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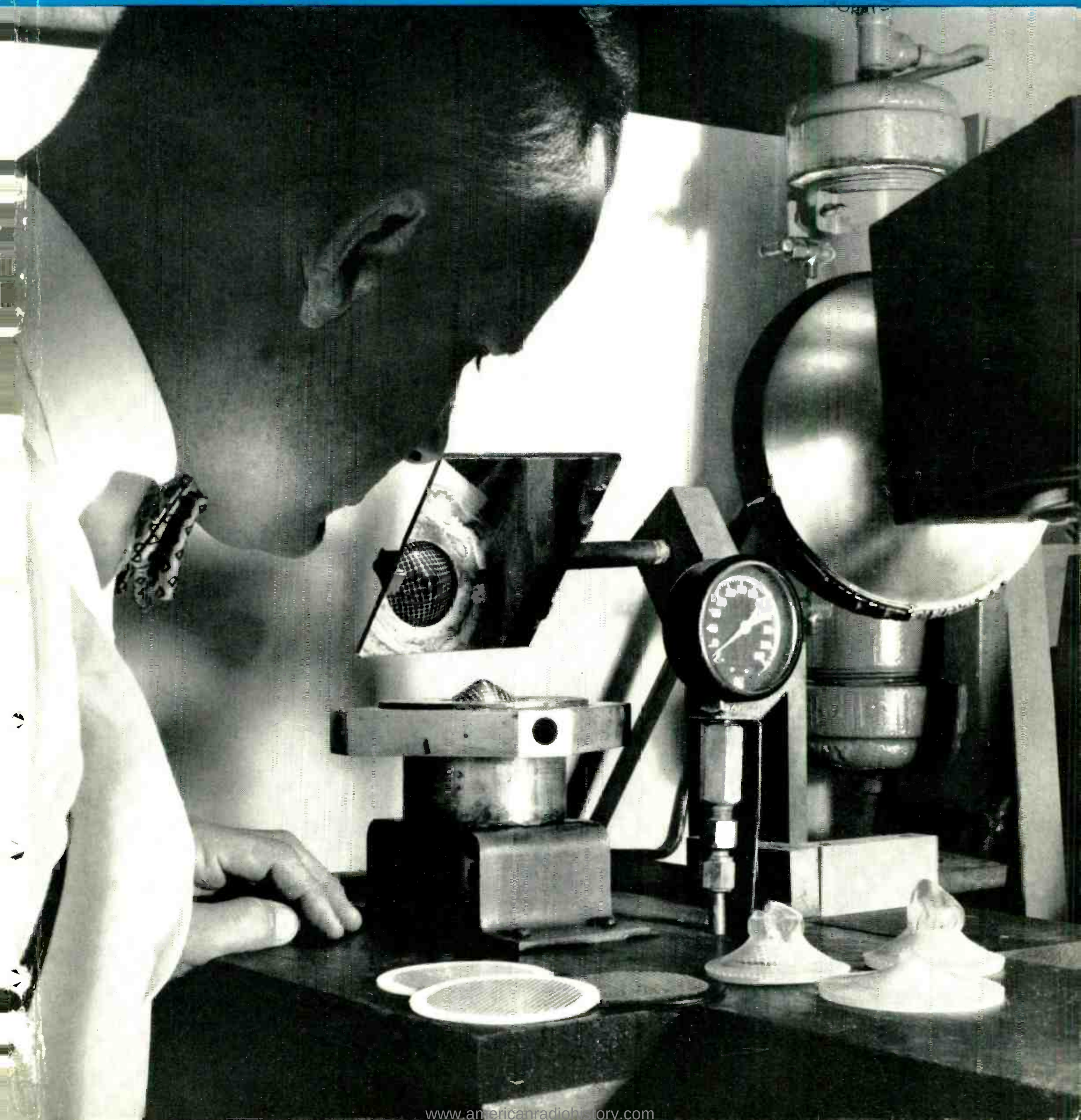

Bell Laboratories RECORD

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Telephone Switching

An Old Field wi

The "new art" of telephone switching means many tl so it is helpful to review some of the background fact ing systems of the future will draw upon eighty year ence, but will also take advantage of many new de

A. E. JOEL, JR., *Switching Systems L*

It is fundamental in the telephone industry that, in addition to having telephones and transmission channels, one also needs "switching systems" — that is, methods of interconnecting channels between calling and called numbers. This concept is so vital to telephony that the first crude telephone switching system was placed in service within a year of the invention of the telephone in 1876.

Early in telephone history, all connections were made manually through crude rotary switches. As the demand for telephones mushroomed, however, it was soon realized that some automatic method would ultimately be required to provide fast, high-quality service. During the past eighty years, much has been done to design, manufacture, install and operate more highly efficient switching systems — ranging from improved manual PBX's to large, automatic crossbar systems for both local and long-

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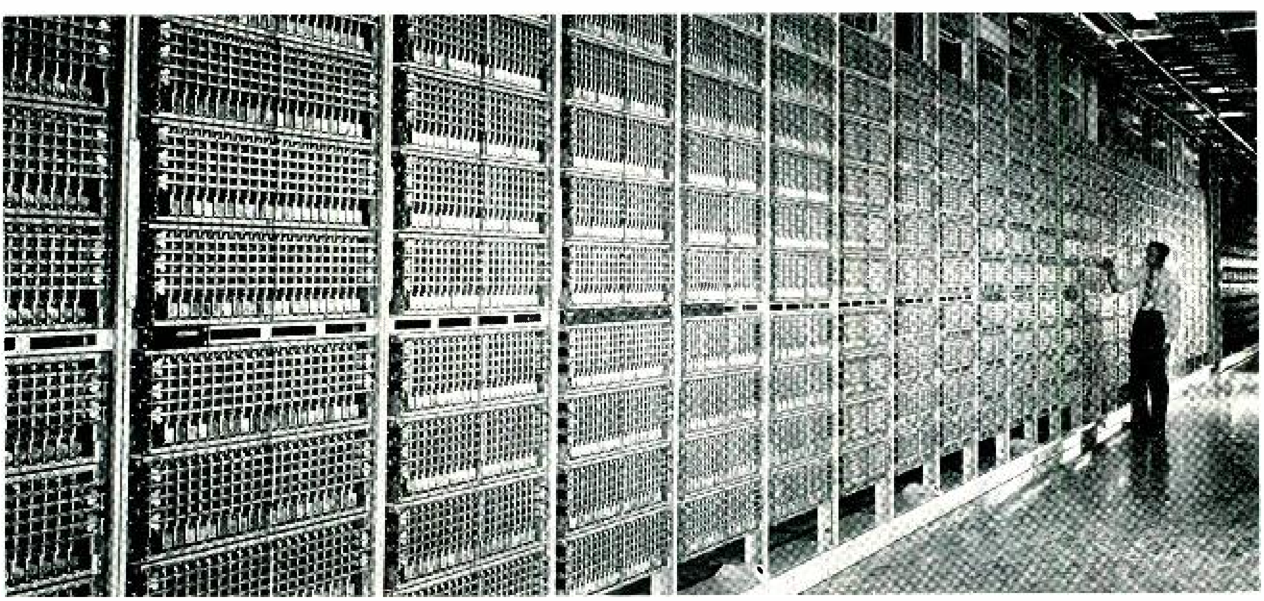
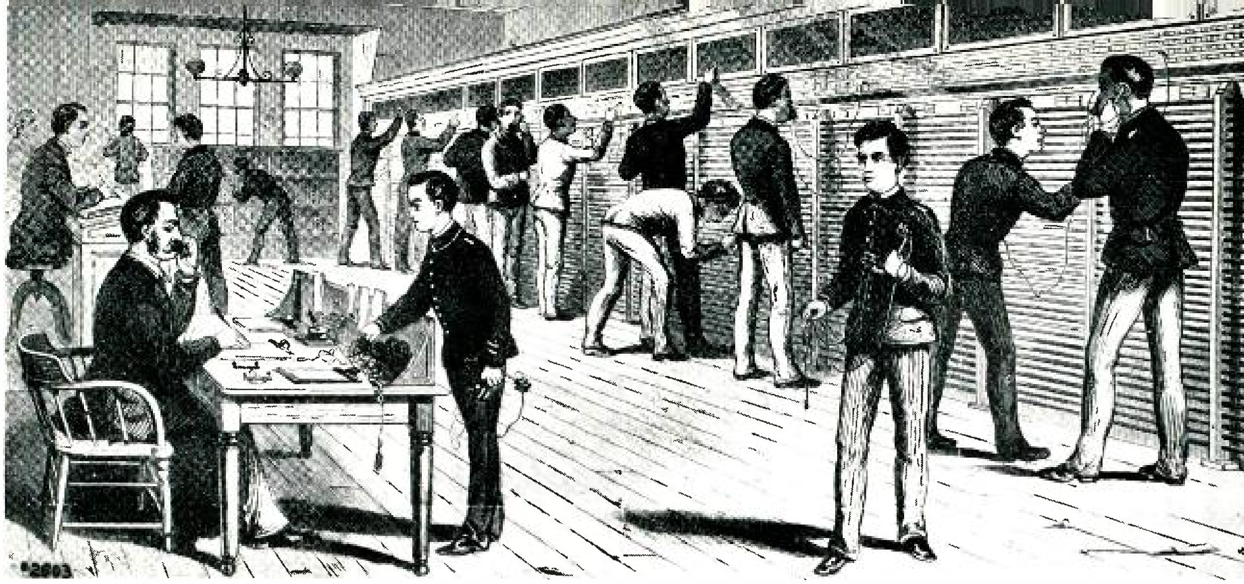
Telephone c the ultimate achieved. And ing with grea new techniqu the last ten y are designing ment and ma cal systems. T... a "new art" in the telephone business, and they



Electromechanical systems, like this No. 5 crossbar office, have reached a high degree of sophistication.



One of the earliest telephone exchanges (New York City, 1879) gives measure of eighty years of progress when compared to modern automatic systems. Need for automatic switching was recognized early.

have consequently stimulated a review of the considerations that make for the design of good automatic telephone systems and service.

Speed and Functional Concentration

The "new art" devices are basically electronic, and as a group they are symbolized by the transistor, announced by Bell Laboratories in 1948. Like the transistor, many are solid-state devices – semiconductor diodes and magnetic cores, for example – which operate many times faster than their electromechanical counterparts. The new art uses this additional speed to advantage in achieving systems that operate more efficiently and that require fewer functional units to handle a given amount of telephone traffic. The new art devices are also smaller in size and require less power, so that telephone central offices employing them, in addition to benefiting from such advantages as potentially long service life, could effect savings in floor space and power drain.

The idea of a new switching art has been even further refined, however, by a concept known as "functional concentration". In brief, this means, for example, the incorporation of widely scattered digital storage functions into one very large "memory." That is, instead of storing pieces of information relating to telephone calls in many places throughout a system, a single functional unit may perform simultaneously all memory operations for many calls. Functional concentration has become a real possibility only in recent years with the development of storage units such as the "flying-spot", "magnetic-core" and others that can remember large amounts of information in a relatively small volume of equipment.

Functional concentration is applicable to other techniques besides memory, however. It can be used, for example, in the switching network itself. With new devices and techniques, it is now possible to increase the speed of establishing and removing connections between particular inputs and outputs. Such actions are performed "on command" from a control unit, which similarly orders actions by other parts of the system. Concentration of such control functions results in many advantages: faster devices in similar circuitry can do more jobs, including operations that are unrelated but of the same general type.

The art of transmission has also grown since the invention of the telephone. But because of the different nature of this phase of the telephone business, transmission specialists learned early how to make measurements of quality and how to apply these measurements directly to the design of transmission systems. As a result, we have progressed from the elementary single-wire, ground-return telephone line to the modern carrier, coaxial-cable and microwave relay systems. These have enabled us to minimize the effect of distance – to provide large numbers of communication channels over many miles with a minimum amount of equipment.

Information Theory

In the past decade, switching engineers have seen the first glimmerings of this type of measurability. Theoretical studies have been gathered together into a form known collectively as "Information Theory." With this theory, the switching-system designer of the future can contemplate a more scientific approach to his problem, and this new approach should result in a much more rapid application of new techniques and devices, and in a better appreciation of what is required and what can be done.

Interestingly, one also finds in the application of Information Theory a common meeting-ground for transmission and switching. As a result, these two fields may merge in the future, but there are other reasons why integrating may occur. The speed factors for electronic switching indicate the need for employing the same design techniques and devices that are used for transmission. Switching now uses two-state devices. To secure high-speed devices with continuous characteristics, signal-to-noise level and bandwidth must be given greater consideration, as in transmission systems.

This new art, along with an appreciation of how it can affect our business, has stimulated a more scientific approach to determining what a switching system must be able to do. With the aid of Information Theory, the problem for analysis can be stated more clearly. New service features can be studied and evaluated more readily and with a greater depth of understanding of the inter-action of the new features with the various parameters of a switching system. Future needs and changes can be anticipated and, in effect, evaluated. Thus, we are finding that before a system is designed, we may more precisely state in terms of charts, graphs and actions what the system must be capable of doing. The result should be better planning. With functional concentration and with higher-speed operation, new services may be offered and greater progress in switching may be expected.

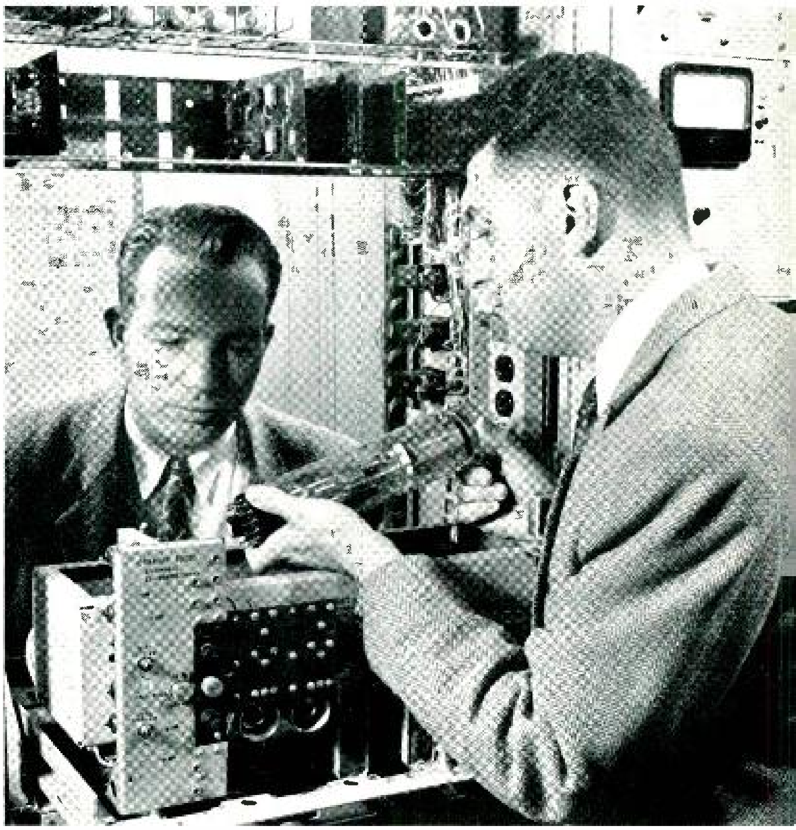
Generalized Circuits

In addition to plans for the over-all system, individual circuits must of course be designed to perform specific functions. With concentration, these functions may be stated more generally. Thus, circuits and devices do not need to be closely coupled to their ultimate application; instead, they may be designed to secure the best compromise between the device and the circuit cost. If the requirements of a device can be divorced from its application, the device becomes more universal and lends itself more to mass production.

With electronic devices, new concepts in equipment design are likely. The mechanical process of making devices, circuits, and equipment units can be integrated with the most economical manufacturing arrangements. Automation is the key to the mass production of new systems that will provide the best telephone service at lowest cost. When the basic equipment units become disassociated from the requirements of a specific system, the same "building block" can be used to provide different communications services.

To this point, we have discussed several important new-art concepts. The description would be incomplete, however, without mention of a technique known as the "stored program". This derives from the digital-computer field and involves applying digital techniques to specify a wide variety of problems without changing the equipment that carries out the computations. It is another step toward providing different services with the same basic system components.

We spoke earlier of the "command orders" required in telephone switching, and it is well to consider processing such orders with an information-handling system having a stored program. With the stored-program technique, the system is given certain information, after which it can "process data" according to the "coded rules" of the program. The "rules" of a telephone switching system are governed by the nature of the system itself and by the services it supplies. The "coding" of these rules —



Electronic switching incorporates efficient memory systems: a "barrier-grid store" under test at the Laboratories for use in experimental equipment.

the phrasing of the rules in a numerical language the system can understand – is guided by Information Theory. The "data processed" are the data of telephone calls – dialed digits and other information having as an end product successful telephone connections and services.

New Flexibility

This may sound like a discussion of old ideas with new words, but the difference is this: present systems code data with relatively inflexible wiring arrangements, while possible new systems with stored programs could code data merely by feeding a paper or magnetic tape into the information-handling equipment. Present systems are limited by the fact that any but fairly minor changes often require considerable modification of equipment, rearranging of wires, and reassembly. Stored-program systems could have more latitude; a wider departure from initial plans could be made before requiring physical changes in the equipment and circuitry. Sometimes, even a major change might be made merely by plugging in additional general-purpose units and by giving the system a new set of instructions.

