is shown in the first of the three diagrams on the next page. It consists of the conventional carbon protector blocks, a series current-limiting resistor, and a bipolar silicon-alloy diode.

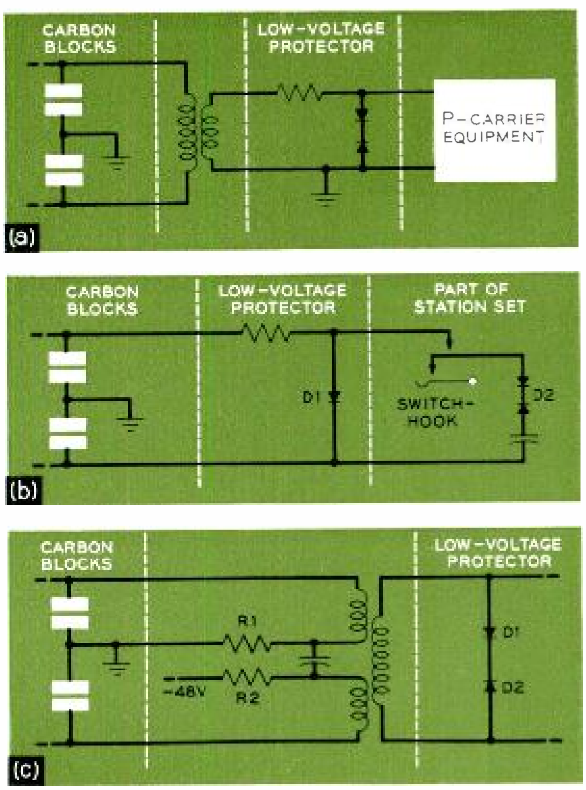
If we neglect the effects of unbalance, the surge potentials impressed on both conductors at a magnitude *below* the spark-over voltage of the *lower* breakdown valued block cause no surge currents in the secondary circuit of the transformer because there are no paths to ground. Also, surge potentials *above* the spark-over voltage of the *higher* breakdown valued block cause both the blocks to operate, thereby shunting the surge current to ground. Any transient voltage sufficient to operate only one of the two blocks, however, causes the surge voltage to appear across the circuit and, in turn, across the secondary of the transformer. At that point the resistor and diode act to limit the voltage to a value that the associated semiconductor devices can withstand.

The low voltage protection network was in place during two lightning seasons, and a subsequent examination of the equipment has shown that the diodes successfully performed their protective function. The presence of discharge marks on the carbon blocks proved that lightning did in fact appear on the open-wire conductors.

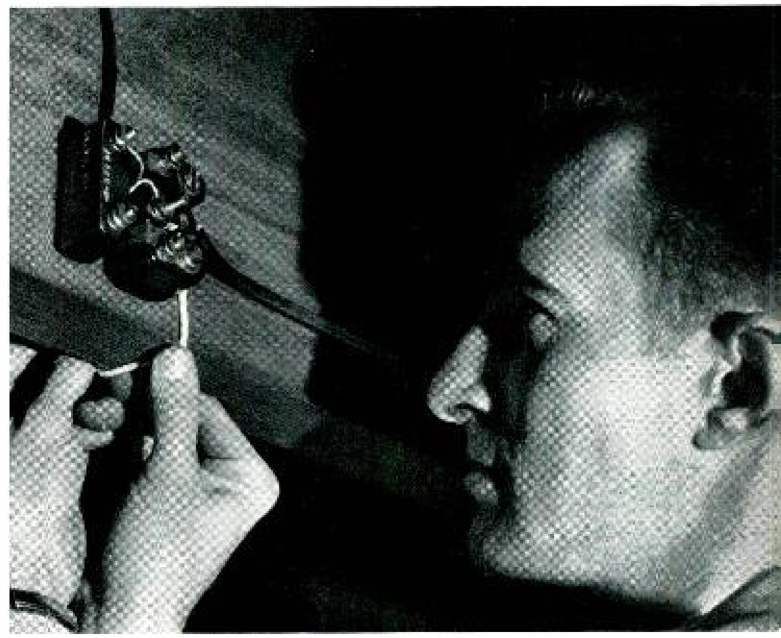
A number of other applications of two-stage protection of transistorized equipment have been developed. At Crystal Lake, Illinois, a field trial is currently in progress in which a new station set, compatible with an electronic-switching system, is being evaluated. Protection for this set is furnished by the network shown in part (b) of the figure below.

Here there are three stages of protection. The first stage, consisting of carbon block discharge gaps, limits potentials appearing on either conductor to the gap spark-over potential.

The principal protection diode, D_1 of the figure carries the major part of any surge currents that pass one of the discharge gaps. This diode is a diffused-junction unipolar unit with a nominal reverse-breakdown potential of 57 volts. It is necessary only to use a single diode at this point because the central office battery provides the necessary bias. Thus, the diode is non-conducting for all normal telephone signals, but conducting for voltages large enough to reach the forward conducting region, or reach the reverse breakdown potential.



Protection networks for transistorized equipment: (a) P-carrier terminals and amplifiers at central offices and on poles; (b) a three-stage network designed for station apparatus compatible with an electronic switching system; (c) diode arrangement for protection of electronic switching equipment exposed to excessive potentials.



The author examines a station apparatus protector which has been mounted on premises of a customer for his and the telephone's protection.

The double diode unit, labeled D_2 in the figure, limits the potential rise across one winding of a three-winding transformer to approximately eight volts and thereby protects a transistor not shown on the figure. D_2 consists of two unipolar silicon-alloy diodes with reverse breakdown voltages of eight volts.

A proposed electronic-switching system will need diode protection on each line brought into the central office. Part (c) of the diagrams shows the diodes D_1 and D_2 that limit potentials at significant points in such a system. These prevent false operation of, or damage to, gas tubes and associated equipment that connect calls through the office.

The use of a small semiconductor diode to protect its cousin, the transistor, represents a new protection art for telephone systems. Development of this protection was necessary before the transistor could be fully applied in telephone equipment exposed to foreign potentials.

LOW-NOISE AMPLIFIER

For High Frequencies

Uses New Semiconductor Diodes

An experimental device which shows great promise as a low-noise amplifier for ultra-high and microwave frequencies is currently being developed at Bell Laboratories. Preliminary results indicate that this device, which uses semiconductor diodes as the active elements, can improve the performance of many types of microwave receivers. It is relatively simple to construct and operate, and shows prospects of having a long life.

The most important property of the new amplifier is its excellent "noise" performance. Noise has always been a major problem in the amplification of weak microwave signals. Presently available commercial amplifiers and converters add a considerable amount of noise to incoming signals, thus decreasing the sensitivity of receiving equipment. A major reduction in the amount of noise added in radio reception can significantly improve the performance, for example, of receivers used in radar, radio astronomy, over-the-horizon radio relay and UHF television systems.

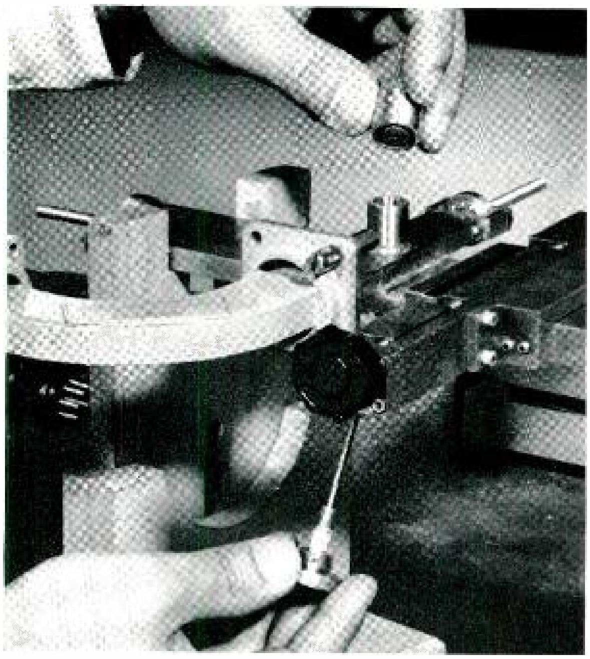
M. Uenohara, left, and G. F. Herrmann prepare to insert new semiconductor diode into equipment for studying diode's amplifying properties.

In radar systems, better reception of very weak radio signals makes it possible to extend the range of detection. Once the transmitting power of a radar system has been pushed to its ultimate limit, the only way to increase the range is to improve the noise performance, or sensitivity, of the receiver. By using diffused-silicon diodes, scientists at Bell Laboratories have obtained, in the UHF range, noise figures which are considerably lower than any that can be obtained with the best available vacuum tubes or transistors.

The "Varactor" Diode

The new amplifier is one of a family of devices known as "parametric" amplifiers, in which a variable reactance, or "varactor," serves as the active component. In the present device, the variable reactance is provided by a semiconductor diode (varactor diode) whose capacitance varies with the applied voltage.

As with other varactor amplifiers, the applied voltage is derived from a high-frequency oscillator, or "pump". This pumping at microwave frequency is somewhat analogous to the pumping action a child uses to increase the amplitude of a swing. It causes the diode to function as a



Close-up of typical single-diode amplifier structure. Right hand holds special diode and enclosure; left hand holds cap that fits on top of holder.

time-varying capacitance, and it supplies the energy necessary to amplify, or increase the amplitude of, the input signal.

Microwave amplification was first demonstrated at the Allentown location of Bell Laboratories by M. E. Hines and H. E. Elder. The low-noise possibilities of such an amplifier using varactor diodes was first predicted by A. Uhlir, Jr. of the Solid State Device Development Department.

At 6,000 megacycles G. F. Herrmann and M. Uenohara of the Electron Device Development Department obtained a bandwidth of 8 megacycles with a noise figure of 5 to 6 db. The gain was 18 db and the pump frequency was 12,000 megacycles. If desired, gain can be traded for additional bandwidth or bandwidth can be traded for additional gain.

Greater Bandwidth

A traveling-wave amplifier configuration, using arrays of several diodes, shows promise of providing bandwidths of 25 per cent or more of the midband frequency in the UHF region. By using four stages with the special diodes in such an array, R. S. Engelbrecht of the Missile Systems Development Department has obtained a bandwidth of 100 megacycles at a 400-megacycle signal frequency, with a pump frequency of 900 megacycles and a pump power of 10 milliwatts. This experimental amplifier, shown on the cover of this issue, has a gain of 10 db and at present has a noise figure of 3½ db.

A single diode can be used to make an amplifier for any desired frequency from the high-microwave region all the way down to dc. The noise performance of such an amplifier improves as the frequency decreases from the microwave region down into the UHF region, thus making it potentially useful for UHF television receivers, as mentioned.

In a typical amplifier of this type, the semiconductor diode is inserted at the junction of two waveguides (*see close-up photograph*). In this arrangement, a pump frequency of 12,000 megacycles enters the junction in the waveguide at the left, and the signal—in this case, 6,000 megacycles—comes in from the right. The signal is then amplified and reflected back inside the same waveguide. The incoming and outgoing signals may be separated by a microwave "circulator" arrangement (RECORD, *August*, 1957) made of a ferrite material.

The heart of this amplifying arrangement is a diffused-base silicon diode with an active area about 0.002 inch in diameter. The diode amplifier is very simple and potentially very reliable. In the photograph, the special diode is inside in the white area of the rod-like structure.

Ordinary Operating Temperatures

The other major components of the amplifier are the waveguide structures and a suitable source of pump signal. Experiments to date indicate that these components can be readily assembled to provide a relatively inexpensive device. No magnetic fields are necessary, and the low-noise characteristics of the amplifier are realizable at ordinary temperatures. No refrigeration is required.

Although the variable capacitance effect is present in currently available diodes, the effect has never been maximized. For this purpose, Bell Laboratories scientists developed, under a Signal Corps contract, special silicon diodes made by a diffusion technique invented at the Laboratories and used extensively in the manufacture of transistors (RECORD, *December*, 1956). Series resistance, which could be a source of noise, is minimized in these diodes.

The development of the varactor-diode amplifier holds promise of providing a whole new family of low-noise amplifiers for the UHF and microwave-frequency ranges. These devices will complement the semiconductor diode "up-converters" (RECORD, *October*, 1957) recently announced by Bell Laboratories, which can also provide low-noise amplification.

"Nation's Economic Strength Depends on Business Strength" Kappel Tells Industrial Leaders

"To promote the general economic welfare, the prime necessity for any business is to keep its essential health and strength," A.T.&T. President F. R. Kappel told the Economic Mobilization Conference of the American Management Association in New York on May 20.

"Weak sisters cannot contribute to a strong economy," he added.

Mr. Kappel was one of the several presidents of leading corporations invited to participate in the conference, designed to show how American management is mobilizing its resources to meet the challenge of the current economic situation. Warning against letting productivity fall, Mr. Kappel said that "using more man-hours to do a given amount of work will cause lasting harm. If productivity goes down, standards of living will go down with it. The habit of hiking wages above and beyond gains in productivity is just a way of living beyond our means . . . this is the road to trouble for everyone."

Mr. Kappel said that the efforts of business to serve the country's well-being "are hampered by those who take out after businessmen for trying to do the very thing that holds the best hope for the future, namely, to keep their companies strong and healthy so that they can take new risks, increase productivity, sell more goods and employ more people." It is impossible, he said, to push profit down with one hand and pull business up with the other.

Mr. Kappel said that the Bell System began to feel the downturn in business in mid-1957, and immediately started to adjust plans for the future. Some $300 million has been cut from the 1958 construction program as it was being planned a year ago, representing a reduction of about 12 per cent, he said. However, this was much less than the decline in growth—40 per cent in telephones and 30 per cent in long distance conversations.

In the 1958 program, which totals $2.2 billion, "we have chosen to go ahead with our modernization program virtually without change," Mr. Kappel said. "We are also adding capacity faster today—in relation to the growth we foresee in the months ahead—than we have done for quite a while. We are sure the capacity will all be used, but some of it will not be used immediately. In short, we have left in our program of expenditure for growth every dollar good judgment can justify."

Mr. Kappel said that System employment is "less than five per cent" below last year, and that the Bell System still has "thousands more people at work today than at the end of the boom year of 1955."

This is in contrast with the nearly 10 per cent decline in the poor year of 1949, he declared. "At that time our earnings were at a low ebb. Today we are in better shape financially to do the things that ought to be done and that keep people working. This is a clear illustration that financial strength and good health benefit everyone."

The things that make for growth—research, development, marketing and door-to-door selling—have been increased and intensified, A.T.&T.'s president declared. The Bell System is spending $90 million—more than ever before—on research and development this year. It is trying hard to shorten the time between development and introduction of new and attractive services. The System has more than 6,000 full-time salesmen aggressively selling the business market—and the number is growing. Operating Companies are increasing the number of home extensions sold in proportion to the number of main telephones installed. We expect sales forces promoting long distance usage to produce some 75 million dollars in additional annual revenue, compared with 60 million dollars last year.

Mr. Kappel pointed out that Western Electric, the manufacturing and supply unit of the Bell System, will buy a billion dollars' worth of goods and services this year from thousands of firms all over the country.

"We are determined to maintain our financial good health," Mr. Kappel concluded, "because only by so doing can we serve the country well today and in the future. I have great confidence in the future, but it rests on the conviction that we must, can and will get a proper understanding that adequate profit is the foundation of progress in our free enterprise system."

As part of a broad attack on the problem of how electrons move through solids, Laboratories research has resulted in the discovery of a new phenomenon—severe attenuation of ultrasonic waves in metals at very low temperatures near absolute zero.

H. E. Bömmel and W. P. Mason

Ultrasonic Attenuation in Superconductors

At temperatures near absolute zero, materials have many interesting characteristics. Perhaps the best known of these are certain mechanical properties; many people have seen a rubber ball immersed in a container of liquid air, after which the ball will shatter like glass.

In the field of communications research, particular attention has been paid to the phenomenon of superconductivity. Near absolute zero, the electrical resistance of some metals seems suddenly to disappear. It has frequently been demonstrated, for example, that the resistance of a metal in the superconducting state can be so low that an induced current will persist unchanged almost indefinitely—a current continued for about two years in one experiment.

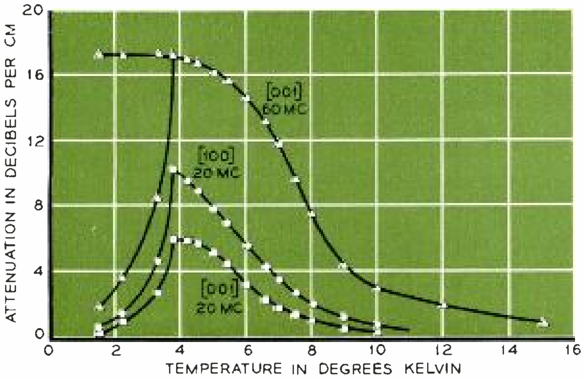
A further important fact concerning the superconducting state is that normal resistivity can be restored by applying a magnetic field. Advantage is taken of this characteristic in such memory devices as the "cryotron," wherein a metal element can be "switched" between the normal and superconducting states as a way of storing information for computers and other purposes.

Recently, an entirely new phenomenon has been discovered in superconductors. Experiments performed at Bell Laboratories (*J. of the Acoustical Society of America*, Vol. 28, *September,* 1956, pp. 930-943) have shown that for metals in the normal-resistivity state, ultrasonic waves transmitted through them at sufficiently high frequencies will suffer considerable attenuation. In the superconducting state, however, ultrasonic attenuation drops to zero as the temperature approaches 0°K.

In passing through a transmission medium, acoustic waves always suffer a certain amount of loss. Sound waves weaken in the atmosphere, and they are also attenuated, but often to a lesser extent, when transmitted through liquids or solids. Aluminum, for example, is a very good medium of support for acoustic energy, whereas lead absorbs sound to a greater degree. The amount of attenuation depends primarily on the relative ease of motion of defects in the crystal structure of the metal. That is, metals having defects that are rigidly "fixed" in the structure will have less tendency to absorb acoustic energy.

The attenuations discussed here, however, are very much greater than those seen in the more familiar sound-transmission situations. In some of the experiments, for example, attenuations in very pure metals in the normal state were over 1000 times greater than attenuations for the same ultrasonic energy traveling through the same metal at room temperature.

Visualization of this attenuation process requires consideration of the crystal lattice structure of the metal and of the free electrons available for the conduction of electricity. As in the first of the drawings *(next page)*, a crystal lattice structure is ordinarily represented by atoms drawn in a repetitive geometric pattern. Now, at room temperature, or in fact at any appreciable temperature, thermal energy will keep this lattice structure in constant vibration; but near absolute zero thermal energy is very low and vibration from this cause is nearly absent. The drawing indicates, however, that vibration can be induced with ultrasonic waves. In the actual experiments,



Extremely pure tin shows high attenuations. (Data are for 20 and 60 mc for two crystal axes.)

or 60-mc curve shows corresponding values for the normal state. At the critical temperature, attenuation is very severe — 275 times as large as the attenuations measured with less pure tin.