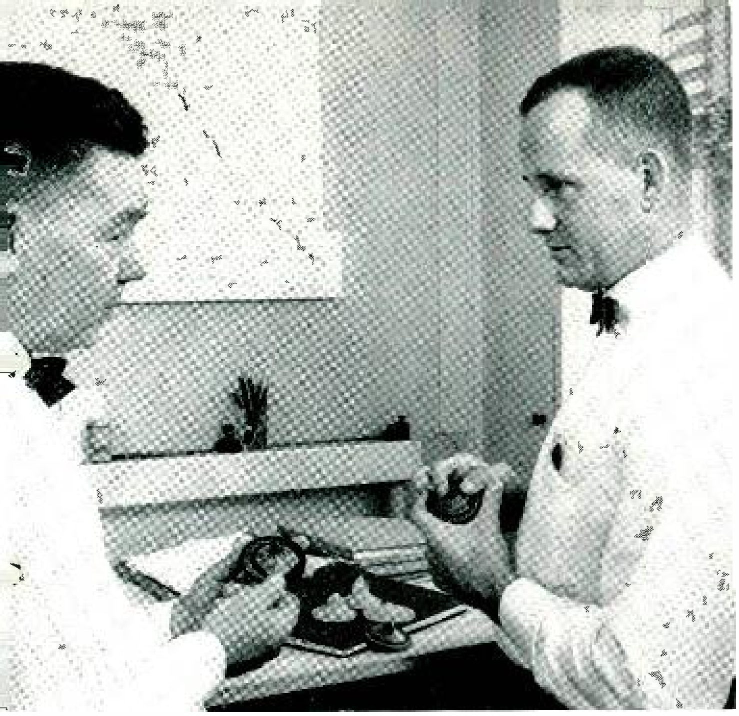
What do these new art ideas mean to the future of telephone service? Electronic switching has not yet progressed to the point where we can state definitely that certain improvements could be offered, but we can state the general *type* of thinking going on at Bell Laboratories. Consider, for example, some of the implications of having a very large-capacity but compact memory device in a telephone office. Depending upon how successfully the new art theory is applied, such a memory could be used in many ways that have so far been impracticable. The memory might be large enough that customers could give to the office information other than the usual dialed digits of a single called number. This "extra" information might consist of instructions for setting up a conference call among several telephones or for placing a series of calls sequentially at stated intervals, or it might consist of simpler numbers to represent numbers called frequently. All of these services are closer to being realized technically and economically by application of the new art.

When new techniques are introduced, they must be tested adequately to ensure serviceability and maintainability. The more changes or advances in the art, the more likely that these tests will be extensive. Generally, the new ideas and devices will have to mature before they gain wide acceptance. More than ever, it will be necessary to make certain that new ideas are channeled toward the primary goal of good telephone service at reasonable cost to the customer.

In some of the early switching offices, the young men who were the first telephone operators often had to search frantically for the correct terminal jack while they dragged their cords behind them. Today, we look at the amazingly subtle No. 4 and No. 5 crossbar systems, and at experimental electronic switching equipment at the Laboratories, and we realize that we have indeed come a long way. In one sense, progress has been continuous, but every so often there seems to occur a resurgence of ideas. The new arts of switching the channels of telephone communications will keep generations of skilled technicians busy improving service and providing new services that were formerly difficult to render or obtainable only at great cost. To realize these goals, the team effort in research, development, manufacturing and operation must continue. This effort will ensure a promising new future in telephone switching.

THE AUTHOR

A. E. Joel, Jr., a native of Philadelphia, received the B.S. degree from Massachusetts Institute of Technology in 1940 and the M.S. degree, also from M.I.T., in 1942. After joining Bell Laboratories in 1940, Mr. Joel worked for a time in the fields of relay engineering and crossbar testing, and later engaged in fundamental development studies, work on circuits for relay computers, and the teaching of switching design. Subsequently, he was concerned with designing AMA computer circuits and making fundamental engineering studies on new switching systems, and presently is Switching System Development Engineer responsible for systems coordination of the exploratory development of an experimental electronic switching system. Mr. Joel, who holds some forty patents for his work at Bell Laboratories, is a member of the A.I.E.E., I.R.E., Sigma Xi and the Association for Computing Machinery



Brittleness in Polyethylene

I. L. HOPKINS *Chemical Research*

Polyethylenes used for Bell System cable sheaths must have great strength and high ductility for long service life. Because early polyethylenes sometimes showed a surprising brittleness, the Laboratories' chemical research group set out to find the cause. A biaxial elongation test and other experimental work showed that cable sheaths were improved by specifying polyethylenes of higher molecular weight. This research also related other structural properties of polyethylenes to their mechanical performance.

Polyethylene – the familiar waxy, strong material – is generally so tough that it is at first surprising to find that it can occasionally be broken with a brittle fracture. Yet early in the use of polyethylene for cable sheath, such fractures did occur, sometimes at bends or twists where the cable was fitted to the inside of a manhole, or in more extreme cases when the cable was straightened on removal from a reel. Many ruptures resulted from exposure to unfavorable environments, but some probably occurred without contamination. Such ruptures are intolerable, since the polyethylene sheath is the first and principal line of defense against water in the cable.

An immediate test of failed sheaths for conformity to the specifications – which included a requirement that the material stretch to five times its original length before rupture – proved that it did conform. This elongation test was performed in a simple "one-way" stretch, as one stretches a rubber band. But when the polyethylene was stretched two ways simultaneously, drumhead manner, it was found that brittle failures occurred. Since most stresses in the sheath during handling of the cable are more complicated than simple tension, the discovery of brittleness of some polyethylenes under complex stresses was significant.

Brittleness under complex stress is not a universal property of polymers, as consideration of inflatable rubber articles will show, and indeed it is not always true for polyethylene. It therefore seemed appropriate to consider what special ductile and brittle properties polyethylenes might possess.

A single polyethylene molecule is, with adequate reason, considered in the ideal case to consist of a long chain of carbon atoms, analogous to a string of beads, with two hydrogen atoms attached to each carbon. The carbon-carbon attachments, as indicated in Figure 2, are such that although the chain is highly flexible, the structure is slightly "zigzag." In the actual case, the molecules of the early polyethylenes were complicated by the fact that at random places along the chain, a hydrogen atom would be missing, and in its place, the end of another polyethylene molecule, called a branch, would be attached. Figure 2 also illustrates the formation of such a branch. Further, in bulk polyethylene, which is composed of millions of these polymer molecules,

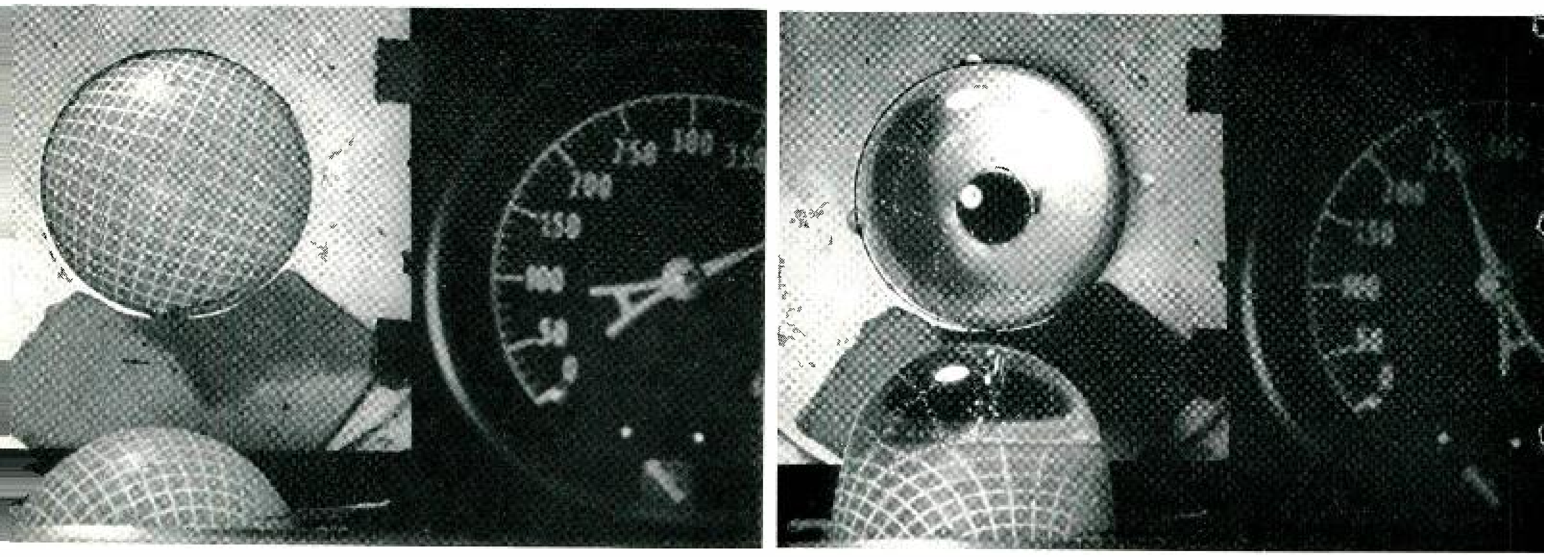


Fig. 1 — By applying water pressure to one side of samples, polyethylene was biaxially strai

there are myriads of places at which several adjacent chains find themselves zigzagging in parallel.

When this happens, the tiny aggregate of parallel segments comprises a minute crystal, or crystallite. Then, the different chains "wander off," each taking part in other crystallites. This structural feature is in fact so prevalent that perhaps 60 per cent of all the polyethylene in a given piece of the material is in crystallite form. The remaining 40 or so per cent comprise the comparatively random amorphous constituent. Further, there is a tendency for the crystallites to arrange themselves in groups around a common center. These groups, which may be a thousandth of an inch in diameter, are called *spherulites.*

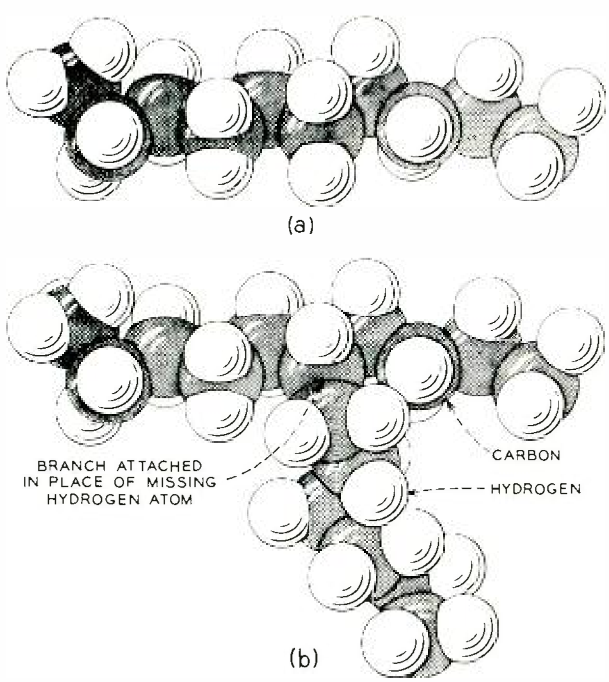
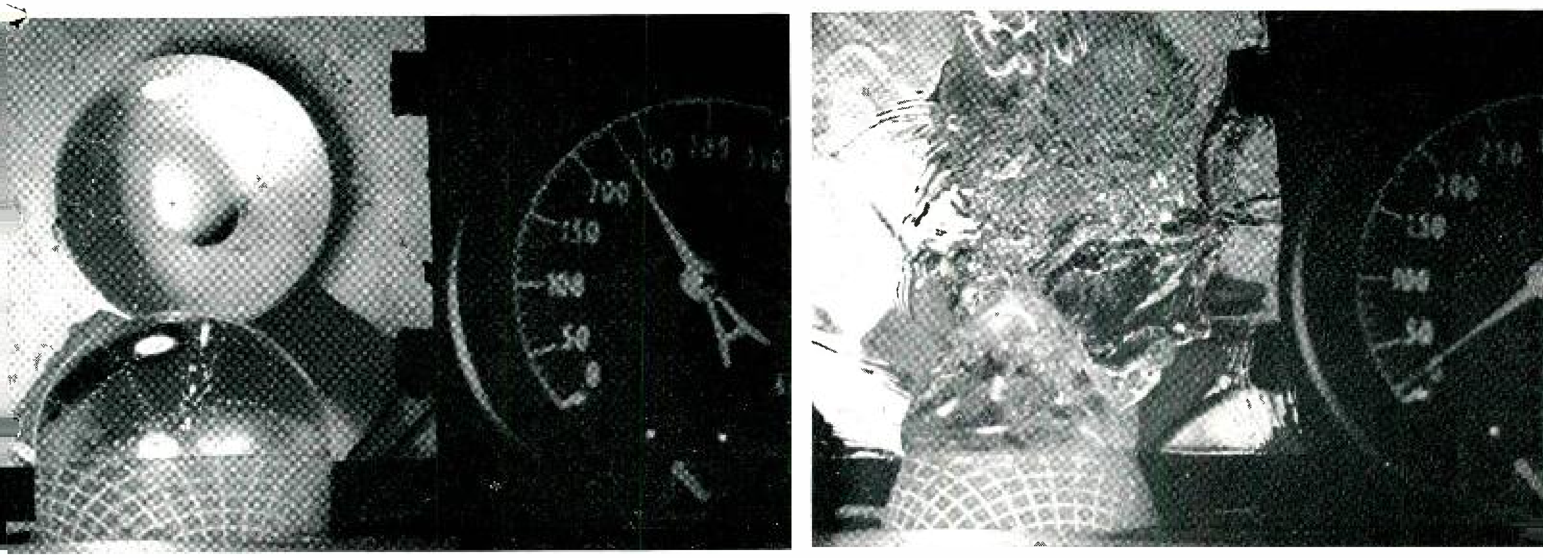


Fig. 2 — Essential structure of polyethylene molecule — (a) a long chain of carbon atoms, slightly "zigzag," and (b) branch chain attached in place of hydrogen atom missing from the long chain.

If the polyethylene is heated above room temperature, the thermal energy in the molecule causes the degree of crystallinity to lessen, until, at about 115°C, it completely disappears (along with the characteristic milky appearance – the material becomes quite transparent). Now the totally amorphous polyethylene is soft and rubbery. A knowledge, then, of the structure of the material at any temperature involves knowing how many carbon atoms there are in a typical or average chain, how broad is the distribution of numbers of atoms around this average, how many branches there are and their average length, and how much of the material is in the form of crystallites. This is a formidable list, and is known only in part. Nevertheless, comparison can be made between materials and the influence of these factors can be assessed. This was the avenue through which brittleness in polyethylene was investigated.

The chief tool was an apparatus for testing under conditions of drumhead tension. The specimen – a disc about three inches in diameter and a tenth of an inch thick – had a grid with a spacing of 0.1 inch stencilled in contrasting paint on one side (Figure 3). This disc was then clamped in a holder,



various degrees of elongation or to point of rupture. Illustrations show sample with mirror above.

leaving a free circular area with a diameter of 1.8 inches in the center, in which the grid could be seen. Water under pressure was brought in under the specimen, causing it to bulge and stretch (Figure 1). This was done gradually, and a motion-picture camera recorded the details of the grid distortion, the radius of curvature of the polyethylene dome, and the pressure. After development, the film was projected, and measurements were made to permit calculation of the progress of both stress and strain during the test and up to the point of rupture. It was found that polyethylene which had conformed to the "one-way" stretch specification, but which nevertheless failed in cable, ruptured at low values of biaxial elongation – 28 per cent in one case.

In further tests, the polyethylene material was divided into three groups of differing molecular weight by dissolving it in hot trichlorethylene and then harvesting the precipitates at different temperature ranges as the solution cooled. The three groups consisted of a waxy substance too weak to test, a second which ruptured at about 30 per cent elongation, and a third which ruptured at about 80 per cent elongation. This last figure is about the minimum for a satisfactory material. Also, when the weak, waxy, low-molecular-weight material was combined with one known to be satisfactory, the resulting polyethylene was quite brittle. This showed that the low-molecular-weight fraction having short-chain molecules was causing the brittle fractures.

A striking confirmation of these results was afforded by experiments on a series of special polyethylenes provided by Imperial Chemical Industries, Ltd. In the polyethylenes of this series, the main (and so far as possible the only) variable was molecular weight. The data from these experiments were clear proof that the percentage of elongation at rupture from biaxial, extensional stress increases with molecular weight. The value of elongation either approaches an upper limit or passes through

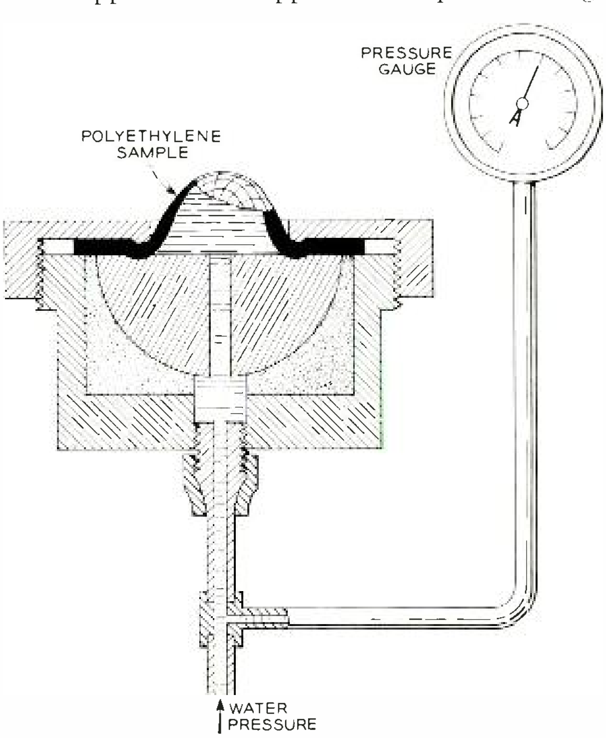


Fig. 3 -- Method for biaxial stressing of polyethylene samples to test for brittleness.

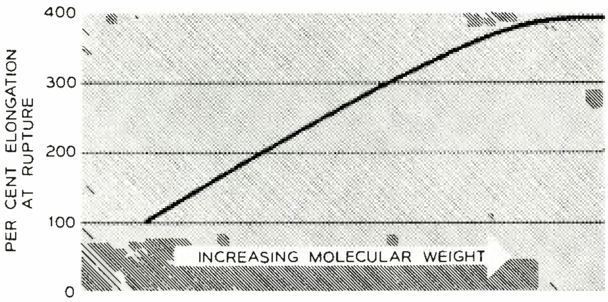


Fig. 4 — Research on polyethylenes established relationship between maximum elongation and molecular weight of various samples.

a broad maximum at the highest molecular weights considered in the tests (Figure 4).

In addition, the effect of crystallinity was tested using both annealed and quenched samples of the same material. The annealed samples were raised to a temperature somewhat over 115°C – the melting point of the crystallites – and were then cooled slowly. The crystallites had time enough to re-form, and the resulting specimens usually were about 60 per cent crystalline. The quenched samples, on the other hand, were raised to the same temperature, and then cooled as quickly as possible in liquid nitrogen. They were consequently somewhat less crystalline, but the main structural difference was that the spherulites were of much smaller size. In the biaxial stress-strain test, it was found that they were less stiff and that they broke at greater extensions than the annealed samples. The association of decrease of strain at rupture with increase of crystallinity and spherulite size was corroborated with similar work on other polymers.