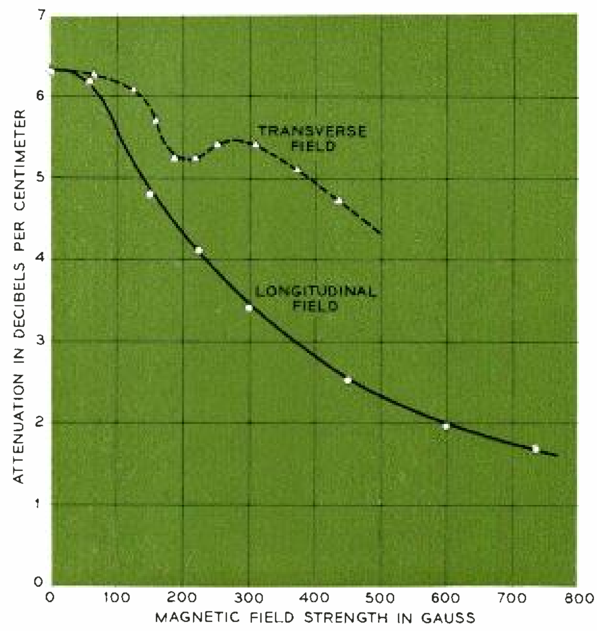
With these ultra-pure samples of tin, the presence of magnetic fields resulted in some additional interesting effects. The graph at the lower right shows attenuation-vs-field strength for a longitudinal field (same direction as ultrasonic wave) and a transverse field (perpendicular to direction of wave). These measurements were made at 4.2°K, at which temperature all electrons were in the normal-conducting state. The mean free path of the electrons was again larger than the acoustic wavelength.

In the presence of the longitudinal field, attenuation decreases smoothly with increasing field strength. This means that in flowing through the crystal, the electrons tend to spiral around the direction of the field, and as the field increases, this spiraling effect is intensified. Electrons must therefore travel a greater distance over a spiral path to traverse a given linear distance. Hence, an electron has more difficulty in escaping from that portion of the lattice from which it derived its additional energy, and the attenuation decreases.

More interesting still is the effect of the transverse magnetic field indicated in this same illustration. As contrasted with the longitudinal field, where the spiraling is around the direction of propagation of the ultrasonic wave, the electrons here tend to spiral perpendicular to the direction of the propagation. At certain values of the field, the diameter of the spiral will be one-half the acoustic wavelength. Under this condition, the electrons will receive, on both sides of the orbit, momentum in the same direction as the original momentum. When this happens, attenuation increases, which may explain the peak in the curve at about 300 Gauss. On an atomic scale, this is the principle of the cyclotron accelerator, and for this reason such responses can be called cyclotron resonances. The higher the frequency, the greater the strength of the magnetic field required to produce cyclotron resonance.

These experiments were part of a more general study of ultrasonic attenuation in metals. Velocity of propagation of the ultrasonic wave, for example, has been investigated under various conditions, and other studies were made to determine how attenuation changes with frequency. All of these experiments were aimed at achieving a deeper understanding of the physical and electrical behavior of solids at the atomic level.

This work has contributed to our knowledge of elastic constants of crystals. It has also enabled us to specify more exactly the location and effects of impurities and imperfections in nearly pure, nearly perfect crystals. The attenuation as a function of crystal orientation in the normal state has told us something about the shape of the "Fermi surface" of metals. It is the change of shape of this surface with stress that determines the direction and amount of flow of electrons through a solid in ultrasonic vibration. In addition, the rapidity with which the attenuation drops off as the temperature is lowered below the transition temperature tells a good deal about the properties of the superconducting state. In particular, the form of the attenuation curve has been used under certain conditions to derive some of the parameters of the energy gap in the new theory of superconductivity of J. Bardeen, L. Cooper, and J. R. Schrieffer of the University of Illinois.



Ultrasonic attenuation decreases with strength of longitudinal magnetic field; curve for transverse field has peak from "cyclotron" resonance.

Gears, shafts and cams work in harmony with electrons, semiconductors and magnets in Bell System switching apparatus. One example of the intricate mechanical devices used in many modern switching systems is the trouble recorder, which automatically produces a card record of the progress of a call whenever trouble happens to occur in the telephone switching process.

M. Salzer

THE TROUBLE RECORDER

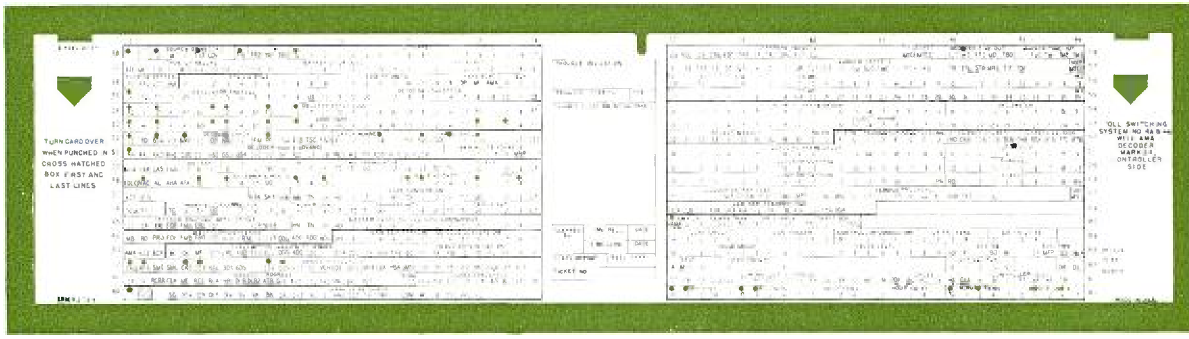
Modern dial telephone systems involve many automatic circuits in addition to the actual switches. Some of these circuits are in use for the duration of a telephone call, while some of the common-control circuits may be used for only a fraction of a second. Like the human body, an automatic switching system is subject to occasional failures, both major and minor. Also like the body, a switching system sounds an alarm in the event of trouble. Pain is the warning of the body; lamps and gongs are the warnings of today's modern systems for telephone switching.

In the No. 1 crossbar system, common-control principles developed earlier (RECORD, *November*, 1926; *May*, 1928; *December*, 1928) were used as the basic control element of the system. These common-control circuits made the new system more efficient, but at the same time made it more complex. Consequently, a trouble indicator was developed to indicate the progress through the system of a call in trouble. When trouble occurs, switchboard-type lamps set in banks light to identify the equipment units involved in the call failure. These lamps remain lighted until a maintenance man releases the display after he has manually recorded the trouble information. To pinpoint a trouble, however, two or more displays are usually needed. Also, manually recording the information and releasing the displays takes time and keeps maintenance personnel from other work.

Many changes and improvements were included in the design of the No. 5 crossbar system. Among these is the automatic recording of the progress of a call when trouble occurs by punching a permanent record in a paper card. The trouble recorder is fast and automatic, and a record can be made even when the office is unattended (RECORD, *May*, 1950). The trouble-recorder card, shown at the top of the next page, presents information, punched in several of a possible 1,080 positions, in a form that maintenance people can readily analyze (RECORD, *June*, 1955). Writing space is also available on the cards so that the maintenance man can note the disposition of the trouble. The card can then be filed for future reference.

Fast Operation

The trouble recorder is a self-contained unit, slightly over two feet high, that mounts in a frame in the maintenance center as shown in the photograph overleaf. Plug-in connections permit the entire recorder to be easily replaced if necessary. Blank trouble-recorder cards are stored in an "in-bin" at the rear in quantities up to 400, and associated visual and audible signals give a warning when the stack gets low. The top card is always in position for the initial punching operation. When a trouble occurs, this card is punched, moved successively to eight other accurately located positions, where it may or may not be punched, and then dropped into the "out-bin". The entire punching procedure, regardless of the number of punches, takes about 1.5 seconds.



A punched trouble-recorder card. Colored dots shown on the card are perforations; actual length of card is approximately 18 inches. This coded information greatly speeds maintenance work.

The trouble recorder is an intricate mechanical device with many interrelated parts. For purposes of explanation, it can be divided into three functional groups: arrangements for punching, positioning and control.

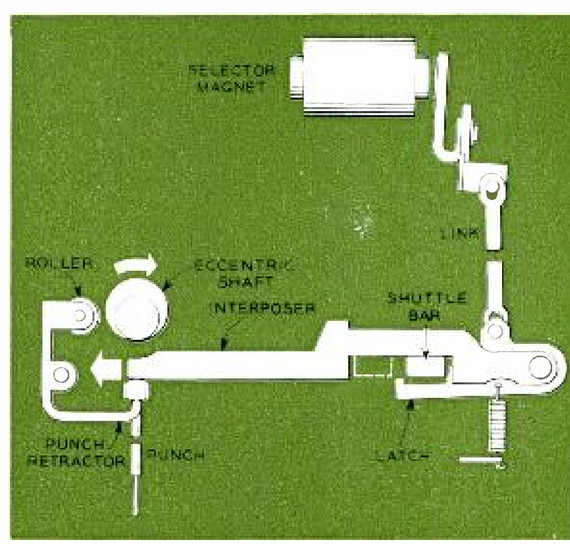
The first steps in the punching operation actually start at the finish of a recording cycle — that is, the top card of the stack in the in-bin is picked up by hooks on an endless chain drive and moved to the "home" (initial punching) position, ready to be punched. In this position, two rows of sixty punches each (plus two extra punches in each row for future expansion) are located immediately above the first and tenth lines on the card. These sixty punches correspond to the sixty columns across the card. When a trouble actuates the recorder, eccentric shafts begin to rotate above the punches. This arrangement and other details of the punching portion of the recorder are shown in the sketch at the lower right.

Relay scanners have already checked the common-control circuits to determine what "punch-or-no-punch" information is associated with various circuit functions and have operated the selector magnets of the recorder accordingly. An operated selector pulls up a latch associated with a corresponding punch, permitting an interposer to be inserted between the punch and the eccentric shaft. As the eccentric shaft rotates, it forces the selected punches downward through the card. If the trouble indicates that a particular punch should not be operated, the associated interposer is not inserted and the shaft rotates above the punch without moving it.

Latch Mechanism

The eccentric shafts drive two cams, and these in turn cause two shuttle bars to oscillate back and forth above the two rows of latches. If the latch has been raised by an operated selector magnet, the shuttle bar pulls the latch and interposer into position so that a perforation will be made. The punches are returned to their normal positions by punch retractors driven by the same two eccentric shafts.

With each oscillation of the shuttle bar, the positioning portion of the recorder mechanism is moving the card along so that all 18 lines come under the punches, two at a time. A positive-drive clutch driven by an eight-step Geneva movement provides intermittent motion of the cam switch and the card-feed drive shaft through gear and chain drives. The Geneva movement, shown at the bottom of page 260, consists of a slotted wheel driven by an off-set pin on the end of the driving shaft. As the driving shaft rotates, the pin enters one of the slots and drives the slotted wheel through one-eighth of a revolution



Important details of punching arrangement used in the trouble recorder. Drawing shows the relative sizes, shape and location of the various parts.

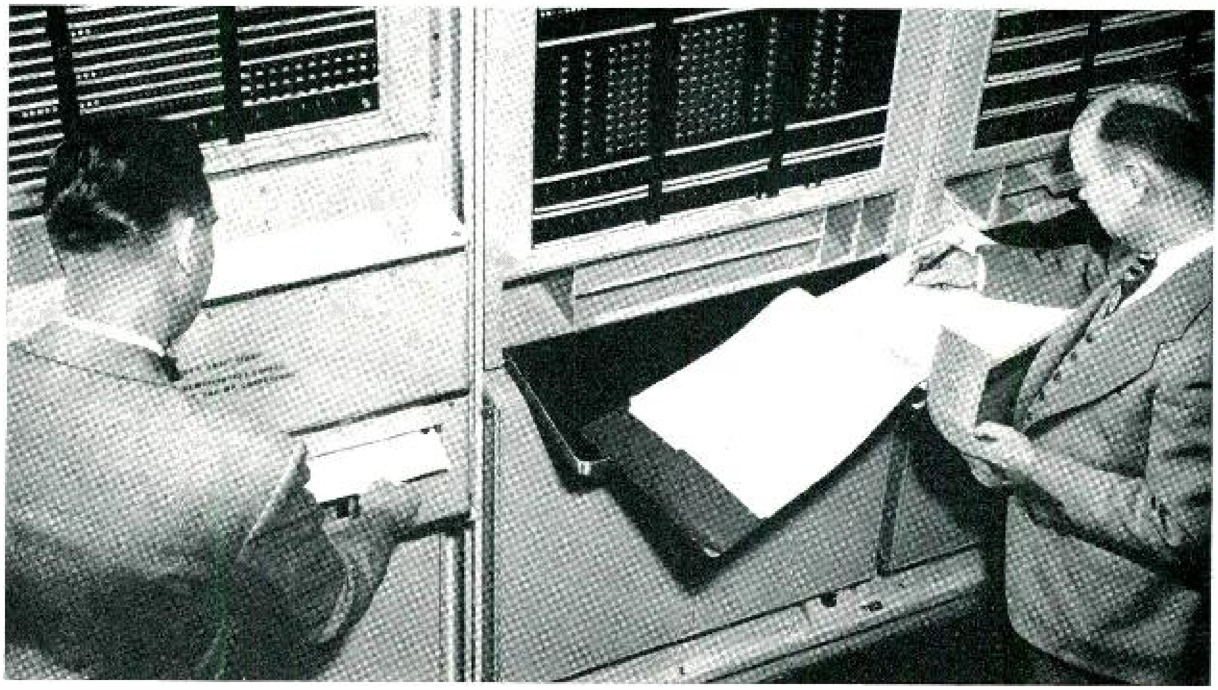
before emerging from the slot. The slotted wheel and driving shaft are so shaped that during the time the pin is out of the slot, it is impossible for the slotted wheel to move. The punching operation occurs during this interval. This arrangement provides eight definite steps in the driving power applied to the card feed.

As soon as any trouble indications coded on the first and tenth lines of the card are punched, the card is stepped along to the second position (second and eleventh lines) and punched again where required. This sequence continues until all of the lines have been positioned under the punch, and then solenoids disengage the Geneva movement and engage the continuous-drive cone clutch seen in the sketch of the clutch mechanism. The card is then carried along by the chain-drive until it falls into the out-bin. At the same time, the chain drive picks up the top blank card from the stack and moves it into the home position to complete the entire punching and positioning cycle.

The chain drive consists of two bicycle-type chains equipped with card-hook shoes and card-failure (alarm) contact springs. Four shoes and four springs appear alternately on each chain. The card stack is held up against the chain by a spring-loaded follower in the in-bin so that the hooks can push the top card forward into the home position at the end of a cycle. Each hook is sled-shaped, with two raised parallel edges spaced to grip a card securely; they fit into the notch and hole located at each end of the card. Both the notch and hole can be seen in the accompanying illustration of the card *(page 258)*.

If a card is not in the home position at the start of a recording cycle, one or both of the contact springs makes a short circuit across two rails that are normally insulated by the card when it is in the proper position for perforating. This short circuit actuates an alarm and stops the machine. Throats at each end of the in-bin guide the card into the home position and permit only one card to pass at a time. If the machine should jam or stop for any reason, a detachable hand-wheel can be used to run it through a cycle by hand.

Complete control of the machine lies in a cam-switch unit and a stopping-latch arrangement. In the cam switch, three sets of cams perform three types of control. One set of five cams is driven continuously by the main shaft. Operations involving the timing of the start relay, latch and Geneva movement are controlled by these cams. A second group of four cams, driven by the Geneva movement, controls such functions as operating the cone clutch and turning off the machine after a cycle is completed. A third set of eight cams



Trouble recorder, left, installed in 4A toll crossbar office in Newark, New Jersey. K. Southard, at the left, removes a punched card from the out-bin, and J. Lawless records the trouble information in a ledger kept at the maintenance center of the office. Both men are with New Jersey Bell.

controls the scanning relays so that the proper information for each line will be supplied to the selector magnets.

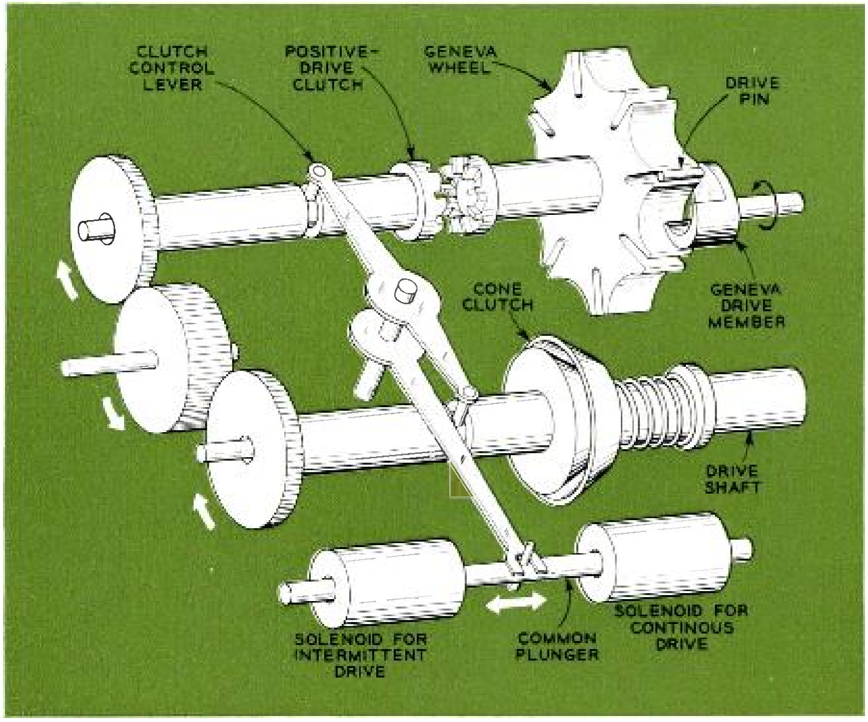
At the start of a cycle, the information appropriate to the first and tenth lines is supplied to the magnets through contacts on scanning relays. During the first punching operation, the magnets are released. After the Geneva movement has operated through one step, one of the cams tells the scanning relays to supply information appropriate to lines two and eleven. This step-by-step type of automatic control continues until all of the recorder-card lines are scanned.

To keep the over-all cycle time as short as possible, the machine runs at a higher speed when the cone clutch is engaged near the end of a cycle. To control the stopping impact of the mechanism, the latch unit provides fast, accurate braking. The cone clutch is released when the machine nears the home position of a cycle, and the latch applies braking through a cam and a heavily spring-loaded brake roller. The latch is driven through a heavy coil spring — the overtravel spring — attached to the drive gear and to the shaft. As the shaft slows down, the backward-stop pawl drops into position and then the forward stop roller strikes a projection on a second cam, bringing the shaft to a complete stop.

The drive gear continues to turn for a very short time until arrested by the overtravel stop pin; this winds up the overtravel spring. With the latch shaft stopped, the spring tension rotates the latch gear and drive shaft backward a slight amount until the back of the overthrow notch stops it. This is the home position. To start a new cycle, the latch magnet raises the forward stop roller above the cam projection so that the mechanism can operate.

Power for all of the mechanical operations of the machine is supplied by a 1/6 horsepower electric motor, hinge-mounted on the frame. Proper tension on the drive belt is supplied by an adjustable idler pulley and the weight of the motor. The drive pulley has one adjustable flange so that the V-belt can be made to ride at different distances from the shaft to adjust the speed. An overload clutch disengages the motor if the load becomes too heavy for any reason.

In addition to its original design function — use in the No. 5 crossbar system — the trouble recorder is now being used in the 4A toll crossbar system, crossbar tandem and in most of the step-by-step automatic-ticketing systems presently being converted for automatic message accounting operation (RECORD, *July*, 1957). Well over 900 of these trouble recorders are currently in use throughout the Telephone Operating Companies of the Bell System.



The Geneva movement incorporated into the mechanism furnishes eight steps in positioning the trouble-recorder card under punches. The cone clutch then moves card along to the out-bin.

Modern low-temperature research requires a new and unusual "set of tools." For such work, scientists at Bell Laboratories have developed a highly sensitive and extremely stable thermometer based on the coefficient of resistance of a doped-germanium bridge.