This work demonstrated, then, that there are two principal parameters influencing the biaxial brittleness of polyethylene – molecular weight and crystallinity. The degree of potential crystallinity in the materials which were available for use was, however, not significantly variable. Also, the manufacturing methods insured that this potential was approximately realized. The suppliers of polyethylene for use in cable sheaths were then asked to increase the molecular weight – the only important variable which could be changed. Cable sheaths have thus been assured of freedom from brittleness under adverse stress conditions. This, combined with the prevention of degradation by oxidation * and sunlight,† provides a material which can confidently give trouble-free service for many years.

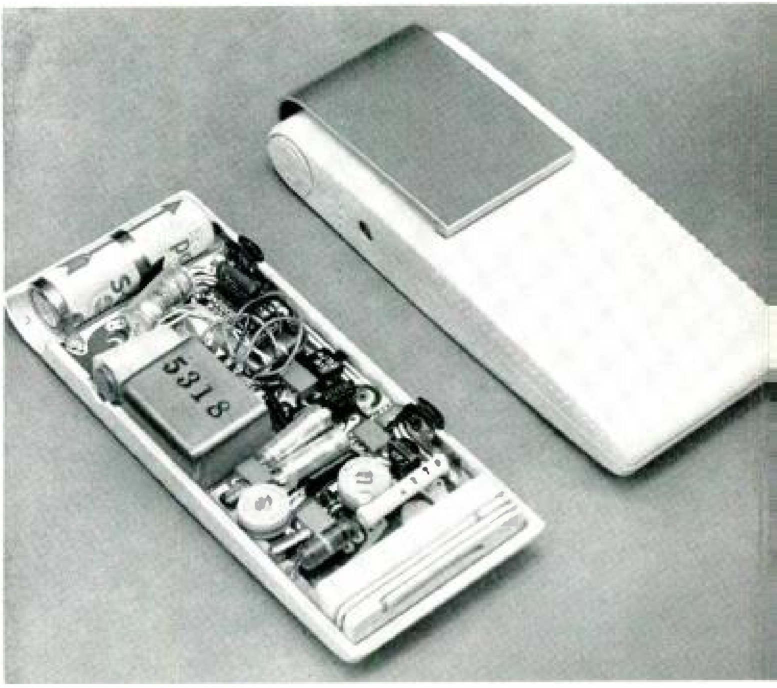
The relationships among crystallinity, spherulite size and brittleness have subsequently been confirmed by the properties of the newly available unbranched polyethylenes. Absence of branches permits a close alignment of molecules, and the direct result is an increase in crystallinity from about 60 per cent to over 90 per cent. These materials rupture at low levels of biaxial strain, and even the limit of uniaxial strain becomes low (material can be stretched only 100 per cent or less) if the speed of straining exceeds a rather low value.

* RECORD, *January*, 1956, *page* 1. † RECORD, *July*, 1957, *page* 246.

THE AUTHOR

I. L. HOPKINS, born in Plymouth, Maine, was graduated from M.I.T. in 1927 with the degree of B.S. in Mechanical Engineering. He joined the Apparatus Development Department of the Laboratories on July 1 of that year. Mr. Hopkins has been concerned with the physical properties of plastics, and has been responsible for the design of testing methods and machines. Several machines of his design are being manufactured by testing-machine manufacturers and are in use throughout the plastics industry. For the past nine years Mr. Hopkins has been associated with the polymer research division of the Chemical Research Department, with particular interest in the viscoelastic and associated properties of polymers, and more lately, of glass. He is a licensed Professional Engineer in New York State, and a member of the Society of Rheology.

Pocket-Radio Signaling



W. STRACK *Special Systems Engineering I*

Salesmen, doctors, and others who are frequently away from their telephones may find very convenient a small, pocket-radio receiver that will signal them when someone calls. Personal radio service has great potentialities, but at present there are many unknowns. A recent trial and laboratory work have given valuable information on the technical arrangements required for efficient transmitting and receiving equipment.

City-wide personal radio signaling is a potential new service now being tested in the Allentown-Bethlehem area of Pennsylvania. Basically, the system serves to indicate to a particular customer — perhaps a doctor or a salesman — that his secretary or some other party is trying to reach him. The customer carries a small radio receiver slightly larger than a kingsize package of cigarettes in his pocket or clipped on his belt. On receiving a radio signal with the proper code, the radio will emit an audible tone of sufficient loudness to inform the user that he is being called. He then goes to a telephone and calls his office or other pre-designated number where he is given the message. Fundamentally, personal radio signaling is thus an extension of the telephone bell.

One of the primary purposes of the Allentown installation is to answer various operational and technical questions. Operationally, the trial is providing valuable information on the reaction of the public to the service and is also establishing the requirements of various groups of users. In addition, tests are under way to obtain technical data, particularly with regard to the attenuation or loss which takes place when a radio signal travels from a fixed-station transmitter to a pocket-carried radio receiver.

To call a customer located somewhere within the coverage area, a person dials a particular telephone number and is connected with a personal-signaling operator. The operator responds with "signaling-service operator — number please." The calling party gives the operator a 4-digit number which corresponds to the code associated with the radio receiver assigned to the called party. With present equipment, the operator then places this number into the system by setting a series of four rotary switches. A total of 24 such codes may be set up at any one time.

The codes are scanned at a rate of about 16 per minute and are translated into combinations of four out of nine audio frequencies. A total of about 3,500 codes can be assigned on a single radio channel. Each number in the code corresponds to a particular audio frequency — No. 1 is a frequency of about 160 cycles, No. 2 about 170 cycles, and so on up

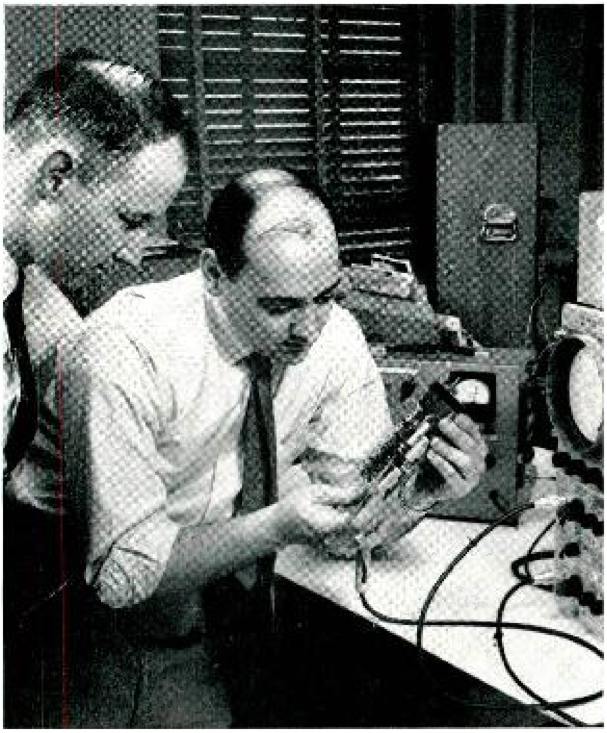


Fig. 1 — The author (left) and J. Franzblau testing experimental receiver in the laboratory.

to No. 9 which is a frequency of about 300 cycles.

These audio frequencies sequentially modulate a 250-watt AM transmitter which operates on one of the common-carrier mobile telephone frequencies at about 35 mc. Each tone is sent for about four-tenths of a second—four tones (one code) requiring a total of 1.6 seconds. The spacing between code transmissions is approximately 2 seconds. Thus the total time per signal is about 3.6 seconds.

When the RF signal is picked up by the receiver, it is demodulated and the audio tones are recovered. These tones are amplified and used to energize a group of four highly selective vibrating reeds which will respond only if the proper frequencies are applied. If, during any coding interval, all reeds in a particular receiver are energized in the proper sequence, an audio oscillator is triggered, and an alerting tone informs the customer that he is being called. By depressing a small push button, the user can silence the oscillator and ready the receiver for the next call.

One of the major equipment problems associated with providing such a service is that of obtaining suitable radio receivers. These units must be small and light in weight if they are to be carried on the person. The model shown on page 9 is now in use in Allentown. These receivers, manufactured by the Stromberg-Carlson Company, weigh approximately eight ounces and will fit conveniently into a coat pocket. They employ a single 4-volt battery having a life of about 900 hours. This is sufficient to provide about six months of service under normal operating conditions.

A block diagram of a receiver is shown in Figure 2. The circuit employs four transistors — a surface-barrier transistor as a super-regenerative detector, two *pnp* junction transistors as audio amplifiers, and one *npn* junction transistor connected as a blocking oscillator, which is triggered when the proper code is received.

A block diagram of the transmitting station equipment used at Allentown is shown in Figure 3. The installation consists primarily of a memory bank, a tone generator and encoder, a director and identifier, and the radio transmitters. Except for the radio transmitter, the equipment in use at Allentown was manufactured by the Scantlin Electronics Company. The memory bank — which consists of 24 groups of rotary switches, four switches per group — is used for setting up the various codes. It is located in the operator's room at the Allentown central office. The other equipment is located elsewhere in the same building. The tone generator, as the name implies, supplies the nine precise audio frequencies used for signaling. These are all derived from a single crystal oscillator by using frequency-dividing circuits.

The encoder controls the scanning of the memory bank and the translation of the switch positions into a sequential code of the proper audio frequencies. To comply with FCC regulations, the identifier is used to send out the station call letters automatically at particular intervals. The director is used to route the coded audio signals to the various transmitters when more than one is necessary to obtain

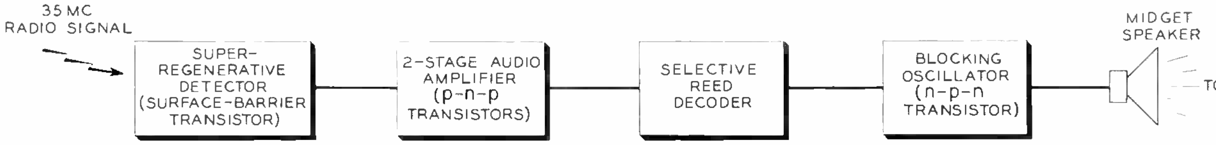


Fig. 2 — Block diagram of the receiving circuit employing four transistors.

satisfactory radio coverage of an area. Two 250-watt AM transmitters are used for the trial — one located in Allentown and the second in Bethlehem, Pennsylvania, about five miles away.

The service range varies, depending upon whether a customer is in an open area or is partially shielded

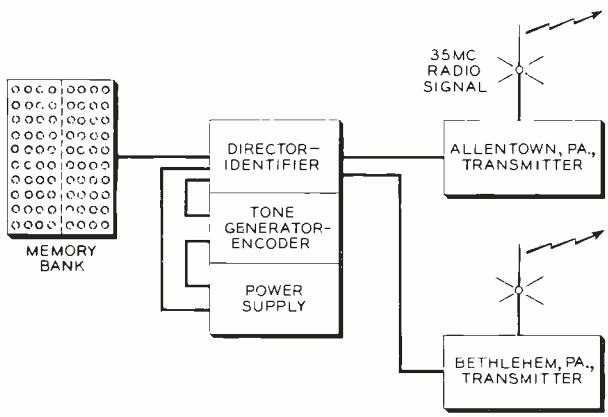


Fig. 3 — Block diagram of central office arrangements as used in Allentown-Bethlehem trial.

by a building or an automobile. It is estimated that ranges of about two to four miles from each transmitter will be experienced in the Allentown-Bethlehem area. This will be adequate to cover all of the business districts and the major portion of the surrounding suburbs. When larger areas are to be covered, it is expected that additional "satellite" transmitters will be employed.

Extensive studies and tests were conducted at the Laboratories in advance of the Allentown installation to establish the probable area of coverage and to realize the best performance possible from the equipment. Information on coverage was obtained by measurements of the field-strength of signals in Allentown and Bethlehem using measuring equipment shown in Figure 4. Special testing arrangements were devised whereby plant operating forces will be able to calibrate the sensitivity of the receivers and check performance in other respects.

Experience gained at Allentown has served to highlight those areas requiring further development. For instance, a number of improvements would be desirable in the central-office arrangements. In particular, the rotary switches now being used in Allentown to set up the codes have been found to be awkward and time consuming. Plans are underway to allow an operator to place a call by dialing the number or by using a conventional key set. This information will then be stored in relays and will be read out automatically by a scanning device. To compensate for variations in radio propagation, any given code may be transmitted approximately three times from each radio transmitter. At the end of the last of these transmissions, the code will be "wiped off" the storage unit, which will then be available for service to another customer.

Control facilities will be included so that a particular radio channel may be used exclusively for selective signaling, as in the Allentown area, or used jointly by selective signaling and standard two-way mobile telephone service. With this arrangement, the signaling calls will be transmitted only when the mobile telephone service is idle.

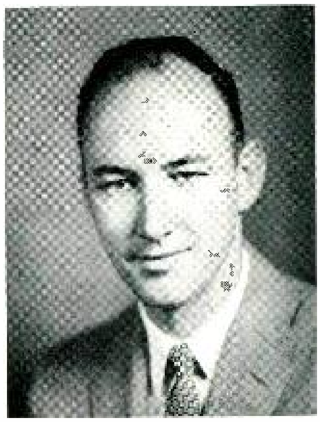
Fundamental study and development are also in progress to improve receiver performance. Much of this effort is aimed at the possibility of a transistorized receiver operating at 150 mc in conjunction with mobile telephone systems which operate in this frequency range. Preliminary studies have shown that these frequencies may be more desirable for the radio-paging type of transmission.

Fig. 4 — Tests performed in the Allentown-Bethlehem area. Portable antenna was used to measure the radio-frequency field strength of test signals.

At this frequency, however, receiver design problems become more severe. A higher order of selectivity and frequency stability will be required to avoid interference from other services operating in these bands. To achieve this selectivity and stability, crystal-controlled superheterodyne rather than super-regenerative circuitry will be required. Figure 1 shows testing of this type of receiver in the Laboratories. Because of the added complexity, appreciable effort will be necessary to achieve a sufficiently small and light-weight unit having an acceptable battery life. Study is also continuing on other signaling techniques using subminiature components which will operate at a faster speed and will permit more customers to be placed on a given radio channel.

The possibilities of this type of service are very broad, depending always, of course, upon customers' needs and upon the ability to engineer equipment within economic limits. The new art of solid-state electronics holds promise of reducing costs to this point.

THE AUTHOR



WALTER STRACK, a native of Long Island, received the B.E.E. degree from the Polytechnic Institute of Brooklyn in 1944. After graduation, he served in the U. S. Navy, where he engaged in the design of electronic weapons equipment for the Naval Ordnance Laboratory. Mr. Strack joined Bell Telephone Laboratories in late 1945, where he was initially concerned with work on mobile radio systems. Subsequently, he engaged in path-loss measurements preceding the first transcontinental TD-2 microwave radio-relay route, and he also spent about three years on a systems engineering study of a special military project. He then began systems engineering work on personal radio-signaling equipment, and is currently planning and evaluating new aspects of radio-signaling devices and systems. Mr. Strack is a member of the I.R.E. and of Eta Kappa Nu.

Bell Laboratories Members to Receive I.R.E. Awards

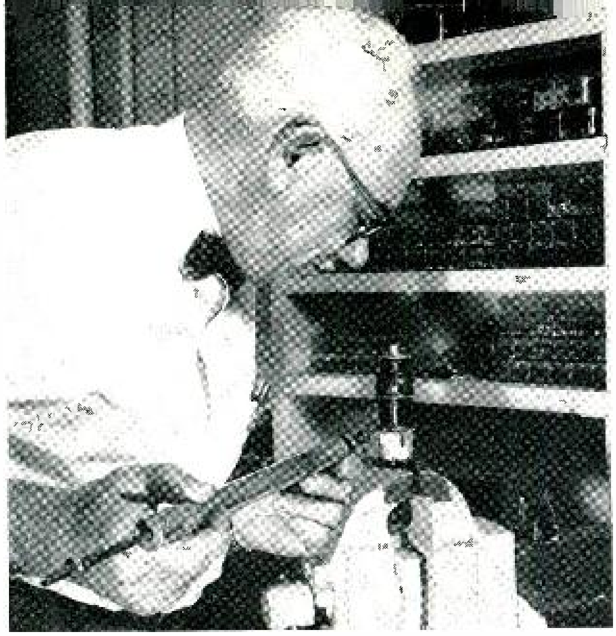
The Board of Directors of the Institute of Radio Engineers has named a number of Bell Laboratories members to receive awards in 1958. The I.R.E. has also announced that W. H. Doherty, Assistant to the President of the Laboratories, has been elected a Director of the I.R.E. for the 1958-1960 term.

Four members of the Laboratories and one retired member have been awarded the grade of Fellow of the Institute: M. L. Almquist, Director, Systems Engineering I, "for his contribution to the planning of telephone and radio systems;" A. C. Beck of the Radio Research Department "for his contributions to microwave antennas and transmission lines;" W. A. Marrison, retired member of the Laboratories, "for the achievement of high precision in the measurement of frequency and time by the use of piezoelectric materials;" S. E. Miller, Assistant Director of Radio Research at the Laboratories, "for leadership and invention in the waveguide art;" and W. M. Sharpless of the Radio Research Department "for research and development in the microwave field."

The grade of Fellow is the highest membership grade offered by the I.R.E. and is bestowed only by invitation on those who have made outstanding contributions to radio engineering or allied fields.

In the announcement of awards, the I.R.E. Board of Directors also named Arthur Karp of the Laboratories to receive the 1958 Browder J. Thompson Memorial Prize. This is to be given in recognition of Mr. Karp's paper entitled "Backward-Wave Oscillator Experiments at 100 to 200 Kilomegacycles" which appeared in the April, 1957, issue of the *Proceedings of the I.R.E.* The Thompson Prize is given annually to an author under thirty years of age for a paper recently published by the I.R.E. which constitutes the best combination of technical contribution and presentation of the subject.

The I.R.E., an international society of 62,000 radio engineers and scientists, will hold its 1958 National Convention in New York City from March 24 to 27. The Fellow awards became effective on January 1, and recognition of all awards will be made by the President of the I.R.E. during the convention.



New Ground Strip for Electron Tubes

Certain electron tubes used in carrier telephone equipment have metal shields which must be reliably connected to ground. A poor ground connection, or complete absence of a ground connection, will cause noise and/or crosstalk until the condition is remedied. Trouble of this type in a single equipment unit can affect a large number of telephone conversations.

These electron tubes are shielded by two sheet metal pieces formed to fit around the outside of the tube. The shields are connected to ground by "ground strips," one for each of the two shields. The ground strips are mounted on the socket at the mounting holes and press against the shields.