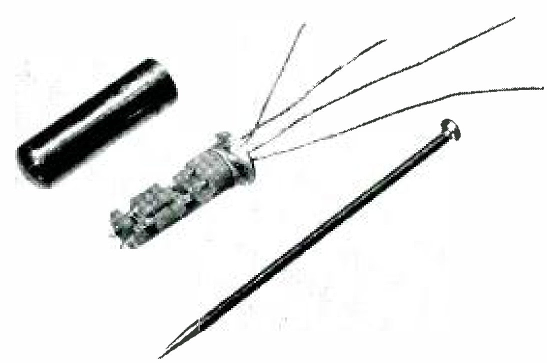
GERMANIUM RESISTANCE THERMOMETER

A germanium resistance thermometer that has high sensitivity and exceptional stability in the temperature range near absolute zero has been developed by J. E. Kunzler, T. H. Geballe and G. W. Hull of Bell Laboratories. Once calibrated, this thermometer is reproducible to better than a few ten thousandths of a degree at the boiling point of helium (4.2 degrees K) even after repeated cycling from room temperature.

Continued emphasis on low-temperature research at Bell Laboratories and elsewhere has highlighted the need for a thermometer which indicates low temperatures accurately and reliably, and does not need continued recalibration. Such a device would be very valuable in low-temperature calorimetric work. The sensitivity, stability and reproducibility of the thermometer indicate that it might be useful for the accurate measurement of temperatures in outer space.

The heart of the germanium resistance thermometer is a very small "bridge" cut from a single crystal of arsenic-"doped" germanium. Actual size of the bridge is about 0.025 by 0.020 by 0.210 inches. Current and potential leads are attached to the bridge, which is supported in a strain-free manner in a platinum-glass enclosure filled with a small amount of helium to aid in thermal conduction. Temperature is determined by measuring the potential drop due to resistance when a small known current (approximately 10 microamperes) is passed through the doped-germanium bridge.

Germanium can be doped with arsenic to produce a high and fairly constant temperature coefficient of resistance at temperatures near the boiling point of helium. For example, a typical thermometer made at Bell Laboratories had a resistance of about one ohm at room temperature, 14 ohms at 10 degrees K and 216 ohms at 2 degrees K. Both the temperature coefficient and the actual resistance vary widely with minute changes in the amount of doping, making it possible to fabricate a thermometer having any of a wide range of characteristics. A typical thermometer of this type will retain its calibration despite repeated cycling over temperatures ranging from 300 degrees K to 1 degree K.



A germanium resistance thermometer developed at Bell Laboratories compared in size with a common straight pin. Germanium bridge, where changes in temperature are actually measured, can be seen mounted in notch with leads attached to both ends. Cover is shown at the left.

Basic research in one field often produces unexpected by-products in another. As part of a study of the permeability of glass, Bell Laboratories chemical research has found a new way to recover helium.

Helium Separation and Purification By Diffusion

K. B. McAfee holding a bundle of capillary tubes of the type used for helium diffusion. These tubes have an outside diameter of 0.015 inch and a wall thickness of about 0.003 inch.

A diffusion technique for separating and purifying helium has been developed by K. B. McAfee of the Chemical Research Department. This technique, a by-product of basic research at Bell Laboratories on the mechanism of diffusion, promises to facilitate greatly the large-scale separation of helium from gaseous mixtures such as natural gas. Helium with no detectable impurities may also be obtained by using the new technique as a purification process.

Any process for readily recovering helium should be of great commercial value, because the demand for helium in the United States has risen much faster than our ability to produce it. The only present sources of supply are a few natural-gas wells, where helium exists at concentrations ranging from less than 1 per cent to 6 or 7 per cent. Helium is recovered from these helium-natural gas mixtures by an expensive and elaborate low-temperature distillation process.

Mechanism of Diffusion

By contrast, in the newly developed diffusion process, helium is separated from a gaseous mixture by passing the mixture over the surface of a glass barrier, which has a high permeability to helium and a low permeability to other gases at room temperature.

The permeability or diffusion properties of glass under tension, compression and shear have been studied at Bell Laboratories for some time. These studies are part of a program of fundamental research on the mechanism of diffusion. Some of this work has also been directly related to various submarine-cable projects, where it is important to understand the possible diffusion of moisture or dissolved gases into cable repeaters submerged in many fathoms of water.

As developed at the Laboratories, the new process separates helium from other gases by diffusing it through the thin walls of very fine glass tubing. Essentially, the glass walls of the tubes act like sieves to the helium atoms, but resist the passage of other gases. Hydrogen, for example, the next most diffusible element, passes at a rate 1,000 times slower than helium. Except for neon, the other components present in natural gas will not pass through the glass at all.

To obtain appreciable quantities of helium, a large surface of glass must be exposed to the gas mixture, the walls of the glass tubing must be very thin, and a high pressure-differential must be maintained between the two sides of the glass. An excellent configuration for providing such conditions consists of a bundle of fine, glass capillary tubes, like those shown at the left, arranged so that the gas mixture flows around the outside of the tubing under high pressure. The helium is then recovered from the inside of the capillaries, which are bound together into a common "header" or takeoff pipe. Appropriate seals have been developed for this arrangement.

For the capillaries, silica or pyrex tubing can be drawn with an external diameter as low as two mils (0.002 inch) and with a wall thickness of two-tenths of a mil (0.0002 inch). Such tubing can withstand a compressive stress in excess of one thousand atmospheres, and is ideally suited for the separation or purification of helium. Diffusion through the glass increases rapidly with temperature, and the tubing will withstand temperatures of 400°C and higher over long periods of time without deteriorating.

Tests on an experimental thin-wall, capillary diffusion cell like the one in the accompanying photograph indicate that a similar cell containing enough capillaries to occupy about two cubic yards would pass nearly 1,000 cubic feet per day of helium at room temperature with a pressure differential of 1,000 atmospheres, assuming a concentration of 1 per cent helium in the gas mixture can be maintained. Increasing the temperature to 400°C would permit the recovery of 100,000 cubic feet of helium per day. A cell of this type will not deteriorate with time, and might be placed directly in a gas pipeline.

Exceptionally pure helium results from a single diffusion step, even though the initial mixture contains only 10 per cent helium and 90 per cent hydrogen. A careful analysis indicates that there is less than 0.0009 per cent hydrogen in the helium purified by diffusion.

Results already obtained indicate that this process can be adapted to large-scale commercial purification of helium, and to certain high-volume commercial separations of the gas.

K. B. McAfee and H. Kraft examining experimental cell built to study separation of helium from gaseous mixtures. Gas mixture circulates through tubes protruding from side of cell and helium is taken off from header tube at right end. Cell contains about 1½ miles of glass tubing.

J. B. Fisk Heads U. S. Scientist Group for Nuclear-Test Talks

J. B. FISK

J. B. Fisk, Executive Vice President of Bell Laboratories, has been appointed by President Eisenhower as chairman of a group of U. S. scientists for proposed technical talks with experts chosen by the Soviet Union, as outlined in the President's letter of May 24 to Premier Nikita S. Khrushchev.

The President's letter indicated there might also be experts from the United Kingdom and France and other countries advanced in the knowledge of how to detect nuclear tests, according to the announcement from the State Department. In his letter the President said, "Experts from our side will be prepared to meet with experts from your side at Geneva, if the Swiss Government agrees, within three weeks of our learning if these arrangements are acceptable to you."

The Department of State announced that in addition to Dr. Fisk, Dr. Ernest O. Lawrence, Director of the Radiation Laboratory at the University of California, and Dr. Robert F. Bacher, Chairman of the Division of Physics, Mathematics and Astronomy at the California Institute of Technology, have been selected and have agreed to serve as technical experts for the United States at the proposed talks.

Dr. Fisk, whom the State Department announcement termed "one of the United States' most distinguished scientists," joined the Laboratories in 1939. His career has also included two years as Director of Research of the Atomic Energy Commission and, simultaneously, 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.

In 1949 when he returned to the Laboratories from the Atomic Energy Commission and Harvard, Dr. Fisk was placed in charge of research in the physical sciences. He became Vice President in charge of research in March 1954 and Executive Vice President in June 1955. As Executive Vice President he is in charge of all technical activities of the Laboratories.

During World War II when the potentialities of the microwave magnetron for high-frequency radar were discovered, Dr. Fisk was selected to head the development group at Bell Laboratories. After the war, he was placed in charge of electronics and solid-state research.

Dr. Fisk received his bachelor's and doctoral degrees from Massachusetts Institute of Technology in 1931 and 1935, respectively. He is a member of the National Academy of Sciences, and is a Fellow of the American Physical Society, the American Academy of Arts and Sciences and the Institute of Radio Engineers, and he was formerly a Senior Fellow of the Society of Fellows at Harvard. He is also a member of other scientific and professional societies.

Laboratories Authors Receive Commemorative Volumes from British I.E.E.

The British Institution of Electrical Engineers recently honored several Laboratories engineers for the part they played in the historic joint conference, linked together by telephone transmission over the transatlantic cable last year (RECORD, *February*, 1957). President T. E. Goldup of the I.E.E. presented each of the engineers with commemorative volumes of the papers presented at the Transatlantic Cable Symposium. The presentation luncheon was held at the New York City location of Bell Laboratories on May 2.

Several of the engineers honored are members of the Laboratories. Two are Western Electric men, one is from Long Lines, and one from the Canadian Overseas Telecommunications Corp. Laboratories engineers included M. C. Biskeborn, F. J. Braga, J. W. Emling, H. B. Fischer, J. M. Fraser, T. F. Gleichmann, A. W. Lebert, H. A. Lewis, G. H. Lovell, J. O. McNally, G. W. Meszaros, E. T. Mottram, H. H. Spencer, R. S. Tucker, E. A. Veazie, and M. C. Wooley. Another of the authors, A. H. Lince, was presented with a commemorative volume during a recent trip which he made to London.

Other Bell System authors were W. W. Heffner and H. A. Lamb of Western Electric and J. S. Jack of the A. T. & T. Co.'s Long Lines Department. R. G. Griffith, another author, is with the Canadian Company.

President Goldup also presented copies of the volume to Dr. Kelly, who was also an author, W. J. Barrett, President of the A.I.E.E. and a member of the New Jersey Bell Telephone Co., and L. A. Wright, General Secretary of the Engineering Institute of Canada.