With the present 3A ground strip, shown in Figure 1, left, crosstalk resulting from a faulty ground connection is often difficult to trace because some of it is of an intermittent nature. The poor connection is caused by the fingers of these strips being overstressed. This can reduce the pressure to such an extent that there is little or no contact pressure against the shield. Because of the location of many of the tube sockets in the equipment, insertion of the tube and shields between the ground strip fingers is difficult. Locating the tube pins in their respective contact holes in the tube socket further complicates matters – tube pins frequently catch at the top and in the openings of the ground strip fingers when the tube is inserted at an angle, and the shields may snag on the edges of the ground strip when rotated to orient the pins. Any one or a combination of these conditions could result in impairment of the ground strip function. The tube and shields can only be inserted into the socket without snagging when there is a minimum of misalignment with the ground strip.

With the use of the new ground strip, shown in Figure 1, right, the troubles attributed to the old strip are precluded. This ground strip (coded the 7A) is made of two identical semicircular, tin-plated phosphor-bronze pieces curved to fit around the base of the tube socket. When assembled as shown, the pieces form a four-section ground strip mounted in the same manner as, and interchangeable with, the older one. The sections are designed to minimize the possibility of tube pins catching on the top or in the openings, unless there is a misdirection to the extent that one or more tube pins are outside the ground strip. The tube and shields cannot be put in at an angle because the four sections act as guides, and the sections also allow the tube and shields to be rotated to locate the pins in their contact holes without snagging. Such features are particularly advantageous when a person must reach to insert a tube in a location where he cannot see the socket. Because the individual sections are rugged and are not easily damaged, they insure a reliable ground connection.

A. W. Krueger
Switching Apparatus Development

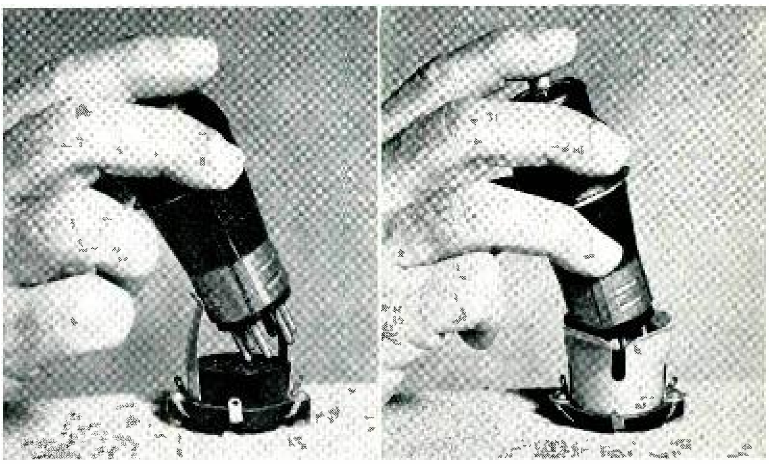


Fig. 1 — Left, the 3A ground strip; possibility of poor ground connections prompted new design. Right, the new 7A ground strip; contact pressure provides good ground connection, and tubes are easily inserted.

New Auxiliary Station Signals

The author installing an eight-inch gong in the protective metal case designed for indoor use.

When a telephone is located in a noisy environment, or is normally unattended, some type of auxiliary signal is usually necessary to call attention to an incoming call. Even with the ringing signal of a 500-type telephone set turned to its highest output, the sound level may not be sufficient to override shop or machinery noise or to summon someone from a distance out-of-doors.

Auxiliary station signals have been used in the Bell System as loud extension ringers for telephone sets for many years. They have also been used in code-calling systems for calling a particular person to the telephone and for multi-signal arrangements. To reduce the number of such signals now in use, new auxiliary signals which embody many improvements have been designed for universal application. These new chimes, bells, and horns allow for ease of manufacture, have a universal housing for easy installation and cover a wide range of sound output. The devices are generally powered by 115 volts, sixty cycles, but in special cases they can operate on lower voltages or direct current. The power is usually applied by an associated relay which is operated by twenty-cycle ringing current from the telephone line, or by low-voltage ac or dc power applied for local operation from PBX offices and key telephone systems.

The new signals, shown in Figure 2 together with oscillograms of their sound output, are a resonant horn, an eight-inch gong chime, a six-inch vibrating bell and a six-inch single-stroke bell. The bells are adjustable for sound output level, and the new six-inch size replaces the four-inch, six-inch, eight-inch and ten-inch bells now in use. All of the units, along with their associated relays, are housed in wall-mounted metal cases having an open grill front. The illustration at the head of this article, which shows the author installing an eight-inch gong in its metal case, also shows the case in some detail. For installation out-of-doors, the case is covered with a weather-protecting hood which has an opening at the bottom to radiate sound. Figure 1

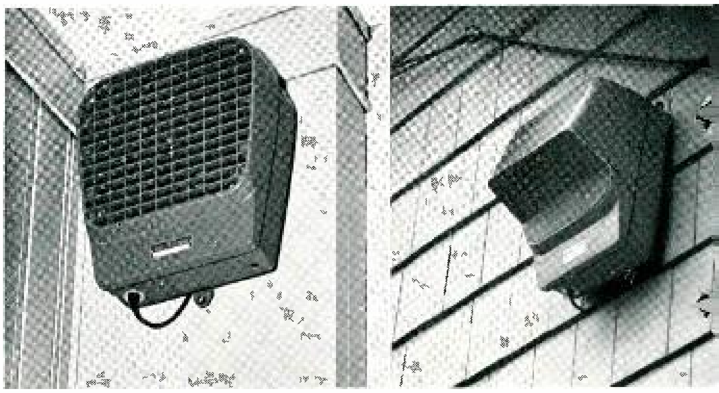


Fig. 1 — Interior (left) and exterior signal installations. Weather-protective hood shows on the exterior case.

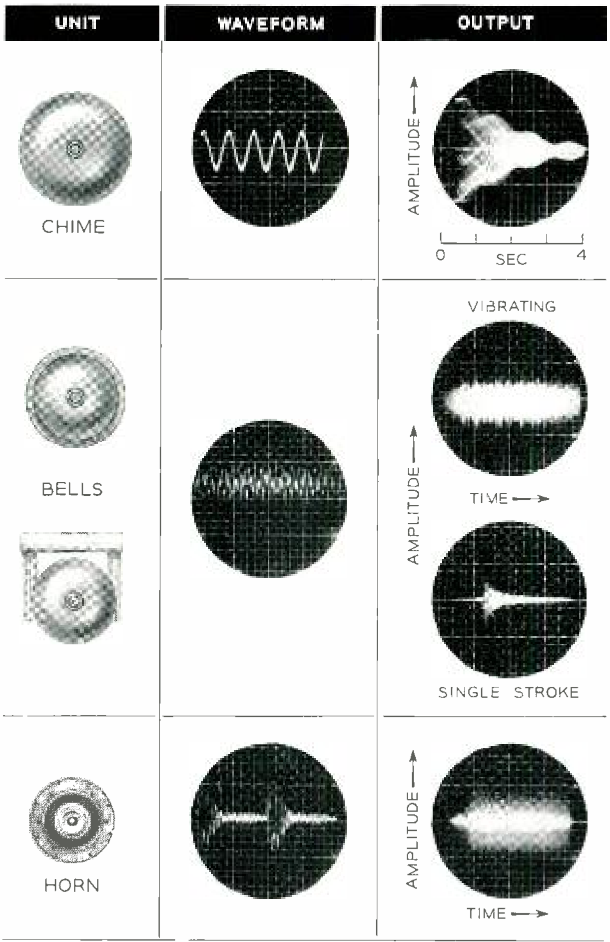


Fig. 2 — The new station auxiliary signals, shown with waveform and output oscillograms.

shows typical inside and outside installations. The signals and case are manufactured for Bell System use by outside suppliers in accordance with Bell Telephone Laboratories specifications.

The fundamental frequencies of the chime and bells are resonated to improve tonal quality, and in addition, the gong chime is selectively damped to suppress overtones, so that its signal approximates that of a bar chime. The fundamental frequency of the chime is nominally 250 cps and that of the bells 580 cps. Acoustic resonators of two types are employed. The chime and one form of the bells have internal resonators. These resonators, mounted underneath the gong, use the driving-mechanism housing. The other bells employ an external resonator mounted close to the gong rim. The signal horn employs a resonant-diaphragm assembly which is vibrated against the pole pieces of the driving magnet. This last unit produces a continuous noise spectrum peaked between 2,000 and 3,000 cps.

These station auxiliary signals are all intended for use as high-level sound radiators. The chime, single-stroke bell and horn are also used in code-

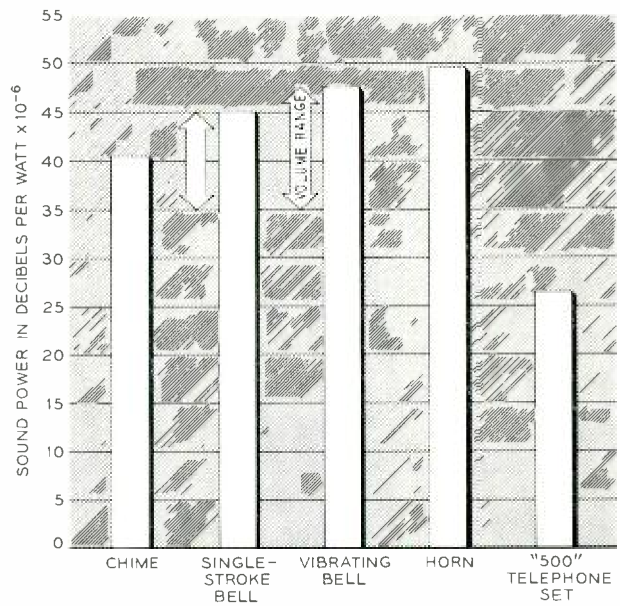
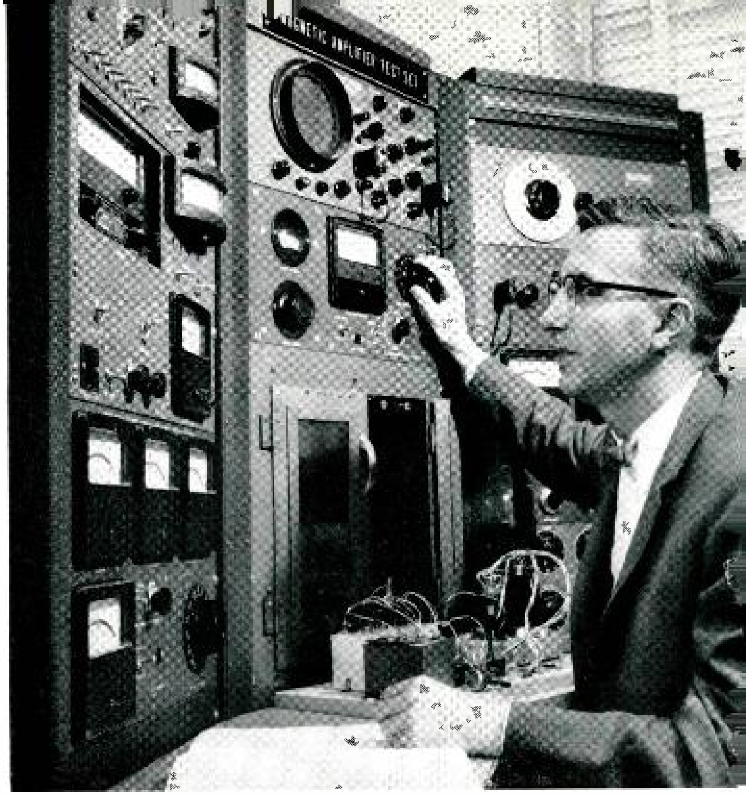


Fig. 3 — Bar chart compares the sound power output of the new signals to output of the 500 set.

calling systems. The relative sound power output of the new auxiliary signals is illustrated graphically in Figure 3. The chime and bells, because of their relatively low, resonated frequency, may be used where the signal from ringers having higher frequency tones is not heard satisfactorily because of impaired hearing. The horn, with a concentration of high-level signal energy in the 2,000- to 3,000-cycle frequency band, has greatest application in noisy environments.

R. T. Jenkins
Station Apparatus Development



Magnetic Amplifiers:

Basic Principles and Applications

L. W. STAMMERJOHN
Military Systems Development

Some of the most satisfying discoveries of all are re-discoveries. In electronics, a very significant re-discovery of the past twenty years has been the magnetic amplifier. The principles of this amplifier have been known for some time but new magnetic materials, modern circuitry and improved semiconductor rectifiers have brought this older art into new usefulness.

The magnetic amplifier is the oldest of the static amplifying devices currently in common use. It antedates the electron tube by more than five years and the transistor by more than forty years. Magnetic amplifiers and modulators were important in the early radiotelephone transmitting equipment developed by the American inventor, E. F. W. Alexanderson, in 1916.

Our current interest in the magnetic amplifier, however, dates from World War II. Experience gained during the war brought recognition of the inherently high reliability the magnetic amplifier shares with transformers and other magnetic devices. During the subsequent ten years, this experience has stimulated the development of a wide variety of devices which may be broadly classed as magnetic amplifiers. Also, the complexity of modern electronic equipment has encouraged an increasing use of magnetic ampliers because of their long life and low maintenance requirements.

Many different names have been given to the magnetic amplifier during the past thirty-five years. These include such terms as saturable reactor, transductor, and a number of trade names. In general, the term saturable reactor defines the nonlinear, magnetic-cored elements of a magnetic amplifier or defines those amplifiers which consist of a reactor element only.

The magnetic amplifier is usually designed for a specific application. It is not basically a substitute for other amplifying devices; it is, rather, a special though valuable adjunct to electron-tube or semiconductor amplifiers. The four most important advantages of the magnetic amplifier are: (1) The construction is rugged and simple. There are no moving or delicate parts involved, and the amplifier can be packaged to be both small and resistant to all types of adverse environment. (2) Efficiency is high since no heater power is required. This is especially true in smaller equipment where the heater power required for electron tubes is often many times greater than the amplifier output. Similarly, the internal heat generated and dissipated is generally negligible. (3) No warm-up time is required, so that the magnetic amplifier is immediately available. (4) The reliability is excellent throughout the life of the device. New core and rectifier materials, and the simplicity of construction, insure the continuous reliability of a well-designed amplifier.

This article is the first of a series of three dealing with magnetic amplifiers and their application and it covers some of the basic principles of magnetic amplifier operation and the basic circuits from which the more complicated amplifiers are built. It also considers the characteristics of the magnetic amplifier of most interest to the user; that is, the inherent capabilities and limitations of the device which govern its application.

Amplification is probably the most commonly used principle of electronics. Amplifiers, using the term generically, control the power delivered to a load by the application of a separate and much smaller quantity of control power. The ratio of the power delivered to the load to the control power is called the power amplification of the device.

An example of a simple amplifier is the triode electron tube. Here, current supplied to a load from a source of *direct current* is controlled by a relatively small voltage applied to the grid of the tube. In a sense, the triode is simply a controllable resistance between the plate voltage and the load. By contrast, the magnetic amplifier controls the current supplied to a load from a source of *alternating current*. It does not, however, provide this control by a simple controllable reactance or impedance inserted between the power source and the load.

Actually, the amplification principle of the magnetic amplifier is not at all analogous to electron-tube amplification except in the broad terms of the

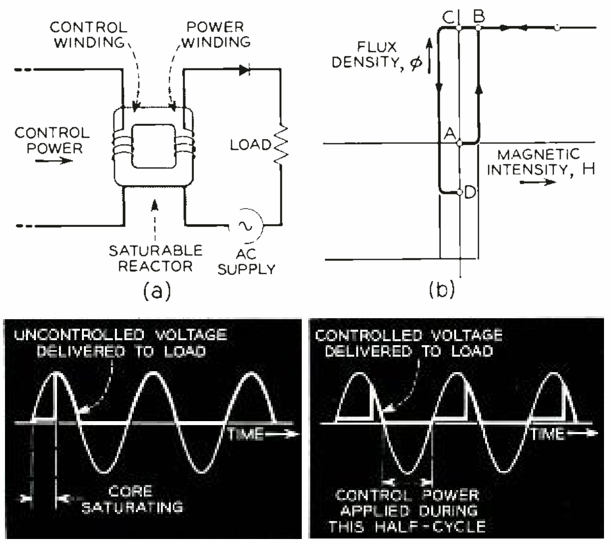


Fig. 1 — Diagrams used to explain the operation of the half-wave, self-saturating magnetic amplifier. The basic circuit (a), the rectangular hysteresis loop (b) of an ideal core, and the uncontrolled (c) and controlled (d) output waveforms.

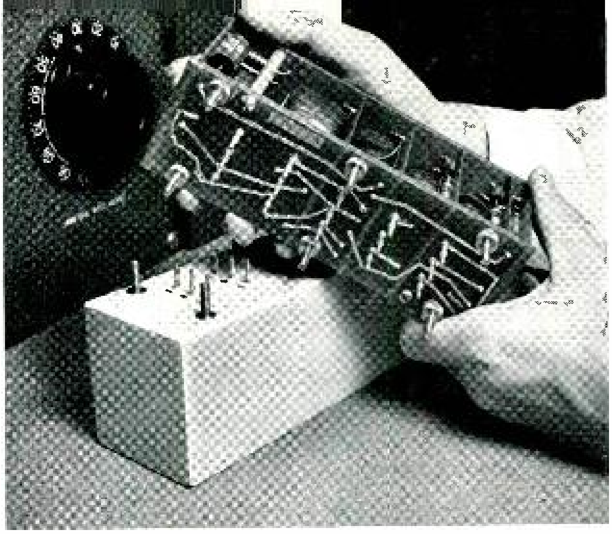


Fig. 2 — Servo magnetic amplifier showing interior construction and completed resin-filled casting.

definition given above. Very simply, it is a device designed to control the ac output power delivered to a load by, and as a function of, a much smaller quantity of control power. The easiest way to explain how the magnetic amplifier does this is to follow step-by-step the behavior of the basic circuit elements as the voltages are applied.

The simplest magnetic amplifier consists of a saturable reactor in series with a half-wave semiconductor rectifier. This basic circuit is shown in Figure 1(a). Power is supplied to the load by an ac source through the power winding of the saturable reactor. Control power is supplied by a separate source to the control winding of the reactor. For purposes of explanation, let us assume the circuit has perfect components. This means that the rectifier is a perfect switch with zero forward resistance and infinite reverse resistance, and that the saturable reactor has zero winding resistance and a core with a rectangular hysteresis loop. These conditions can be closely approached in practice.