The 1957 symposium was the first joint meeting of engineers in the United States, Canada and England. Participating in the conference were the A.I.E.E., the I.E.E. and the Engineering Institute of Canada. The papers presented at this conference were also published in the January, 1957, BELL SYSTEM TECHNICAL JOURNAL.

Dr. M. J. Kelly, left, receives commemorative volume of the papers presented at the Transatlantic Cable Symposium from T. E. Goldup, President of the Institution of Electrical Engineers of England. Others are, from left, L. A. Wright, general secretary, the Engineering Institute of Canada; W. K. Brasher, Secretary of the I.E.E., and W. J. Barrett, President of the A.I.E.E.

NEWS BRIEFS:

M. J. Kelly Named Advisor to Journalism Program at Columbia University

Dr. M. J. Kelly has been appointed an advisor to the advanced science writing program of the Columbia University Graduate School of Journalism, Dean Edward W. Barrett announced recently. Dr. Kelly is one of the 15 leaders in the fields of science, education and publishing who will counsel those in charge of the program on policy matters.

The program, which will begin in September, is intended to give science writers an opportunity to broaden their scientific knowledge and improve techniques of interpreting new developments.

Lamme Gold Medal Awarded to H. S. Black

H. S. Black, Systems Research Engineer, has been awarded the 1957 Lamme Gold Medal by the American Institute of Electrical Engineers. The Medal was presented to Mr. Black on June 23 during the Summer General Meeting of the A.I.E.E. in Buffalo, New York.

Mr. Black was honored "for his many outstanding contributions to telecommunications and allied electronic arts, especially the negative feedback amplifier and the successful development and application of the negative feedback amplification principle."

The A.I.E.E. also noted that his more than 60 inventions have made major contributions to long distance and overseas telephone communications and to the field of electronics in general.

At the presentation ceremonies, H. I. Romnes, Vice President for Operations and Engineering of the A. T. & T. Co., spoke on the "Establishment of the Medal," and Dr. M. J. Kelly spoke on the "Career of the Medalist." Mr. Black's acceptance remarks were on "Invention in Engineering." The medal and certificate were presented by W. J. Barrett, President of the A.I.E.E. and a member of the New Jersey Bell Telephone Company.

The Medal was established in 1924 to honor a member of A.I.E.E. "who has shown meritorious achievement in the development of electrical apparatus or machinery," and is named for Benjamin G. Lamme, an electrical inventor and engineer of world-wide reputation and Chief Engineer of Westinghouse Electric Co. from 1903 until his death in 1924. Mr. Black is the first member of the Laboratories to receive the award. The late Frank A. Cowan of the Long Lines Department of A. T. & T. was Lamme Medalist for 1953.

Other distinguished scientists and engineers honored with the Medal include Edward Weston, Vannevar Bush, Comfort A. Adams and V. K. Zworykin.

Laboratories-Designed Exhibits Go on Display at Brussels Exposition

Three Laboratories-designed exhibits went on display at the Brussels Universal and International Exposition on April 17. The exhibits all concern semiconductors. One features four transistor experiments that demonstrate some of the properties of semiconductor devices. Another display illustrates the theory of holes and electrons in the junction transistor and single crystal growth and zone-melting purification of semiconductors. The third exhibit is a demonstration of the Bell Solar Battery.

These exhibits were developed for the National Science Foundation, the organization responsible for the United States' contribution to the Fair. They appear in the exposition's International Science building as part of the exhibit on solid-state physics.

New Format for Bell Laboratories RECORD

Beginning with last month's special transistor issue, and continuing with this and subsequent issues, the Bell Laboratories RECORD appears in a new format. This new appearance is part of a continuing effort to use the elements of graphic design to publish each article as a more functional combination of text, artwork and photographs.

To this end, expert advice was sought in the matters of typography, illustration and page layout. On the recommendation of Leo Lionni, Art Director of *Fortune* and former President of the American Institute of Graphic Arts, changes of the sort apparent in this issue have been incorporated. Those associated with the RECORD hope that this modernization will help make each issue more interesting and informative for the increasingly busy reader.

C. E. Fisher Elected President of A.S.Q.C. for 1958-1959 Year

C. E. Fisher, Central Office Quality Engineer, has been elected President of the American Society for Quality Control for the 1958-59 year. Mr. Fisher, who was elected at the society's meeting in Boston on May 26, is a Fellow of the A.S.Q.C. and has held other offices in past years.

Intermetallic Crystals Grown by New Zone-Refining Technique

A technique for growing single crystals of bi-metallic semiconductors which ordinarily decompose on melting was described by J. M. Whelan of the Semiconductor Research Department at the 133rd National Meeting of the American Chemical Society in San Francisco. The basic experimental work was performed on gallium arsenide, but the method should be applicable to a variety of compounds which are thermally unstable at their melting points.

According to the paper presented by Mr. Whelan, the floating-zone method appears to be superior to other methods of growing GaAs single crystals. Composition of the liquid phase at the melting point is strongly dependent on the partial pressure of arsenic. This pressure is controlled by using a sealed system containing excess arsenic and regulating the minimum temperature of the arsenic. The rate of growth is easily controlled and spurious nucleation is greatly reduced by the geometry of the freezing interface. These conditions lead to a high degree of reliability in the growth of single crystals.

The new method has other advantages; regularity of impurity distributions and minimum apparatus contamination. The relatively large ratio of surface to volume favors the approach to equilibrium between the liquid and vapor phases. In addition, the small volume of liquid minimizes temperature variations in the melt, and the consequent concentration gradients of the principal components.

The technique should be most useful with binary compounds (compounds containing two elements) in which only one of the component elements has a considerable vapor pressure at its melting point. This compound must have a high enough electrical conductivity to allow heating by radio-frequency induction. The surface tension and density of the molten material must also be able to support a molten zone during the process.

In the basic floating-zone refining technique, a rod is supported vertically. A heat source, for example an induction coil operated at radio frequencies, is moved up or down the rod, melting a zone to the liquid state which traverses the rod. Surface tension supports the liquid zone. With this method, a single crystal can usually be grown and purified in the single floating-zone refining operation.

Contents of the May, 1958, Bell System Technical Journal

The May, 1958 BELL SYSTEM TECHNICAL JOURNAL contains the following articles:

Distribution of the Duration of Fades in Radio Transmission — Gaussian Noise Model, by S. O. Rice.

Frequency Shifts in Axial Cavities Containing Longitudinally Magnetized Small Ferrite Disc Samples, by H. Seidel and H. Boyet.

The Effects of Mode Filters on the Transmission Characteristics of Circular Electric Waves in a Circular Waveguide, by W. D. Warters.

Research Models of Helix Waveguides, by C. F. P. Rose.

Table of First 700 Zeros of Bessel Functions $J_1(x)$ and $J'_1(x)$, by C. L. Beattie.

Evaluation of Surface Concentration of Diffused Layers in Silicon, by G. B. Backenstoss.

Measurement of Sheet Resistivities with the Four Point Probe, by F. M. Smits.

Piezoelectric and Dielectric Characteristics of Single Crystal Barium Titanate Plates Having Predominately c-Domains, by A. H. Meitzler and H. L. Stadler.

Organic Deposits on Palladium Contacts, by H. W. Hermance and T. F. Egan.

Relay Contact Behavior under Non-eroding Circuit Conditions, by H. J. Keefer and R. H. Gumley.

Gray Codes and Paths on the n-Cube, by E. N. Gilbert.

Biennial Award Presented to B. P. Bogert By Acoustical Society

B. P. Bogert of the Transmission Research Department has received the Biennial Award of the Acoustical Society of America for his "substantial contributions" to the science of acoustics. The Biennial Award is presented every other year to "a Member or Fellow of the Society who is under 35 years of age and who, during a period of two or more years immediately preceding the award, has been active in the affairs of the Society and has contributed substantially through published papers, to the advancement of theoretical and/or applied acoustics", according to the Society.

The award was presented at the 55th Annual Meeting of the society in Washington.

Mr. Bogert's principal contributions, the Acoustical Society noted, have been in the fields of physical acoustics and speech transmission. His early research was on the cochlea, the part of the inner ear which converts sound into nerve impulses. Another contribution has been the discovery of a new "approach to the analysis of viscous losses of sound waves in tubes and cavities." He has also worked on speech problems, transmission of sound and the VOBANC (VOice BANk Compressor), a speech-bandwidth compression system. Presently, Mr. Bogert is engaged in long-range studies of new telephone instruments suitable for high-speed switching systems.

He is a Fellow of the Acoustical Society of America and a member of the American Physical Society and Sigma Xi.

TALKS

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

AMERICAN CERAMIC SOCIETY, Pittsburgh, Pa.

Dillon, D. M., see Egerton, L.
Egerton, L., and Dillon, D. M., *Piezoelectric and Dielectric Properties of Ceramics in the Potassium-Sodium Niobate System.*
Rigterink, M. D., *Ceramic Insulating Materials.*

133RD NATIONAL MEETING, AMERICAN CHEMICAL SOCIETY, San Francisco, Calif.