Let us also assume that the electrical and magnetic action starts with no control voltage applied and the reactor core completely demagnetized. The core will then start saturating at point A on the dynamic hysteresis loop, Figure 1(b), as the power-supply voltage is increased from zero, in a direction to cause the rectifier to conduct. The flux in the saturable reactor will increase until the core is saturated at point B. This means that no further increase in flux is possible; thus, the voltage induced in the power winding of the saturable reactor suddenly drops to zero. With no reactance in its path, the entire power-supply voltage appears across the load for the remainder of the half-cycle that the rectifier is conducting. During the second half-cycle, the rectifier is nonconducting and the core returns to its remanent point, C. At the beginning of the third half-cycle, the magnetic state of the core remains at point C and no increase in flux is possible, so the power-supply voltage appears across the load for the entire half-cycle. Thus, unless control is introduced by means of the second winding, the core will remain saturated and have no effect on the power delivered to the load. A waveform of the uncontrolled power delivered to the load is shown in Figure 1(c).

With the simple action of the circuit elements established, let us proceed with the method of control. If, during the nonconducting half-cycle of the rectifier, a voltage of proper polarity is applied to the control winding of the saturable reactor, the flux in the core may be changed to some value between positive and negative saturation. The amount of flux change is determined by the amount of control voltage applied during the nonconducting half-cycle. Let us say that the control voltage applied is sufficient to reset the flux to point D. On the next conducting half-cycle, the flux in the core must be changed from D to B before the entire power-supply voltage is delivered to the load. The time required for the core to saturate is a function of the power-supply voltage and the reset level, point D, so that if the same control voltage is applied to the control winding each nonconducting half-cycle, the controlled, steady-state condition shown in Figure 1(d) becomes the amplifier output.

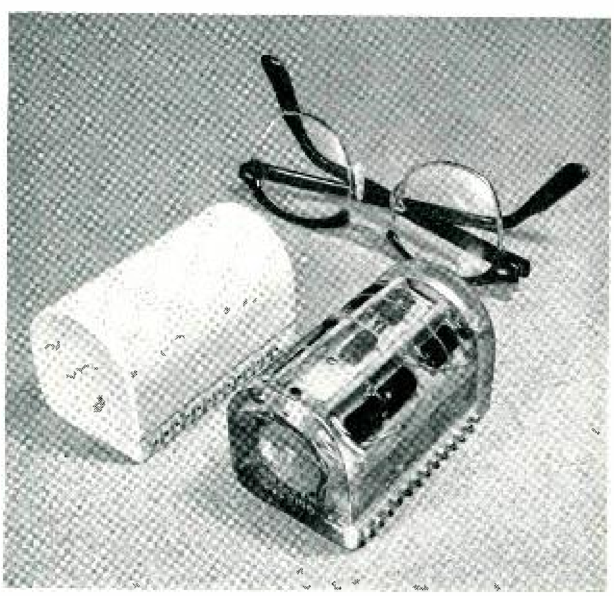
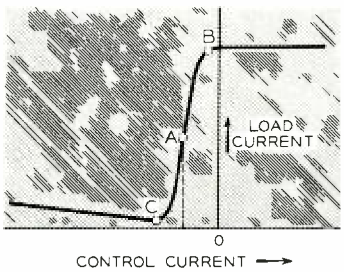


Fig. 3 — Servo amplifier packaged in clear plastic shows details of circular arrangement of components around cores. Glasses illustrate size.

The mechanism of control is thus established. This mechanism is composed of three important, sequentially related elements: the control voltage, the value to which the flux is reset, and the time conduction starts. The amount of control voltage applied determines the value to which the flux is reset in non-conducting half-cycles. This value of reset

Fig. 4 — Transfer characteristic, in terms of current, of a magnetic amplier of the self-saturating type.



flux in turn determines the time at which conduction commences in the conducting half-cycles. Finally, the time that conduction starts determines the values of current that will be delivered to the load. By lumping all of the elements of control into one term — control voltage — we can define the control action of the amplifier rather simply as follows. One voltage — the control voltage — exercises control over a second voltage — that appearing across the load — which does not resemble the first in form. The difference between the two power levels may be several orders of magnitude.

The time sequence of the control action — inserting control during one half-cycle and delivering the controlled voltage to the load during the next half-cycle — is a characteristic of all self-saturating magnetic amplifiers. This means that there is a fixed delay between the instant control voltage is applied and the controlled, load-voltage output. For this reason, some magnetic amplifiers are described as half-cycle (the delay limit) response amplifiers. Other delays may be added in the control circuit, but the delay cannot be reduced to less than one half-cycle of the power-supply frequency. This characteristic may limit magnetic amplifiers for some applications, but if a specific response time is required, it can theoretically be obtained by increasing the power-supply frequency until the desired response time is greater than one period of the power-supply frequency.

Amplifiers may be built with output powers rated from a fraction of a watt to kilowatts. In general, the magnetic amplifiers designed at the Laboratories for both Bell System and military applications have output power ratings between 0.1 watt and 1,000 watts. Control power may be as low as 10^{-12} watts.

An experimental single-stage amplifier has been built in the Laboratories with a power amplification of 10^9 or 90 db. Single-stage power amplification, however, is usually 1,000 or less.

The output of a magnetic amplifier generally has the waveshape shown in Figure 1(d). This output is not normally filtered, since the devices which magnetic amplifiers work into are usually designed to operate on the average value, or the rms value of the output voltage.

In the literature on other types of amplifiers, what we have defined as the "control voltage" is often referred to as "input voltage," or perhaps more generally, "signal voltage." For most magnetic amplifier applications, the relation between input (control) and output quantities is expressed for convenience in terms of currents rather than voltages. A typical current transfer characteristic is shown in Figure 4. Maximum output current is limited by the value of load resistance, and minimum output current is limited by the exciting current of the saturable reactor. The control quantity is the summation of control ampere-turns, indicating that a number of control windings can be closely coupled and used concurrently. For zero or positive control values, the output current is maximum. With increasingly negative control values, the output current decreases to a minimum — point C on the characteristic plot. Beyond this point, the output again increases.

The steep slope between points C and B on Figure 4 represents the region of greatest amplification and is the normal operating region of the quasi-linear amplifier. By means of additional control windings, bias values of control can be set at points such as A to permit operation somewhat similar to that of class A electron-tube amplifiers. Biasing in the vicinity of point C will result in operation similar to Class C electron-tube amplifiers.

The half-wave magnetic amplifier as a building

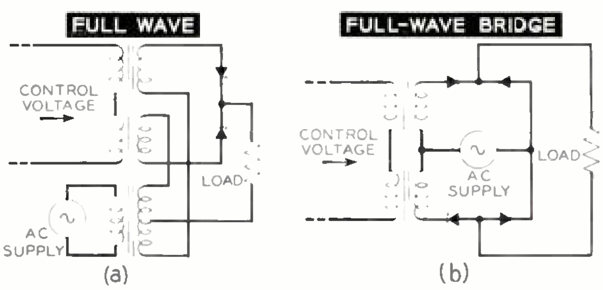


Fig. 5 — Simplified circuit diagrams of two common magnetic amplifier arrangements — the full-wave circuit (a), and the full-wave bridge circuit (b).

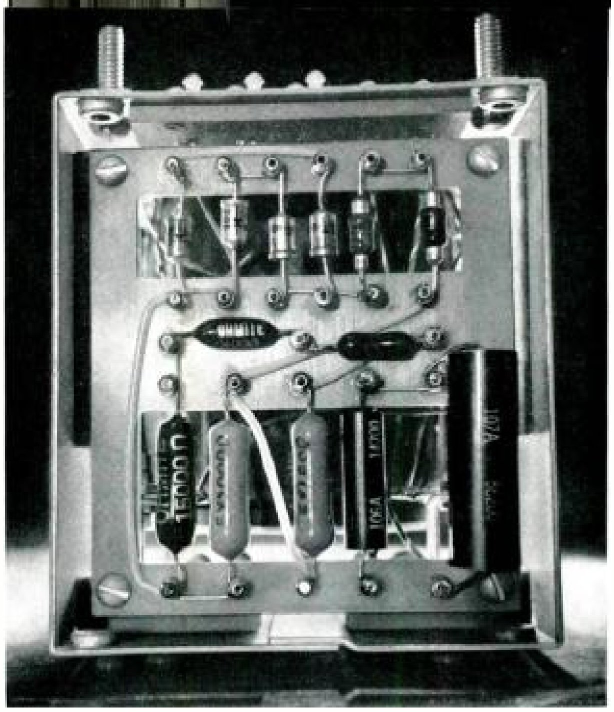


Fig. 6 — Magnetic amplifier used in TJ radio-relay power supply. Components along top row of mounting board are miniature semiconductor rectifiers.

block may be combined into a number of basic circuits. Most common circuits combine two half-wave elements with control and power circuits connected to reduce greatly the coupling between the power supply and the control circuit at the fundamental power frequency.

One such circuit, known as the full-wave circuit because of its resemblance to a full-wave rectifier, is shown in Figure 5(a). This circuit delivers a rectified alternating current to the load. The center-tapped transformer is required to provide voltages 180° out-of-phase to the two saturable reactors. The full-wave circuit is generally used when working into resistive loads or when available signal power is small. This basic amplifier circuit is often incorporated into power supplies, multistage amplifiers and balanced modulator arrangements.

The second of these circuits, known as the full-wave bridge circuit, is shown in Figure 5(b). This circuit employs four rectifiers instead of two, but does away with the need for a special power-supply transformer. The arrangement of rectifiers at the right provides a path short-circuiting the load for current flow in one direction. This proves useful when the load includes inductance as well as resistance. The control provided by a magnetic amplifier requires interruption of the load current for a portion of each half-cycle, and ordinarily inductance in the load circuit materially interferes with this process. In this circuit, however, these same rectifiers provide a path independent of the saturtor tubes* and point-contact rectifiers capable of efficient operation in this new band.

It is the purpose of this article to describe the point-contact silicon rectifier designed for such application. The rectifiers discussed here are referred to as "wafers" because they are flat and thin like a wafer, in contrast with the conventional round-cartridge or coaxial-type point-contact rectifiers used for longer waves.

Figure 1(a) is a drawing of the wafer-type millimeter-wave rectifier. The frame of the unit is made from stock steel 1/16 inch thick and is gold plated after the milling, drilling and soldering operations are completed. The silicon end of the rectifier consists of a small square of heat-treated boron-doped silicon, pressed into the end of an insulated copper rod. (See illustration on previous page, which shows S. E. Reed performing this operation.)

The assembly is held in place with a bonding resin which also serves as the insulating material needed for a two-micromicrofarad by-pass capacitor. This by-pass capacitor prevents loss of millimeter wave power but allows the direct and intermediate-frequency current to pass through the output lead. The point-contact spring, which makes contact with the silicon, enters from the opposite side of the 0.031 inch by 0.234 inch rectangular slot, which forms a short section of waveguide, with the rectifier located directly across the transmission path from top to bottom. A single rectifier, with its bypass capacitor and a short section of waveguide, is thus contained within each wafer unit, and when a rectifier is removed from a circuit, the entire wafer assembly is withdrawn. An enlargement of the region containing the point-contact area only is shown in Figure 1(b).

* Record, *July*, 1957, *page* 241; *May*, 1955, *page* 173.

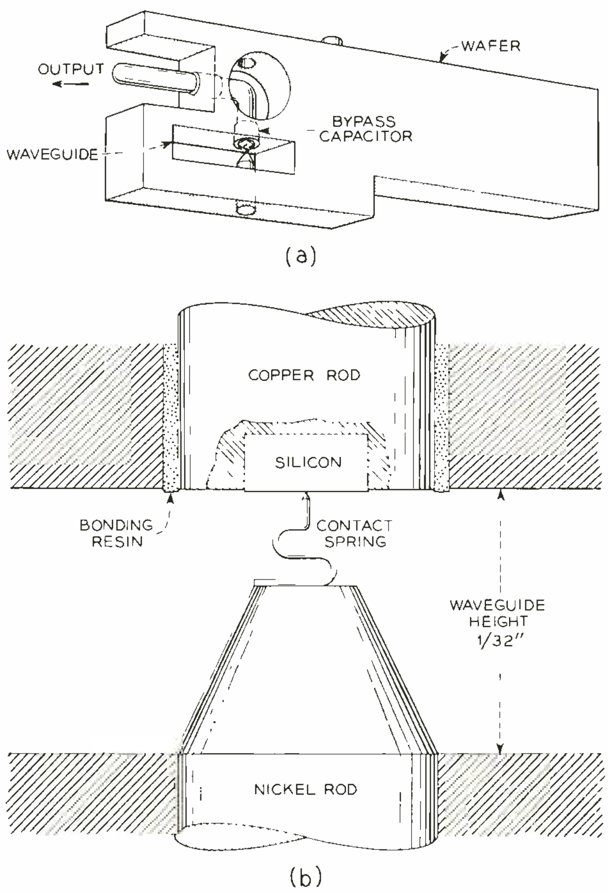


Fig. 1 — (a) The wafer unit for rectification of millimeter waves; (b) enlarged detail of point-contact area of the millimeter-wave rectifier.

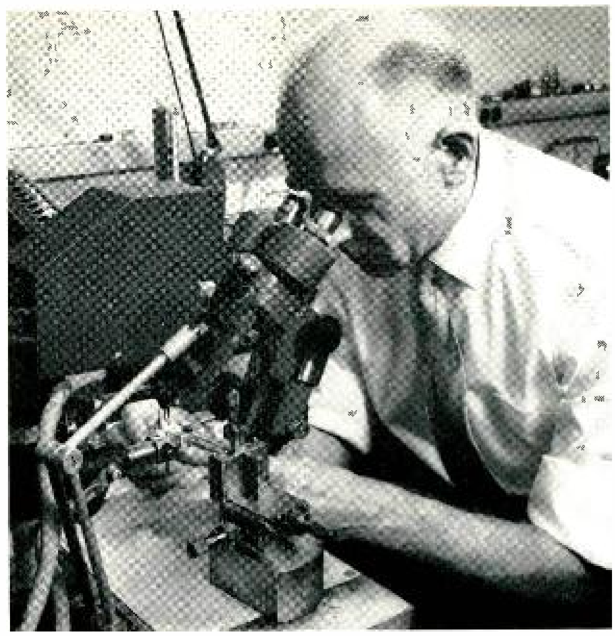


Fig. 2 — E. F. Elbert performing intricate welding operation in laboratory assembly of wafer units.

An exploded view of the holder designed to use the wafer rectifier units is shown in Figure 4. At the input end of the converter block there is a short waveguide taper section used to match from standard waveguide (RG98U) to the 1/32-inch high waveguide used in the wafer unit. As the wafer unit is moved in and out of the slot to match the resistive component of the rectifier's impedance to the waveguide, the output pin of the wafer unit slides in a chuck on the inner conductor of the coaxial output jack. To clamp the unit in position after matching adjustments are made, the knurled thumbscrew is tightened. This pushes a cylindrical slug, containing an adjustable piston, against the wafer unit.

The piston is a short septum which slides in shallow grooves in the top and bottom of the 1/32-inch high waveguide, thus dividing the waveguide into two guides which are beyond cut-off. The septum is made of two pieces of thin beryllium copper bowed in opposite directions so that good contact is made to the sides of the grooves in the top and bottom of the waveguide. Since the piston with its connecting rod is very light in weight and is held firmly in place by the spring action of the bowed septum, no additional locking mechanism need be provided. And, since the rectifier is essentially a broadband device, the adjustment of the piston is not critical and is readily made by hand.

After the two simple tuning adjustments of the piston and sidewise position of the wafer are made, the entire assembly is locked in place, and the unit is ready for operation. When it is necessary to insert a replacement rectifier, the thumbscrew is loosened one-quarter turn, the old rectifier is withdrawn, and a new rectifier is inserted and rematched. The complete replacement takes but a few seconds.

Earlier coaxial-type millimeter-wave rectifiers were mounted in a fixed position in their mixer holders, and they usually required adjustment of several interacting matching probes before the device could be brought into tune. These probes, which are like several little tuned circuits, generally absorb power and narrow the operating band. They are also difficult to adjust and they tend toward instabilities. The sidewise adjustment allowed for with the new wafer-type millimeter rectifiers has eliminated the need for such probes, and complete matching is achieved with two simple and positive broadband adjustments.

A pilot group of one hundred of these units has been fabricated at Holmdel to determine the practicability of the design and to obtain a sample of sufficient size to yield representative test data. Measurements made of this pilot group yielded the performance data given in the bar graphs of Figure 4. Figure 3(a) shows the distribution of the signal conversion loss "L" associated with the conversion of the signal to a 60-megacycle intermediate frequency for amplification. Figure 3(b) gives the rectifier's noise output "N_R" which is the ratio of the noise power available from the rectifier to the noise

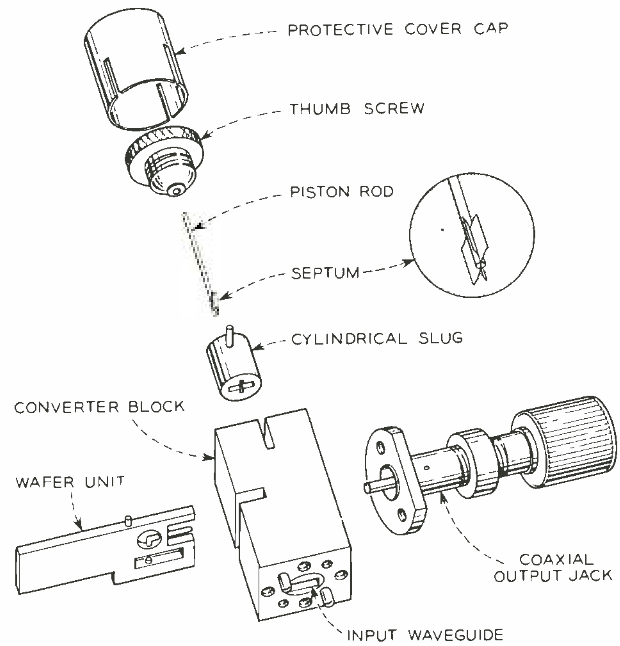


Fig. 4 — Exploded view of the new converter.

power available from an equivalent resistor at room temperature. The output impedance of the rectifier at the intermediate frequency of 60 mc, "Z_{IF}" is given in Figure 3(c). From the bar graphs it may be seen that the wafer units have the following average performance characteristics at a wavelength of 5.4 millimeters:

Signal conversion loss "L" . . . . . 7.2 db (5.3 times)
Output noise radio "N_R" . . . . . . 2.2 times
IF impedance (60 mc) "Z_{IF}" . . 338 ohms

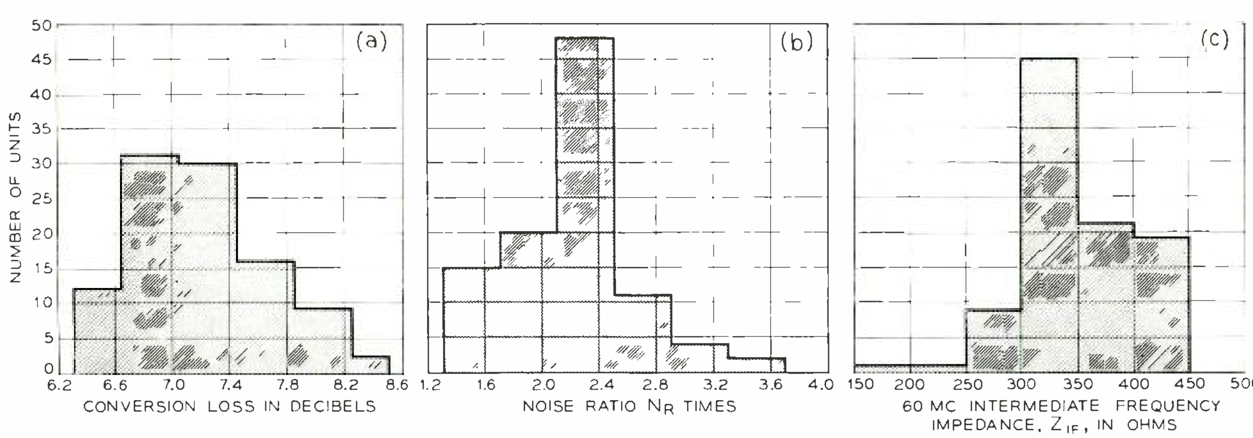


Fig. 3 — Graphs show how pilot group of 100 wafer units varied in (a) conversion loss, (b) noise ratio, and (c) intermediate frequency impedance. Receiver with such rectifiers has good input noise figure.