Douglass, D. C., see McCall, D. W.
Garn, P. D., and Sharpe, L. H., *Characteristics and Regeneration of Cupric Chloride Etching Solutions.*
Garn, P. D., and Gilroy, H. M., *The Determination of Maleic Anhydride in Polyesters.*
Gilroy, H. M., see Garn, P. D.
Hawkins, W. L., see Winslow, F. H.
Laudise, R. A., *Kinetics of Hydrothermal Quartz Crystallization.*
Loeffler, B. B., see Winslow, F. H.
Matreyek, W., see Winslow, F. H.
McCall, D. W., and Douglass, D. C., *Self-Diffusion in Paraffin Hydrocarbons.*
Schlabach, T. D., *The Temperature Dependence of Electrical Resistivity of Laminated Thermoset Materials.*
Sharpe, L. H., see Garn, P. D.
Wasserman, E., *Optical Activity of Bimesityl Derivatives.*
Whelan, J. M., *Application of the Floating Zinc Technique for Growing GaAs Single Crystals.*
Winslow, F. H., Hawkins, W. L., Loeffler, B. B., and Matreyek, W., *Thermal Oxidation of Polyethylene Containing Carbon Black.*

ELECTROCHEMICAL SOCIETY, New York City

Aschner, J. F., *A Double-Diffused, Silicon, High-Frequency Switching Transistor Produced by Oxide Masking Techniques.*
Atalla, M. M., and Scheibner, E. J., *Properties of Thermally Oxidized Silicon Surfaces.*
Benson, K. E., see Wernick, J. H.
Biondi, F. J., *Status of Semiconductor Device Process Technology.*
Byrnes, J. J., see Wernick, J. H.
Dewald, J. F., *Theory of Electron Transfer Reactions at Semiconductor Electrodes.*
Dewald, J. F., *Experiments on Electron Transfer Reactions at the ZnO Electrode.*
Dorsi, D., see Wernick, J. H.
Gillich, J. J., see Wernick, J. H.
Isenberg, C. R., see Trumbore, F. A.
Kaiser, W., and Thurmond, C. D., *Nitrogen in Silicon.*
Kolb, E. D., *Uniform Resistivity p-type Silicon by Zone Leveling.*
Porbansky, E. M., see Trumbore, F. A.
Scheibner, E. J., see Atalla, M. M.
Smits, F. M., *Factors Influencing Diffusion Processes in Semiconductors.*
Thurmond, C. D., see Kaiser, W.
Trumbore, F. A., Isenberg, C. R., and Porbansky, E. M., *Solid Solubility of Tin in Silicon.*
Trumbore, F. A., Isenberg, C. R., and Porbansky, E. M., *Solid Solubilities and Electrical Properties of Aluminum and Gallium in Germanium.*
Turner, D. R., *Electropolishing Silicon in Hydrofluoric Acid Solutions.*
Wernick, J. H., Benson, K. E., Byrnes, J. J., Dorsi D., and Gillich, J. J., *Techniques and Results of Zone Refining Some Metals.*

ACOUSTICAL SOCIETY OF AMERICA, Washington, D. C.

David, E. E., Guttman, N., and Van Bergeijk, W. A., *An Investigation of Monaural Interaction of Closely Spaced Clicks by Binaural Fusion.*
Guttman, N., see David, E. E.
McSkimin, H. J., *Measurement of the Adiabatic Elastic Moduli of Single Crystal Alpha Uranium.*
Schroeder, M. R., *Spatial Fluctuations of Steady-State Sound Fields in Rooms.*
Van Bergeijk, W. A., see David, E. E.

WESTERN JOINT COMPUTER CONFERENCE, Los Angeles

Cornell, W. A., *A Special Purpose Solid State Computer Using Sequential Access Memory.*
Finch, T. R., *Transistor Resistor Logic Circuits for Digital Data Systems.*
Ross, I. M., *Switching Transistors.*

OTHER TALKS

Aamodt, N. O., *Wind Induced Vibrations of Aerial Cable and Wire Plant*, A.I.E.E., Omaha, Neb.

Anderson, P. W., *Theory of Superconductivity*. Solid State Seminar and Theoretical Seminar, Ithaca, N. Y.; Brandeis University, Waltham, Mass.

Babington, W. and Weissmann, G. F., *Damping Properties of Magnesium Alloys*, Meeting of Magnesium Assoc., Philadelphia, Pa.

Baker, W. O., *Perspectives on Atoms, Bonds and Crystals*, Mellon Institute, Pittsburgh, Pa.

Barney, H. L., *A Discussion of Some Technical Aspects of Speech Aids for Post-Laryngectomized Patients*, Am. Laryngological Assoc., San Francisco, Calif.

Barrett, W. A., *The Twistor Memory*, Binghamton Chapter of the Professional Group on Electronic Computers, I.R.E., Johnson City, N. Y.

Bashkow, T. R., *Circuit Analysis by Digital Computers*, Columbia University, N.Y.C.; Harvard University, Cambridge, Mass.

Batterman, B. W., *X-ray Measurements of Perfection in Germanium*, X-ray Colloquium, M.I.T., Cambridge, Mass.

Becker, F. K., *Experimental Receivers for a Signature Verification System*, 12th Annual Spring Technical Conf., Cincinnati Section, I.R.E., Cincinnati, Ohio.

Bender, W. G., *System Models*, 9255th Air Reserve Squadron, Research and Development Flight, Madison, N. J.

Benes, V. E., *Characterization and Decomposition of Stochastic Processes with Stationary Independent Increments*, Am. Mathematical Soc., N.Y.C.

Blanchard, T. G., *Magnetic Amplifiers in Communications*, New Jersey Bell Telephone Company, Newark, N. J.

Bobeck, A. H., *Twistor*, Philadelphia Sections of A.I.E.E.-I.R.E., University of Pennsylvania, Pa.

Bobeck, A. H., *A New Solid State Memory Element—The Twistor*, I.R.E. High Speed Switching Session, University of Arizona, Tucson, Ariz.

Budlong, A. H., *Boolean Algebra Applied to Switching*, Montclair State Teachers College, Montclair, N. J.

Buhrendorf, F. G., *Automatic Positioning*, Newark College of Engineering, Newark, N. J.

Burford, T. M., *Topics in Estimation Theory*, Dept. of Electrical Engineering, Columbia University, N.Y.C.

Campbell, M. E., *Voices Under The Sea*, St. Peter's Parish House, Mountain Lakes, N. J.

Cohn, D. L., *Analytic Study of the Structure of the Vascular Tree*, Argonne National Laboratories, Lemont, Ill.

Day, T. M., *The Planning and Design of a Shopping Center Type Cafeteria*, The Work Shop Sessions of Inplant Food Management Magazine, New York City.

Descloux, A., *Queuing Theory and Some of its Applications*, Orientation Seminar on Operations Research, Am. Management Assoc., New York City.

Dillon, J. F., Jr., *Magnetostatic Modes in Ferrimagnetic Spheres*, Am. Phys. Soc., Washington, D.C.

Dillon, J. F., Jr., *Domain Structure and Optical Properties of Transparent Ferrimagnetic Crystals*, Iowa State College, Ames, Iowa.

Dimond, T. L., *Handwritten Character Recognition*, Albuquerque-Los Alamos Section, I.R.E., Albuquerque, N. M.

Feher, G., *Electron Nuclear Double Resonance Experiments*, Annual Meeting of the National Academy of Sciences, Washington, D. C.

Feinstein, J., *The Conversion of Space Charge Wave Energy into Electromagnetic Radiation*, Symp. on Electronic Waveguides, Polytechnic Institute of Brooklyn, N. Y.

Felker, J. H., *Computing Machines in the U.S.*, Conf. of Engineering Societies of Western Europe and the U.S., New York City.

Ferrell, E. B., *New Applications of Time Division Techniques*, Philadelphia Section, I.R.E., Philadelphia, Pa.

Ferrell, E. B., *Control Charts for Log-Normal Universes*, Delaware Section of A.S.Q.C., Wilmington, Del.

Ferrell, E. B., *Statistical Methods in Engineering Design*, Western Massachusetts Section of the A.S.Q.C., Springfield, Mass.

Fitzwilliam, J. W., see Sproul, P. T.

Foster, F. G., *Microscopy in the Communication Field*, Philadelphia Electron Society Symposium, Camden, New Jersey.

Fox, A. G., *Mavar Amplifiers*, University of Syracuse, Syracuse, N. Y.

Garrett, C. G. B., *Semiconductor Surfaces*, General Electric Research Laboratories, Schenectady, N. Y.

Geils, J. W., *The Engineer in the Electronics Field*, Stevens Institute of Technology, Hoboken, N. J.

Geller, S., *Crystal Chemistry of Synthetic Magnetic and Nonmagnetic Garnets*, Delaware Valley Association of Crystallographers, Villanova University, Villanova, Pa.

Gumley, R. H., *Contact Selection and Design to Minimize Resistance and Noise*, Audio Engineering Soc., RCA Institute, N.Y.C.

Hamlin, K. B., *Patents and Patent Law as a Career*, Student Branch of A.I.E.E.-I.R.E., Ohio State University, Columbus, Ohio; Mathematics and Physics Club, Heidelberg College, Tiffin, Ohio.

Hamming, R. W., *Stable Predictor-Corrector Methods for Integrating Ordinary Differential Equations*, RCA Research Laboratories, Princeton, N. J., and IBM Research Laboratories, Poughkeepsie, N. Y.

Harary, F., *Structural Balance*, Mathematics — Psychology Colloquium, University of Pennsylvania, Philadelphia, Pa.

Harary, F., *Status and Contrastatus*, Interdisciplinary Seminar on Applications of Mathematics to Social Science, University of Michigan, Ann Arbor, Mich.

Hardy, F., *Development of Special Lubricants and Lubrication*

Practices for Small Apparatus, Convention of the Am. Soc. of Lubrication Engineers, Cleveland, Ohio.

Harmon, L. D., *Some Devices for Artificial Intelligence*, Brookhaven National Laboratory, Upton, L. I.

Harmon, L. D., *Visual Recognition*, Eastern Psychological Association, Philadelphia, Pa.

Harvey, F. K., *High Fidelity and the Hearing Process*, I.R.E.-A.I.E.E., Student Branches, City College of New York.

Hawkins, W. L., Winslow, F. H., Loeffler, B. B. and Matreyek, W., *New Protectants for Hydrocarbon Polymers*, 8th Canadian High Polymer Forum, McDonald College, St. Anne de Bellevue, Quebec, Canada.

Hawkins, W. L., *New Protectants for Hydrocarbon Polymers*, 8th High Polymer Forum, Montreal, Quebec.

Hebel, L. C., Jr., *Physics as a Career*, Millburn Senior High School, Millburn, N. J.

Hefele, J. R., *Experimental Transmitter for Bank Signature Verification System*, 12th Annual Spring Technical Conf., Cincinnati Section, I.R.E., Cincinnati, Ohio.