Fig. 5 — Balanced mixer using two wafer-type rectifiers. This unit cancels noise sidebands.

These figures mean that an average millimeter-wave double-detection receiver operating with these rectifiers will have an input noise figure (the ratio of the available signal-to-noise power at the receiver's input terminals to the available signal-to-noise power at the receiver's output terminals) of between thirteen and fourteen decibels, which compares favorably with noise figures commonly obtained in the super-high frequency range.

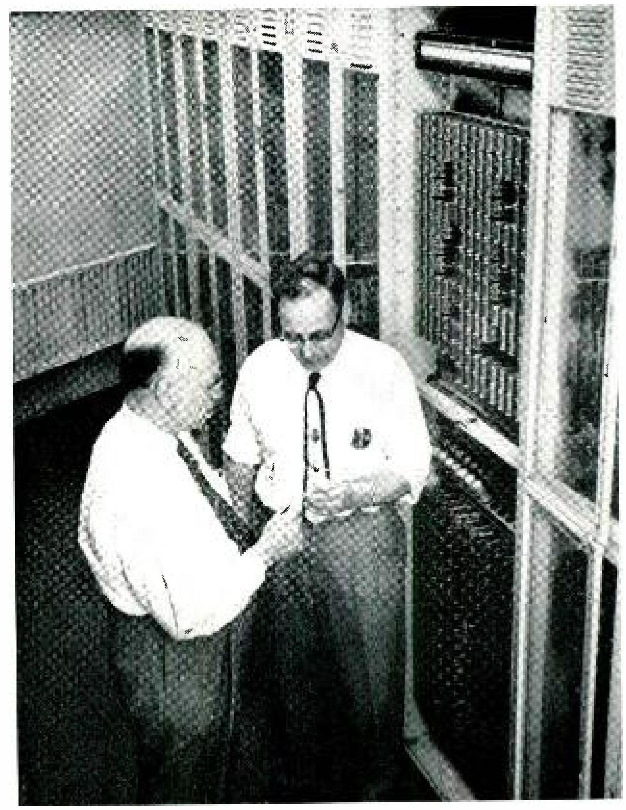
The above figures can be realized in practice if a balanced mixer is used at the input of our receiver. The balanced mixer uses two rectifiers rather than one so that it becomes possible to cancel certain objectionable noise side bands from the beating oscillator; these noise side bands are especially pronounced at millimeter waves. Figure 5 is an illustration of such a mixer. The two small rectangular waveguides, shown extending toward the upper right and the lower right of the photograph, are the inputs for the signal and for the local beating oscillator. The connections for the intermediate or difference frequency output circuit are made through the two parallel output jacks extending toward the upper left in the photograph. The handle-ends of the two wafer rectifiers are shown extending downward toward the lower right on either side of the input waveguide for the beating oscillator.

With point-contact rectifiers in a balanced mixer, there is a distinct advantage circuit-wise in employing two units of opposite polarity. For this reason, a reversed-polarity wafer-type rectifier has also been developed. This was done by interchanging the silicon and the point-contact spring in an otherwise standard unit. The standard and reverse-type wafer units have the same outer physical dimensions, and thus they may be used interchangeably in the holders as dictated by the specific problems at hand.

This project has been part of a broad attack by the Laboratories, aimed at a better understanding of the many new problems involved in building a communication system intended for operation in the millimeter-wave band. The experience gained in working with the millimeter-wave wafer-type rectifiers will be most helpful in designing new fast-acting switching and detecting types of rectifiers that will surely be needed in the future. Bell System projects of tomorrow seem destined to make very extensive use of miniature point-contact rectifier devices similar to the millimeter-wave wafer unit.

THE AUTHOR

W. M. Sharpless was born in Minneapolis, Minnesota, and received the B.S. degree in Electrical Engineering in 1928 and the E.E. degree in 1951, both from the University of Minnesota. He joined the Radio Research Department of the Laboratories in 1928, working for several years on numerous problems associated with transatlantic short-wave radio reception. He has also been concerned with studies of the angle of arrival of microwaves and the design of artificial dielectrics and microwave antennas. More recently he has been associated with research studies having to do with point-contact silicon rectifiers and low-level power measurements in the millimeter-wave field. Mr. Sharpless is a member of the Scientific Research Society of America, the American Physical Society and a Fellow of the I.R.E., and is also a member of the I.R.E. Professional Group on Microwave Theory and Techniques.



As the telephone art advances, digital-computing techniques are contributing more and more to the design of switching mechanisms. One such computing function, for example, is the subtraction of time values necessary for Automatic Message Accounting. Novel use of non-decimal "bisexenary" networks and other digital computing circuits has improved the speed and efficiency of the AMA Assembler-Computer.

Computing in the AMA Assembler-Computer

T. C. REHM *Telegraph and Special Systems Development*

In an Automatic Message Accounting System, time notations formerly handled by operators are recorded and processed automatically. In principle, the computing arithmetic in this system is quite simple: the time the completed telephone call is disconnected minus the time the call was answered equals a duration of time from which a "charge time" is derived. The notations of time appear on punched paper tapes, which are processed by an AMA Assembler-Computer.* This unit automatically computes charge time, and also computes message-unit charges for calls that are billed on the basis of multiples of a standard charging unit.

The "reader" of the assembler-computer encounters the time entries on the tape and "reads" them into the machine, which stores the data on "assembling registers." Subsequently, the information is transferred to the computer frame of the equipment, where the two time entries are translated into a form suitable for computation. The charge time is then used by the assembler-computer for determination of message-unit charges. Determination of charges for long-distance calls, also based on the charge time, is performed in subsequent processing stages of the information.

In the assembler-computer, time values are registered in hours, minutes, and tenths of minutes. Hours are expressed in tens and units starting with 00 at midnight and proceeding consecutively to 23 for 11:00 P.M. Minutes are also expressed in tens and units from 00 to 59. Thus, an entry registered in the machine as 14:35.8 is interpreted as "35 and 8/10ths minutes past 2 P.M." For ease of description, names are given to the constituent digits of such a number: *hour tens* (1), *hour units* (4:) *minute tens* (3), *minute units* (5) and *minute parts*

* RECORD, *October*, 1957, *page* 423.

tinue this process to get the 5 x 5 square detached-contact array seen as Figure 3. By following the proper vertical and horizontal lines in this array, we trace the subtraction of any digit 0-4 from any other digit 0-4.

Figure 3 also includes a detached-contact representation of the "borrow" and "no borrow" functions of bi-quinary subtraction. These functions derive from the borrowing required in ordinary arithmetical subtraction, and typical computer circuitry for this purpose is illustrated in Figure 4. In this schematic, additional contacts are shown on relay A1 to handle the subtraction "zero minus one." In such a case (minuend greater than the subtrahend), the rules for subtraction ordinarily require that we borrow a one (actually a ten) from the adjacent column so that we can subtract "ten minus one equals nine." In the bi-quinary network of Figure 4, however, the circuit borrows a five so that the computation is "five minus one equals four."

When borrowing is not required (for example "four minus one", "three minus one", and so forth), the "no borrow" lead is grounded. When a borrow is required, as in "zero minus one", the "borrow" lead is grounded. Thus, one network electrically informs the next whether a borrow is needed. Figure

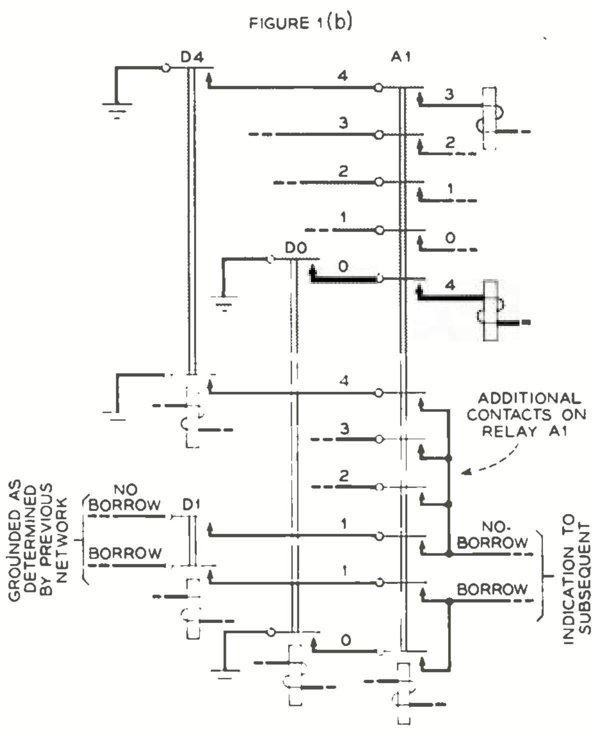


Fig. 4 — Contacts added to the A1 relay of Figure 1 (b) to handle the borrow and no borrow functions of the AMA assembler-computer circuits.

4 also shows two more "borrow" and "no borrow" contacts in the right part of the illustration. These are to take care of the situation in which the two digits to be subtracted are equal. If subtraction in

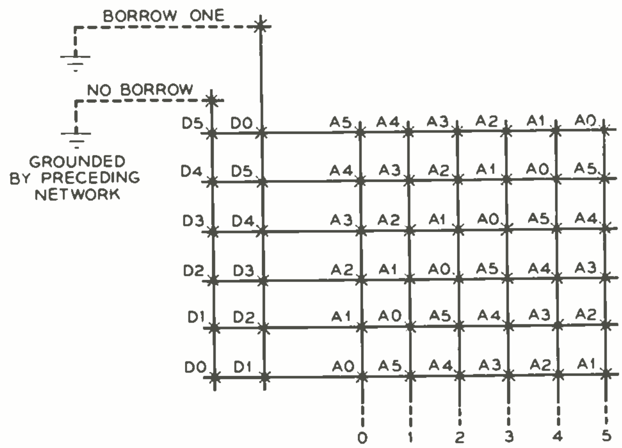


Fig. 5 — A 6 x 6 detached-contact array representing duodecimal subtraction analogous to the decimal subtraction of Figure 3.

the previous column has not required a borrow, then subtraction of two equal digits give the result "zero". If, however, the previous subtraction has resulted in a borrow, the two digits will now no longer be equal, and a subsequent borrow will be required. The additional "borrow" and "no borrow" leads anticipate these eventualities in arithmetical calculations.

To this point, the discussion has concerned bi-quinary subtraction using the 5 x 5 array of detached contacts, and it is evident that representing a sexenary computation merely involves the drawing of a 6 x 6 array. This is shown as Figure 5, which is typical of the assembler-computer circuits involved in bi-sexenary or duodecimal subtraction (for hours and minute tens). In both the bi-sexenary and bi-quinary circuits, the associated "borrow" networks have somewhat more contacts than the "square" arrays. Also, in both circuits contact arrangements are provided for the binary elements of the digits. These are similar to the borrow networks but have a smaller number of contacts.

In this simplified description, a number of additional computing functions have been omitted. A complication is encountered, for instance, if a call is placed just before midnight and is concluded just after midnight. The subtraction to be performed might then be something like 00.02.5 minus 23:55.2. In such case, the circuitry in effect borrows a full day to achieve the correct computation.

Among other digital computing features involved in these circuits, a translation is required prior to computation in a bi-sexenary unit. The reason for this is that hours and minute tens are registered as decimal entries and must be translated into their duodecimal equivalents. Also, at another stage of the computations, a "rounding-off" operation is sometimes required in the treatment of minute parts. In addition, "formula circuits" are required when the arithmetical result of a subtraction is to be used to determine message-unit charges. These formula circuits are similar to those used in the AMA computer,* but are improved by designing them as "plug-in" units. This feature is of great convenience when circuits must be altered to accommodate changes in rates. Finally, the assembler-computer circuits are arranged to save computation time as much as possible. A subtraction can be performed in the time required for only two relays to operate. Such computation speed is one of the main reasons for the fast and efficient operation of the assembler-computer.

Fast computation is also aided by the use of mercury relays, which operate at high speed and which have high-resistance windings. Advantage is taken of both of these characteristics for the borrow relays. For some time values, the windings of as many as eight borrow relays are in parallel, and if the low-resistance general-purpose relay were used, a high current overload would result on the contacts of other relays of the computer network.

The AMA assembler-computer is thus seen to be a specialized digital-computing machine which is a significant element in supplying high-speed, efficient, and automatic telephone service. Besides its utility in this particular AMA application, it illustrates the continuing trend in the telephone industry toward applying digital techniques to the problems of communications.

* RECORD, *July*, 1952, *page* 289.

THE AUTHOR

T. C. REHM, a native of Haledon, N. J., joined the Laboratories upon graduation from Cornell in 1937 with the degree of Electrical Engineer. He was initially associated with testing and development of step-by-step and manual switching systems, and during World War II he transferred to the Transmission Development Department, where his work was concerned mainly with pulse modulation and carrier systems. After the war, he spent a short time on a project studying relay contact life, and he later became a member of a group developing circuits for the AMA accounting center. About 1950 he engaged for a time in the development of circuits for CAMA in crossbar tandem offices, subsequently returning to accounting center development, where his work mainly concerned the assembler-computer. Mr. Rehm is now engaged in developing circuits for SAGE. He is an Associate Member of the A.I.E.E. and a member of Eta Kappa Nu.

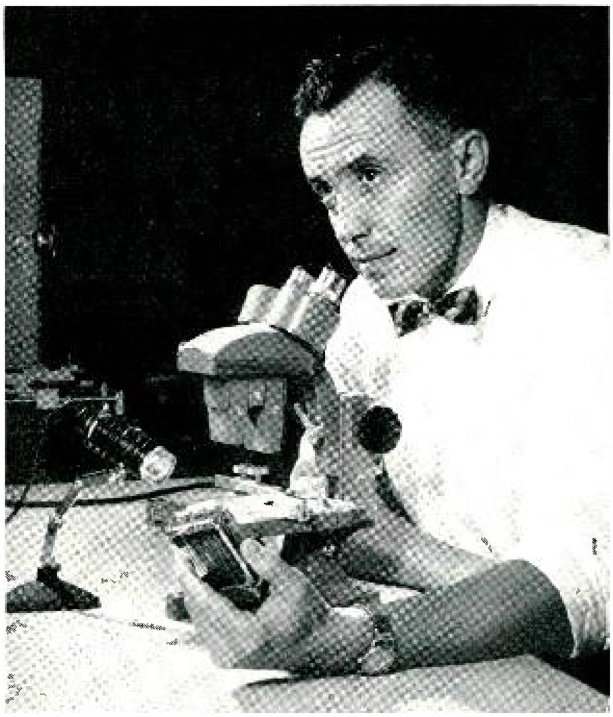
G. H. Wannier Participates in Physics Study Program

G. H. Wannier of the Physical Research Department at the Laboratories recently visited the University of New Hampshire under the auspices of American Institute of Physics and the American Association of Physics Teachers. The visit, during late November, was part of a broad nationwide program to stimulate interest in physics.

Mr. Wannier received the Ph.D. degree in Mathematical Physics from Basel University, Switzerland, and was a Swiss-American exchange fellow at Princeton. He has been a consultant in the Office of Field-Service, Office of Scientific Research and Development, and is a Fellow of the American Physical Society. His research has been in the fields of molecular and crystal structure, ferromagnetism, statistical mechanics, gas discharges and electron physics.

While at the University of New Hampshire, Mr. Wannier gave lectures, talked with students and assisted faculty members with research problems in physics. The visit was made possible by a grant from the National Science Foundation.

A New Method for Cleaning Wire-Spring Relays



R. W. MacDONALD *Component Development*

H. W. HERMANCE *Chemical Research*

High quality telephone service — a constant aim of the Bell System — depends on attention to the many minute details affecting telephone operations. Sometimes these details are as minute as fine particles of dust, since contamination on relay contacts can cause contact failures. To combat this problem, a Laboratories' study of both the contaminating conditions in the manufacturing environment and the most modern cleaning methods has resulted in an entirely new approach to the cleaning of wire-spring relays.

A modern No. 5 crossbar central office serving 10,000 customers uses about 40,000 general purpose wire-spring relays. These relays may make a hundred billion contact operations per year. If the contacts have non-conducting or high-resistance foreign matter on their surfaces, operational trouble may result because of "open" contacts. Laboratories engineers have studied open contacts by the plastic replica method,* and have found that certain contaminants (phenol fiber, gummed oils, rosin particles, and others) of manufacturing origin persisted on the contacts through several years of operation. Detailed examination of the plastic replicas often shows that one of the twin contacts has been inoperative throughout this period, thus reducing the security margin built into the relay. To minimize this contamination, the wire-spring relay contacts are cleaned after manufacture and then protected from dust by individual covers over the contact portion of the relay.

* Record, *August*, 1956, *page* 289.

Formerly, dust was air-blasted from the relay contacts into an exhaust throat. An alternative method was to flush the contacts in a bath of condensing trichlorethylene vapor. These methods are fast and economical, but they are not very effective in removing contaminants or particles that are plastic enough to "lock" into contact irregularities. Also, modern telephone circuitry demands higher relay speed and greater sensitivity, both of which are improved by lower contact forces. These lower forces in turn necessitate cleaner contacts to insure reliability. The increasingly widespread use of general purpose wire-spring relays presented an opportunity to find a new cleaning method that would effectively clean the contact surfaces. The Laboratories, with the cooperation of the Western Electric Company, undertook an investigation of various cleaning methods.

The first step was to determine the types of foreign matter encountered during manufacture. Studies were made of the contact surfaces as they progressed through various stages of manufacture, and a variety of contaminants was observed. Some were derived from non-specific external sources such as mineral and cinder particles, pollen and woody tissue. Other contaminants were peculiar to the manufacturing environment; among these were gummed and carbonized oil, rosin, textile fibers and phenol fiber fragments, and foreign metals including copper, nickel, lead and iron.

The most prevalent contaminant found on assembled relays was phenol fiber dust, produced when cards and insulators used in the relay are punched. Such dusts are transferred to the contacts during assembly in two ways: by direct contact from the workers' fingers, and by settling from the surrounding air. To reduce this source of contamination, Western Electric engineers designed and built a special cleaning machine for the phenol fiber cards. After the mechanical operations are finished, the cards are scrubbed by rotating, nylon-bristled, pencil-shaped brushes, and the phenol particles are exhausted by an air jet.

The next most prevalent contaminants are the various fibers derived from clothing, paper products, and the abrasion of wood surfaces. Such materials have so many origins that their control is difficult. External dusts entering through open windows and oil mists given off during metal machining operations were likewise found difficult to control. In view of these environmental conditions, the best approach to the problem seemed to be

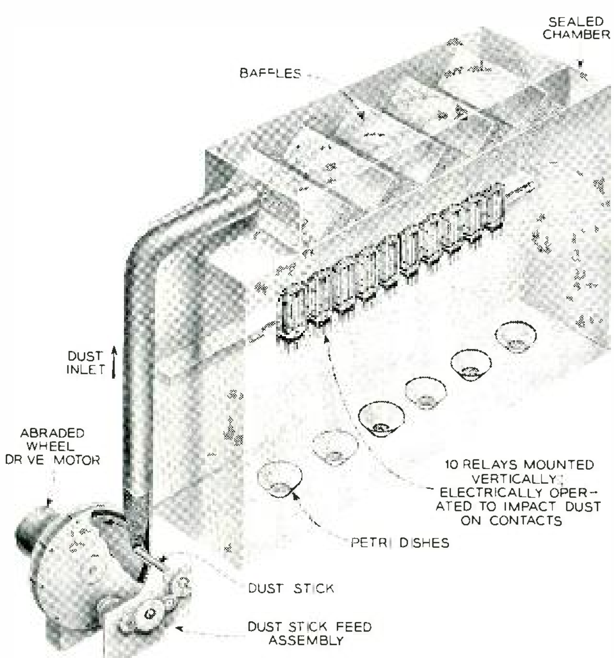


Fig. 1 — The dust box and dust generator, illustrated in phantom and partially cut away.

Fig. 2 — A. H. Yeager inserts a dust stick in generator for laboratory studies of contamination.

an effective cleaning of each relay immediately before putting on the protective cover. Although it is easier to clean the individual piece parts of the relay, cleaning assembled relays proved more effective against foreign matter picked up subsequent to piece-part manufacture and assembly.

On the wire-spring relay, the parts to be cleaned are those enclosed by the contact cover. Special emphasis in the cleaning is centered on the contact surfaces, and on the armature and surfaces against which it makes contact when operated and released. Adjacent surfaces are important because tacky foreign matter on these surfaces can cause the armature to stick. Although such failures are encountered very rarely, it seemed a worthwhile precaution to include these surfaces in the new cleaning method. Rinsing the armature and core surfaces in a chlorinated hydrocarbon solvent such as trichlorethylene will usually remove any tacky foreign matter.

To evaluate various cleaning techniques, some time had to be devoted to developing a reproducible method of intentionally contaminating contacts. Since phenol fiber and textile fibers are the two most prevalent manufacturing contaminants, a cylindrical "dust stick" — made of cotton "flock" and ground phenol fiber of controlled particle size held together by a small amount of methyl cellulose — was used as a particle source. Dust sticks held in a special holder (Figure 2) and fed at a constant rate against a rough-faced, high-speed disc in a blower housing, release the particles which are in turn channeled into the top of a chamber containing replica-cleaned relays. The test relays had their "twin" wires electrically separated to act as single contacts. During the tests, the relays were operated every ten seconds to impact any dust particles falling onto the contact surfaces. During a 48-hour exposure, about two grams of dust were generated and passed through the dust box, sketched in Figure 1. About fifty per cent of the contacts became so contaminated that they remained open.

Following the establishment of a satisfactory method of contaminating the relay contacts, the next step was to compare the efficiency of various cleaning methods and evaluate them by replica analysis and contact-resistance measurements. The following cleaning methods were studied: (1) air blowing, (2) flushing by condensing solvent, (3) electrolytic cleaning, (4) pile-fabric scrubbing, (5) liquid honing (wet-blast), (6) nylon-brush scrubbing, and (7) ultrasonic cleaning. Electrolytic cleaning, pile-fabric scrubbing and liquid honing were not studied in detail since these methods could not be easily adapted for cleaning contacts on assembled relays. Further, preliminary work had already indicated that a combination of mechanical scrubbing and solvent-flushing was superior to other methods, and the principal effort was therefore aimed toward perfecting this method.

A laboratory arrangement based on brush-cleaning was devised using a series of disc-shaped brushes with crinkled-nylon bristles rotated sub-

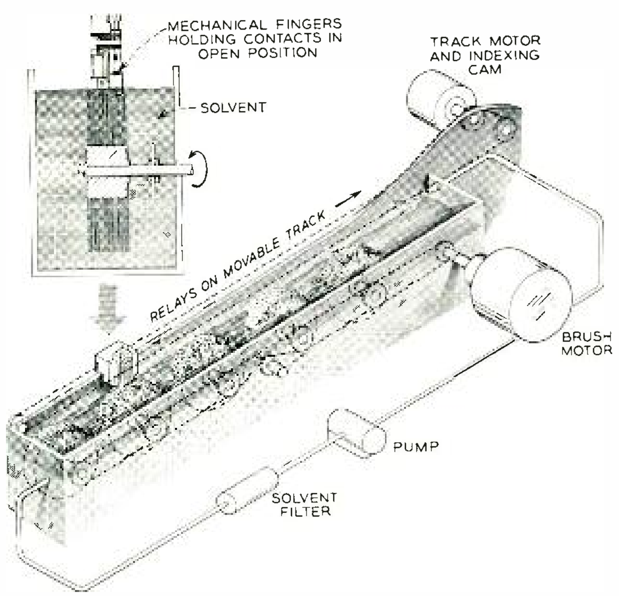


Fig. 3 — Experimental contact-cleaning device set up to test effectiveness of brush-cleaning and to simulate production-line cleaning of relays.

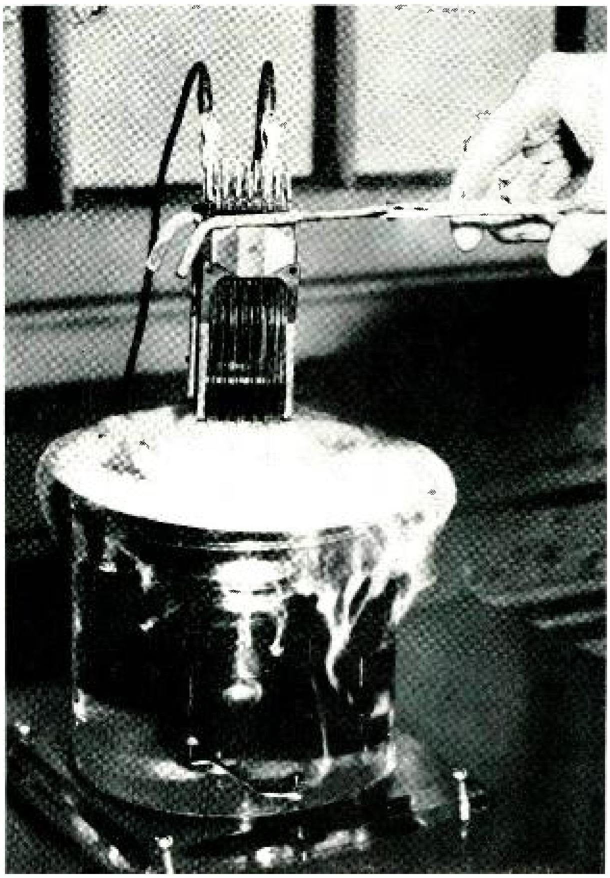


Fig. 4 — Ultrasonic cleaning: steam is actually a mist of small droplets — the fountain effect — caused by ultrasonic agitation of trichlorethylene.

merged in trichlorethylene. This medium was chosen because it is an excellent de-greaser, is non-inflammable, has reasonably low toxicity, and does not attack the organic parts of a relay. As shown in Figure 3, the relay – positioned with its contacts down and opened wide by mechanical fingers – moved into the bristles of the first brush to a predetermined depth for four seconds of scrubbing. It was then moved to the next of the six brushes, and so on, for a total of 24 seconds of cleaning. As it left the bath, the scrubbed portion was flushed with clean solvent. During its travel through the test machine, the relay armature was operated at least once to allow the agitated solvent to clean the armature backstop area. Finally, the relay was air blown to hasten evaporation of the trichlorethylene, and a clean plastic contact cover was attached. Laboratory tests in the dust chamber have shown that this cover effectively excludes dusts of the sizes and types likely to produce "opens."

In the ultrasonic cleaning method, the object to be cleaned is immersed in a liquid agitated with

TABLE—COMPARISON OF VARIOUS CLEANING METHODS

Methods	*Per cent Particles Removed*	*Per cent Opens Cleared*
New:		
Rotary-bristle scrubbing in trichlorethylene bath	95	99.5
Ultrasonic cleaning in trichlorethylene bath	95	94.5
Present:		
Air blowing	54	32.0
Condensed-vapor flushing	41	52.0

sound energy at a frequency above the audible range. In the laboratory, ultrasonic waves were set up in the liquid (trichlorethylene) by a piezoelectric crystal transducer. Experiments showed that best results were obtained when power to the crystal was increased sufficiently to produce a "fountain effect" at the surface. Figure 4 shows a relay being cleaned with a simple ultrasonic device.

The results of laboratory tests on these two cleaning methods, compared with present methods, are indicated in the accompanying table. The vast improvement of brush scrubbing and flushing and ultrasonic cleaning over the other two methods is evident. Since brush cleaning gave slightly better results than the ultrasonic technique, and was more adaptable to the Western Electric factory layout plans, it was the procedure finally recommended.

Machines for cleaning contacts on various types of wire-spring relays, based on this brush-scrubbing principle, have been designed and built by Western Electric and are now in operation at the Hawthorne and Montgomery plants. Test runs show that the machines do an excellent job of cleaning contact surfaces and also thoroughly degrease the front end of each relay. As a result, the already low rate of "found-open" contacts in central offices – only one per billion contact operations – will be further reduced, and thus will ensure telephone service of even higher quality.

THE AUTHORS

R. W. MACDONALD, a native of York, Maine, received the B.S. in Mechanical Engineering from the University of Maine in 1940. Called into military service shortly thereafter, he served through the entire Italian Campaign in the field artillery, and was released with the rank of Major. He joined the Laboratories in 1945, and was first assigned to the development of the 14-type register with the relay stability studies group. In 1952 he transferred to the wire-spring relay development group where he was primarily concerned with cleanliness problems. Since 1956 he has been engaged in solid-state device development work.

H. W. HERMANCE, a native of New York City, joined the Laboratories in 1927 after two years with the Western Electric Company where he worked on the analytical control of materials. Previously he had worked with the Crucible Steel Company and Procter and Gamble in this same field. During this period, he carried on part-time study at Newark Technical School and at Columbia University. His experience also includes chemical analysis in toxicological and criminological work. Since coming to the Laboratories, he has specialized in micro-analytical methods and has had a prominent part in developing analytical techniques and laboratory facilities. Since 1945 he has been in charge of a group specializing in the diagnosis of chemical and related problems as they affect switching apparatus in the field.

Reading Handwritten Characters

Inventor T. L. Dimond with machine that recognizes handwritten numerals. Pencil used for writing points to special pattern on writing surface.

An experimental device that can read handwritten numerals or identify numerals as they are being written has recently been announced by Bell Laboratories. Invented by T. L. Dimond of the Systems Engineering Department, the machine was demonstrated on December 13 at the Eastern Joint Computer Conference in Washington, D. C.

The machine may eventually become a valuable addition to telephone offices. It could be important in any situation where it is necessary to write and identify large quantities of numerals. For example, each long distance ticket used in the Bell System contains 20 to 30 handwritten characters. Approximately two billion of these tickets are processed each year. A technique for picking up the information on these tickets with a machine rather than the human eye would be a tremendous aid in preparing telephone bills.

For numerals to be read with a minimum possibility of error, mild restrictions must be placed on their size and form. The constraints consist of two vertically-aligned dots, around which the numerals must be formed. Three radius vectors extend out from each of these dots, and a seventh joins the two. Numerals are then sensed by determining which of these radius vectors are crossed.

Information concerning which vectors have been crossed is transmitted to a translator, which contains transistorized logic circuits. Since each numeral has a unique set of crossings, the translator needs only to distinguish each of the sets to produce a different output for each numeral. The outputs are employed in a "utilization" circuit to illuminate a number, operate a teletypewriter, feed the information to a computer, or perform other operations.

To recognize written numerals, a specially prepared plate is employed on which each radius vector appears as a closely-spaced, insulated parallel set of conductors. The numerals must be written with a conductive pencil on a sheet of paper or a card. When this writing is superimposed on the specially prepared plate and properly oriented, the appropriate sets of conductors are shorted out. The information thus obtained is fed to and analyzed by the translator and logic circuit, which determines the proper number and transmits the identification to the utilization circuit.

To recognize numerals as they are being written, a writing surface is provided on which there are two guide dots and in which seven radius vectors, made of conducting material, are embedded in plastic. The writing is done with a metal stylus on the writing surface. Whenever a conductor is crossed, the information is fed to the translator and logic circuit. As necessary crossings are made

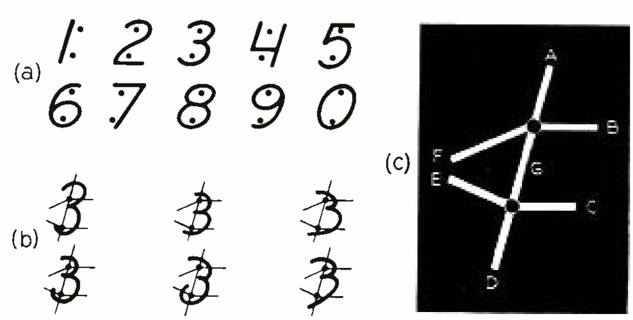


Fig. 1 — (a) How the 2-dot constraint guides the formation of numerals; (b) permissible variations in forming the numeral 3; and (c) layout of the constraining dots and radius vectors.

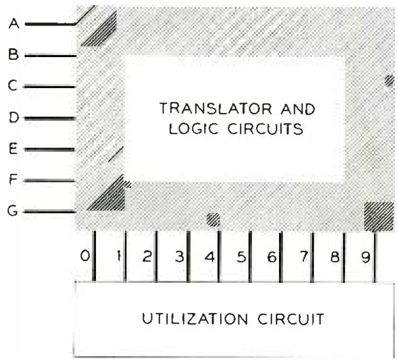


Fig. 2 — Block diagram showing the basic operation of the device for character recognition.

for a particular numeral, the translator again sends the proper information to the utilization circuit. To clear the system for the start of the next numeral, a conducting plate is touched by the stylus.

Figures 1 and 2 illustrate the operation of the device. Figure 1(a) shows how the 2-dot constraint serves to guide the formation of numerals, while Figure 1(b) is an example of the wide variations permissible in forming a numeral. The logic circuits have been set up so that any of the forms of Figure 1(b) would be properly recorded as a 3. Figure 1(c) indicates how the constraining dots and radius vectors are set up.

The block diagram of Figure 2 indicates the basic over-all operation of the device. Information on the seven radius vector crossings is fed to the translator and logic circuits, which determine the numeral being written or read. The number indication is then sent to the utilization circuit, which uses this information in the desired manner.

This technique has been extended to permit the identification of handwritten letters. For this purpose, it appears that a four-dot contraining system with 12 radius vectors is necessary. However, to identify letters as they are being written is somewhat simpler, since advantage can be taken of the order in which the radius vectors are crossed. With this additional information, it is possible to identify either letters or numbers as they are being written by employing the 2-dot constraining system used for numerals.

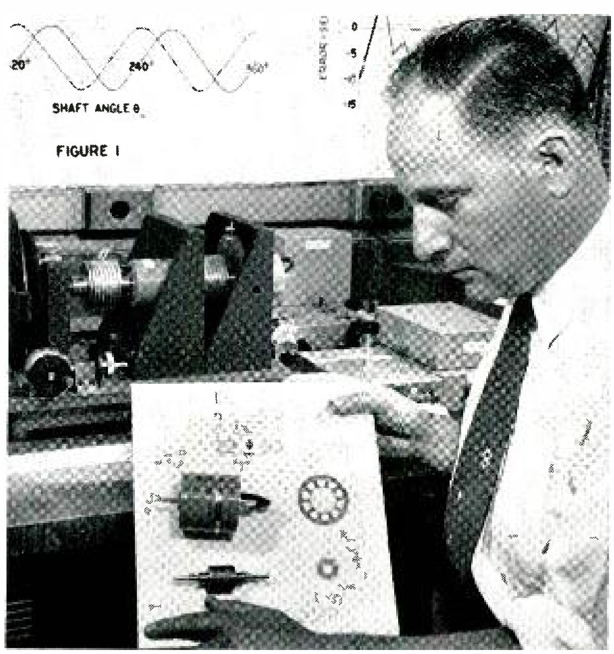
Several experimental models have been built at Bell Laboratories. Each is completely self-contained. The device is operated from flashlight batteries and requires no outside power source. Its small size is made possible by the use of transistors.