Herndon, J. A., *A Vacuum-Grating Spectrograph for the Infrared*, The Southwestern Section, Am. Phys. Soc., Huntsville, Alabama.

Herring, C., *Phonon-Drag Thermoelectric Effects*, Physics Colloquium, Johns Hopkins University, Baltimore, Md.

Higgins, W. H. C., *DEW Line*, M.I.T., Lincoln Laboratory, Lexington, Mass.

Hittinger, W. C., *Transistors and Diodes*, Capitol Area Science Fair, Harrisburg, Pa.

Houghton, E. W., see Sproul, P. T.

Jakes, W. C., *Effects of Rainfall and Anomalous Propagation on Transmission over Short Paths at X-Band*, U.R.S.I. Convention, Washington, D. C.

Jones, A. W., *Mathematics for Operations Research*, 17th Annual Meeting, Metropolitan New York Section, Mathematical Assoc. of America, Hofstra College, Hempstead, L. I.

Kinariwala, B. K., *Synthesis of Active Networks*, Dept. of Engineering and Applied Physics, Harvard University, Cambridge, Mass.

King, J. C., *Effects of X-Ray Irradiation on the Anelasticity of Natural and Synthetic Quartz*, 12th Annual Frequency Control Symposium, Asbury Park, N. J.

Knox, K., *Ferrimagnetism and the Structure of Compounds*, Dept. of Chemistry, University of North Carolina, Chapel Hill, N. C.

Kompfner, R., *New Microwave Devices*, Symposium on Electronic Waveguides, Polytechnic Institute of Brooklyn, N. Y.

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Loeffler, B. B., see Hawkins, W. L.

Maas, W. W., *Guided Missiles*, Lehigh Valley Public Relations Club, Allentown, Pa.

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Matreyek, W., See Hawkins, W. L.

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Meitzler, A. H., *Piezoelectric and Dielectric Characteristics of Single Crystal Barium Titanate Plates*, Physics Department Colloquium, Lehigh University, Bethlehem, Pa.

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Owens, C. D., *Magnetism—A Resume of Theory and Utilization*, Ufology Group, Merrimack Valley, Lawrence, Mass.

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Runyon, J. P., *Logic and the Design of Small Digital Circuits*, Conn. I.R.E. Lecture Series on Digital Computers, Yale University, New Haven, Conn.

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Schlabach, T. D., *The Temperature Dependence of Electrical Resistivity of Laminated Thermoset Materials*, A.I.E.E., San Jose Subsection, Palo Alto, Calif.

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Schroeder, M. R., *A Vocoder and Its Application to the Transmission of High-Quality Speech over Narrow-Band Channels*, Nordwestdeutsche Physikalische Gesellschaft, Bad Neuenahr, Germany; Siemens Zentrallaboratorium, Munich, Germany; and University of Goettingen, Goettingen, Germany.

Schwenker, J. E., *Communications Research at the Bell Telephone Laboratories*, San Antonio Sections, A.F.C.E.A., A.I.E.E., R.E.S.A., Texas.

Sevick, J., *High Frequency Transistors*, Physics Department, Wayne University, Detroit, Mich.

Shea, J. F., *A Study of the Wind Induced Vibrations in Aerial Cables and Related Structures*, University of Michigan, Ann Arbor, Mich.

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Snyder, B. J., *The Technical Aide's Role in a Development Laboratory*, Pennsylvania State University, Allentown, Pa.

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Sproul, P. T., Houghton, E. W., Young, L. G., and Fitzwilliam, J. W., *The TH Radio Relay System*, Northern New Jersey Section, I.R.E., P.G.M.T.T., Murray Hill, N. J.

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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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Williams, H. J., see Ellis, W. C.

PATENTS

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

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Barry, J. F. and Seeley, N. C. — *Method of Shaping Semiconductive Bodies* — 2,827,427.

Becker, J. A. and Brandes, R. G. — *Gas Valve for High Vacuum System* — 2,827,257.

Bemski, G. — *Method of Improving the Minority Carrier Lifetime in a Single Crystal Silicon Body* — 2,827,436.

Blaha, A. L., Davis, T. E. and Peek, R. L., Jr. — *Cathode Ray Tube Display* — 2,831,161.

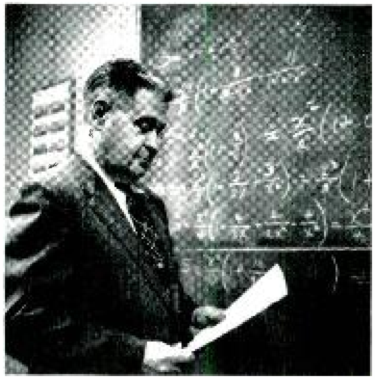
Bowers, F. K. — *Self-Contained Antenna-Radio System in which a Split Conductive Container Forms a Dipole Antenna* — 2,828,413.

Brandes, R. G., see Becker, J. A.

Bryant, H. W. — *Subscriber Telephone Set* — 2,831,067.

Burlin, J. N. and Hose, R. H. — *Telephone Stand* — D-182,498.

Burton, E. T. — *Selectable Base Counter* — 2,828,071.



R. R. Riesz

R. R. Riesz, a native of New York City, joined the Laboratories after receiving an A.B. degree from Ripon College and an M.A. degree in physics from the University of Wisconsin in 1925. His earliest work was on vibratory mechanics, which later led to research in the physics of speech and hearing, including such projects as the artificial larynx and visible speech. Prior to and during World War II he was engaged in developing speech-processing systems such as the Voder and Vocoder. More recently, in the Human Factors Engineering department, he has been engaged in the field of human engineering as applied to telephone systems, including the development of simulation as a means of studying user reaction to new communication systems. He is a member of the Acoustical Society and a Fellow of American Physical Society. Mr. Riesz is the co-author of the article, "Simulation in Engineering", in this issue.

H. D. Irvin, a native of Jacksonville, Florida, joined the Laboratories in 1956 after receiving a B. S. degree in physics from the University of North Carolina. From 1947 to 1952, he was with the Research Division of American Enka Corporation, working on problems of instrumentation in studies of the physics of cellulose fibers. From 1952 to 1956, he was Chief Engineer of Radio Station WUNC at Chapel Hill, N. C. He was also a consultant in instrumentation to medical research and psychological testing laboratories. Since coming to Bell Laboratories, he has been concerned with problems of simulation in the human factors studies of new communication services and devices in the Human Factors Engineering department. He is a member of Phi Beta Kappa, and a senior member of the I.R.E. Mr. Irvin is the co-author of the article, "Simulation in Engineering", in this issue.

H. D. Irvin

H. E. D. Scovil, author of "A Three-Level, Solid-State MASER" in this issue, was born in Victoria, B. C., Canada, and attended the University of British Columbia, from which he received the B.A. and M.A. degrees in 1948 and 1949. Subsequently, he studied at Oxford University, where he was awarded the D.Phil. degree in 1951. During 1951 and 1952, Mr. Scovil was a Nuffield Research Fellow at Oxford, and then returned to the University of British Columbia as Assistant Professor during 1952-1955. In 1955 he joined Bell Telephone Laboratories where, as a member of the Device Development Department, he has engaged in the development of the MASER.

H. E. D. Scovil

J. W. Phelps, a native of Bellevue, Nebraska, attended Omaha University, then Iowa State College, where he received a B.S. degree in Electrical Engineering in 1951. During World War II he served as a Naval Aviation Radio

J. W. Phelps

Technician. He joined the Laboratories in 1951 and, except for brief assignments in the Transmission Systems and Switching Apparatus departments, has been a member of the Outside Plant Development Department. His work with the Electrical Protection Group in that department was principally concerned with power line contacts to open-wire telephone conductors. At present, he is working on the design of an armorless ocean cable. Mr. Phelps is a member of Eta Kappa Nu and Tau Beta Pi. The article, "Electrical Protection for Transistorized Equipment", in this issue is by Mr. Phelps.

H. E. Bömmel

H. E. Bömmel, a citizen of Switzerland, received his Ph.D. degree in Physics from the University of Zurich, Switzerland, in 1943. He was associated with the Physics Department of this University as a research supervisor and lecturer until 1953, and his work there was concerned mainly with various aspects of ultrasonics and, during the last three years, with nuclear physics. Since joining the Bell Laboratories in 1953, Mr. Bömmel has been principally engaged in various applications of ultrasonics to problems of solid-state physics in the Mechanics Research group. Mr. Bömmel is the co-author of the article, "Ultrasonic Attenuation in Superconductors", in this issue.

W. P. Mason, who was born in Colorado Springs, received the B.S. degree in Electrical Engineering from the University of Kansas in 1921. He received the M.S. degree and Ph.D. degree from Columbia University in 1924 and 1928, respectively. Mr. Mason has been principally engaged in investigating the properties of piezo- and ferro-electric materials, in the transmission of sound waves in liquids, solids and filter structures, and in studies of the static and dynamic properties of solids. He has also studied wear, fatigue in metals, and the joining of materials in solderless wrapped connections. He is in charge of the Mechanics Research group of the Mathematical Research Department. Mr. Mason is a fellow and past president of the Acoustical Society, a fellow of the American Physical Society and the Institute of Radio Engineers and a member of the Rheological Society, Sigma

W. P. Mason

Xi and Tau Beta Pi scientific and engineering fraternities. Mr. Mason is the co-author of the article, "Ultrasonic Attenuation in Superconductors", in this issue.

M. Salzer, a native of New York City, joined the Laboratories in 1929 as an apparatus draftsman. In 1939 he was made a Member of Technical Staff, assigned to the new devices group of the Telephone Switching Department. He attended Columbia University and the Polytechnic Institute of Brooklyn, from which he received the M.E. degree in 1932. Mr. Salzer was responsible for much of the mechanical design of the trouble recorder, and at the time of his death in 1957 was concerned with the mechanical phases of other developments in the Switching Apparatus Development Department. Mr. Salzer was the author of the article, "The Trouble Recorder", in this issue.