High-Precision Vernier Resolver

The precise measurement of angles is a basic operation in many technical fields. Such measurement is important, for example, in the observation of stars and the mapping of land, and is also important in certain machining operations. For automatically controlled systems, the angular position of a shaft must often be sensed electrically.

Under an Air Force contract, a high precision sensing instrument, the vernier resolver, has been developed by G. Kronacher of the Laboratories. The precision of this instrument is three seconds of arc. This is about equal to the angle subtended by a baseball at a distance of three miles. At Bell Laboratories the instrument is used in an "angle encoder" which converts a shaft angle to a numerical representation acceptable to a digital computer.

The vernier resolver is a variable coupling transformer of the reluctance type. It is of small size and simple construction, and all windings are on the stator, leaving the rotor free of sliding contacts. Models of the instrument are being built by Clifton Precision Products Company, Clifton Heights, Pa.



G. Kronacher showing disassembled parts of the vernier resolver. Apparatus for checking accuracy of the resolver is on laboratory bench to the rear.

M. J. Kelly Serves as Chairman for Engineering Center Fund

Dr. M. J. Kelly is serving as Chairman of the industrial campaign to raise funds for a new Engineering Center building. The fund drive was launched at a dinner meeting in New York City on November 21, attended by Hon. Herbert Hoover, honorary Chairman of the campaign; Alfred P. Sloan, Jr., honorary Vice-Chairman; and more than one hundred leading industrialists and educators from all parts of the country.

At the dinner meeting, Dr. Kelly announced plans for the building. It is to be a twenty-story tower surrounded by lower structures with landscaped grounds. It will cost an estimated $10,000,000 and is to be erected on United Nations Plaza between 47th and 48th Streets in New York City.

In addition to offices, the building will include the Engineering Societies Library, space for exhibitions of engineering advances, and possibly an Engineering Hall of Fame. It will be the headquarters for five Founder Societies and eleven Associated Societies, whose combined membership has risen rapidly in recent years to a total of nearly 300,000. Several other engineering activities will also be accommodated. The industrial campaign of which Dr. Kelly is chairman is to raise $5,000,000 for the project, and members of the various societies are expected to contribute $3,000,000. The remaining $2,000,000 is available in the assets of United Engineering Trustees, Inc.

In announcing the start of the campaign, Dr. Kelly said, "Engineering Societies are repositories of the fundamental and applied technical knowledge of their fields and are agencies for its dissemination. Their meetings, publications and committee activities crystallize thought on the technical problems of the engineering profession and insure that advances in technology become widely known and available for general application. . . .

"Those of us associated in this campaign believe that the new center is a much needed facility and heartily recommend to industry their financial support of its construction."

Model of the proposed new Engineering Center being inspected by Dr. Kelly and Walter J. Barrett, President of United Engineering Trustees, Inc.

Transparent Magnetic Oxides

A new class of magnetic oxides, structurally distinct from ferrites, has recently been discovered. These materials, known as rare-earth-iron garnets, are transparent and thus permit the internal magnetic-domain structure to be seen with a microscope.

Ferrimagnetism in these garnets was first discovered at the Laboratoire d'Électrostatique et de Physique du Métal of the Institute Fourier in Grenoble, France, and independently by S. Geller and M. A. Gilleo of Bell Laboratories. At the Laboratories, the optical and magnetic resonance behavior of the garnets is being studied by J. F. Dillon, Jr., employing single crystals grown by J. W. Nielsen. Yttrium-iron garnet, $Y_3Fe_2(FeO_4)_3$, is the most completely studied member of the new garnet family.

Most magnetic materials, metals and ferrites alike, are opaque to visible light. Thus, their internal magnetic structure is not visible, and the way magnetic domains are oriented within them has been inferred from reflection of polarized light by their surfaces or by delineating domain boundaries with colloidal magnetic-oxides.

A polarized light beam passing through the transparent magnetic domains in rare-earth-iron garnets has its plane of polarization rotated in one direction in one domain but in the opposite direction in an adjacent and oppositely magnetized domain. This Faraday rotation is wavelength-dependent and amounts to several degrees per mil of thickness; it makes the domains within the crystals clearly visible.

The internal domain structure can therefore be studied over a wide range of temperatures and magnetic field conditions. It is now possible to correlate Faraday rotation in a magnetic material with spectroscopic data over a broad temperature range.

J. H. Miller New Chief Engineer, Mountain States Company

J. H. Miller, a former member of the Laboratories, was elected Chief Engineer of the Mountain States Telephone and Telegraph Company, effective January 1, 1958.

Mr. Miller was a member of the Laboratories Personnel Department from 1936 until 1942, when he entered military service. He was concerned with recruiting and training programs. Returning to the Laboratories in 1946, he was in the systems development group working on toll systems and primary signaling. In 1948 he transferred to the Quality Assurance Department as a field engineer in Denver.

He became Equipment Maintenance Engineer for the Mountain States Company in 1954 and was promoted to Chief Engineer for the New Mexico area in 1955. In March, 1957, he became Regional Plant Extension Engineer for the O & E Department of the A. T. & T. Co. He was responsible for the Eastern Region, which includes the New England, Southern New England, New York, New Jersey, Pennsylvania, Ohio and Cincinnati and Suburban companies.

Contents of the November, 1957, Bell System Technical Journal

The November, 1957, issue of THE BELL SYSTEM TECHNICAL JOURNAL contains the following articles:

A New Storage Element Suitable for Large-Sized Memory Arrays — The Twistor, by A. H. Bobeck.

Non-Binary Error Correction Codes, by Werner Ulrich.

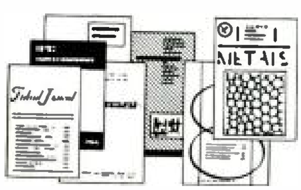
Shortest Connection Networks and Some Generalizations, by R. C. Prim.

A Network Containing a Periodically Operated Switch Solved by Successive Approximations, by C. A. Desoer.

Experimental Transversal Equalizer for TD-2 Radio Relay System, by B. C. Bellows and R. S. Graham.

Transmission Aspects of Data Transmission Service Using Private Line Voice Telephone Channels, by P. Mertz and D. Mitchell.

Design, Performance and Application of the Vernier Resolver, by G. Kronacher.



Papers by Members of the Laboratories

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

Ambrose, J. F., see McCall, D. W.

Batterman, B. W., *Hillocks, Pits and Etch Rate in Germanium Crystals*, J. Appl. Phys., **28**, pp. 1236-1241, Nov., 1957.

Bozorth, R. M., Walsh, Dorothy E., and Williams, A. J., *Magnetization of Ilmenite-Hematite System at Low Temperatures*, Phys. Rev., **108**, pp. 157-158, Oct. 1, 1957.

Buckelew, J. W., and Knab, E. D., *Fused-in-Place Eyelets*, Elec. Mfg., **60**, p. 168, Nov., 1957.

Chynoweth, A. G., and McKay, K. G., *The Threshold Energy for Electron-Hole Pair-Production by Electrons in Silicon*, Phys. Rev., **108**, pp. 29-34, Oct. 1, 1957.

Cook, J. S., Kompfner, R., and Yocom, W. H., *Slalom Focusing*, Proc. of the I.R.E., **45**, pp. 1517-1522, Nov., 1957.

Distler, R. J., and Sturzenbecker, C., *A Magnetic Amplifier Voltage-Current Overload Protection Circuit*, Commun. and Electronics, **33**, pp. 602-606, Nov., 1957.

Eisinger, J., *The Adsorption of CO on Tungsten and Its Effect on the Work Function*, J. Chem. Phys., **5**, pp. 1206-1207.

Ellis, W. C., Williams, H. J., and Sherwood, R. C., *Evidence for Subgrains in MnBi Crystals from Bitter Patterns*, J. Appl. Phys., **28**, pp. 1215-1216, Oct., 1957.

Feher, G., Weissman, S. I., and Gere, E. A., *The Magnetic Properties of Triphenylmethyl at Low Temperatures* J. Am. Chem. Soc., Letter to the Editor, **79**, p. 5584, Oct., 1957.

Geller, S., *Unit Cell and Space Group of $Eu_2(SO_4)_3 \cdot 8H_2O$*, Acta Crystallographica, 10, p. 713, Nov. 10, 1957.

Gere, E. A., see Feher, G.

Gillette, D., *Stochastic Games with Zero Stop Probabilities*, Contributions to the Theory of Games, **3**, pp. 179-187, Nov., 1957.

Greiner, E. S., and Gutowski, J. A., *The Electrical Resistivity of Boron*, J. Appl. Phys., **28**, pp. 1364-1365, Nov., 1957.

Gutowski, J. A., see Greiner, E. S.

Harker, K. J., *Use of Scanning Slits for Obtaining the Current Distribution in Electron Beams*, J. Appl. Phys., **28**, pp. 1354-1357, Nov., 1957.

Hutson, A. R., *Hall Effect Studies of Doped Zinc Oxide Single Crystals*, Phys. Rev., **108**, pp. 222-230, Oct. 15, 1957.

Knab, E. D., see Buckelew, J. W.

Kompfner, R., see Cook, J. S.

Papers by Members of the Laboratories, Continued

Lanza, V. L., see McCall, D. W.

Law, J. T., *The High Temperature Oxidation of Silicon*, J. Phys. Chem., **61**, pp. 1200-1205, Sept., 1957.

Liehr, A. D., *Calculation of the Variation of the π-Electronic Energy and Wave Functions of Ethylene Under Nuclear Displacements*, Trans. of the Faraday Soc., **53**, pp. 1533-1537, Dec., 1957.

Matlack, R. C., *Communications: Present and Future*, Proc. of the Symp. on Systems for Information Retrieval, **2**, pp. 611-618, Apr., 1957.

Mertz, P., *Information Theory and Communications*, Wire and Radio Commun., 75th year, pp. 7-10, Nov., 1957.

McCall, D. W., *Diffusion in Ethylene Polymers I. Desorption Kinetics for a Thin Slab*, J. Polymer Science, **26**, pp. 151-164, Nov., 1957.

McCall, D. W., Ambrose, J. F., and Lanza, V. L., *Diffusion in Ethylene Polymers II. Desorption of Water*, J. Polymer Science, **26**, pp. 165-170, Nov., 1957.

McCall, D. W., and Slichter, W. P., *Molecular Motion in Polyethylene*, J. Polymer Science, **26**, pp. 171-186, Nov., 1957.

McKay, K. G., see Chynoweth, A. G.

McMillan, B., *Where Do We Stand?*, I.R.E. Trans. on Information Theory, **IT-3**, pp. 173-174, Sept., 1957.

Pierce, J. R., *Telephones, People and Machines*, Atlantic Monthly, pp. 141-143, Dec., 1957.

Prince, E., *Crystal and Magnetic Structure of Copper Chromite*, Acta Crystallographica, **10**, pp. 554-556, Sept., 1957.

Sherwood, R. C., see Ellis, W. C.

Slichter, W. P., see McCall, D. W.

Sturzenbecker, C., see Distler, R. J.

Suhl, H., *The Theory of the Ferromagnetic Microwave Amplifier*, J. Appl. Phys., **28**, pp. 1225-1236, Nov., 1957.

Van Bergeijk, W. A., *Observations of Models of the Basilar Papilla of the Frog's Ear*, J. Acoust. Soc. Am., **29**, pp. 1159-1162, Nov., 1957.

Walsh, Dorothy E., see Bozorth, R. M.

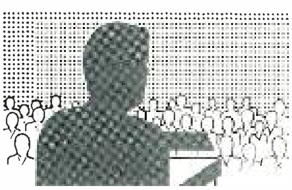
Weissman, S. I., see Feher, G.

Williams, A. J., see Bozorth, R. M.

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

Wolfe, R. M., *Counting Circuits Employing Ferroelectric Devices*, I.R.E. Trans. on Circuit Theory, **CT-4**, pp. 226-228, Sept., 1957.

Yocom, W. H., see Cook, J. S.



Talks by Members of the Laboratories

Following is a list of talks given before professional and educational groups by Laboratories people during November.

Conference on Magnetism and Magnetic Materials, Washington, D. C.

Bobeck, A. H., *A New Concept in Large Size Memory Arrays — The Twistor.*

Boothby, O. L., Wenny, D. H., and Thomas, E. E., *Recrystallization of MnBi Induced by a Magnetic Field.*

Clogston, A. M., *Dipole Narrowing of Inhomogeneously Broadened Ferromagnetic Resonance Lines.*

Crowe, W. J., *The Behavior of the TE Modes in Ferrite Loaded Rectangular Waveguide in the Region of Ferromagnetic Resonance.*

Dillon, J. F., *Optical Properties of Several Ferrimagnetic Garnets.*

Ellis, W. C., Williams, H. J., and Sherwood, R. C., *Growth of MnBi Crystals and Evidence for Subgrains from Domain Patterns.*

Gelles, S., see Gilleo, M. A.

Gilleo, M. A., and Geller, S., *Substitution for Iron in Ferrimagnetic Yttrium — Iron Garnet.*

Glass, M. S., *An Appraisal of Permanent Magnet Materials for Magnetic Focusing of Electron Beams.*

Gyorgy, E. M., *Rotational Model of Flux Reversal in Square Loop Soft Ferromagnets.*

Humphrey, F. B., *Transverse Flux Change in Soft Ferromagnets.*

Monforte, F. R., see Schnettler, F. J.

Nielsen, J. W., *The Growth of Magnetic Garnet Crystals.*

Olsen, K. M., see Wenny, D. H.

Schnettler, F. J., and Monforte, F. R., *The Effect of Cobalt on the Relaxation Frequency of Nickel-Zinc Ferrite.*

Sherwood, R. C., see Ellis, W. C.

Suhl, H., *Origin and Use of Instability in Ferromagnetic Resonance.*

Thomas, E. E., see Boothby, O. L.

Walker, L. R., *Resonant Modes of Ferromagnetic Spheroids.*

Weiss, M. T., *A Solid State Microwave Amplifier and Oscillator Using Ferrite.*

Wenny, D. H., see Boothby, O. L.

Wenny, D. H., and Olsen, K. M., *The Preparation of Alnico VII Castings with Improved Physical Properties.*

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

Other Talks

Anderson, O. L., *Cooling Time of Strong Glass Fibers*, Society of Rheology, Princeton University, Princeton, N. J.

Anderson, P. W., *Magnetic Resonance Line Shapes in Diluted Substances with Inhomogeneous Broadening*, American Physical Society, St. Louis, Mo.

Ballhausen, C. J., *Absorption Spectra of Inorganic Complexes,* University of Cincinnati, Cincinnati, Ohio.

Bavelas, A., *The Problems and the Potentials of a Social Science Research Unit in a Physical Science Laboratory,* Faculty of the School of Industrial Management, Massachusetts Institute of Technology, Cambridge, Mass.

Bavelas, A., *Communications and Learning,* Personnel Group, Chamber of Commerce, Summit, N. J., and U. S. Army Command Management School, Fort Belvoir, Va.

Beckerle, J. C., *The Propagation of Underwater Explosive Signals,* Physics Seminar, Fordham University, N. Y. C.

Brattain, W. H., *The "Solemnity" in Stockholm and the Experiments Leading to the Transistor,* Old Guard of Summit, Summit, N. J.

Cagle, W. B., *Transistor-Diode Logic Circuits,* New York Section, Communications Division, A.I.E.E., New York City.

Ciccolella, D. F., *The Bell Solar Battery,* Research and Development Seminar, Colgate-Palmolive Co., Jersey City, N. J.

Collins, C. A., *New Television Network Switching Facilities,* Communications Section, A.I.E.E., New Haven, Conn.

Compton, K. G., *Atmospheric Corrosion,* National Association of Corrosion Engineers, Mountainside, N. J.

Compton, K. G., *Sources of Underground Corrosion Potentials,* General Florida Conference on Corrosion, National Association of Corrosion Engineers, Miami, Fla.

Cutler, C. C., *Transverse Wave on Ribbon Electron Beams,* Graduate Seminar, Polytechnic Institute of Brooklyn, N. Y.

Darlington, S., *Approximation Techniques,* Professional Group on Circuit Theory and Philadelphia Section of I.R.E., Philadelphia, Pa.

Early, J. M., *Problems in High Frequency Junction Transistors,* New England Electronics Meeting, Boston, Mass.

Feher, G., *The ENDOR Technique,* Radio and Microwave Spectroscopy Conference, Duke University, Durham, N. C.

Ferrell, E. B., *Communication Research at Bell Telephone Laboratories,* A.I.E.E., Oklahoma City, Okla.

Flanagan, J. L., *Spectral Properties of the Glottal Sound Source,* 33rd Annual Meeting of the American Speech and Hearing Association, Cincinnati, Ohio.

Galt, J. K., *Cyclotron Absorption in Bismuth and Graphite,* University of Virginia, Charlottesville, Va.

Gambrill, L. M., *System Applications of Beyond-Horizon Radio,* Student Branch A.I.E.E.-I.R.E., University of Arizona, Tucson, Ariz.

Geballe, T. H., *Investigations of Thermoelectricity and Thermal Conductivity in Germanium,* Solid State Physics Seminar, Cornell University, Ithaca, N. Y.

Gretter, R. W., see Upthegrove, H. N.

Grossman, A. J., *Design of Networks,* Professional Group on Circuit Theory, Philadelphia Section, I.R.E., Philadelphia, Pa.

Hamilton, B. H., *Elementary Theory of Semiconductor Devices,* Radio and Electronic Teachers, Samuel Gompers High School, N. Y. C.

Hamming, R. W., *The Proper Use of a Digital Computer in a Research Organization,* IBM, New York City.

Hamming, R. W., *Numerical Solution of Ordinary Differential Equations,* Lecture Series on Numerical Methods, A.I.E.E., N. Y. C.

Higgins, W. H. C., *Distant Early Warning Line,* Prospect Presbyterian Church, Maplewood, N. J.

Hopkins, I. L., *Stress Relaxation in Glass,* Society of Rheology, Textile Research Institute, Princeton, N. J.

Howard, B. T., *New Developments,* Portchester-Greenwich Conference, New York Telephone Company, Greenwich, Conn.

Jenkins, H. M., *Auditory Generalization in the Pigeon,* Department of Psychology, Columbia University, N. Y. C.

Jensen, A. G., *The Use of the Digital Computer as a Laboratory Tool in Visual and Acoustics Research,* A.I.E.E.-I.R.E., Los Angeles, Calif.

Jensen, A. G., *How Standards Aid the United States and Foreign Motion Picture Industry,* Convention of the American Standards Association, San Francisco, Calif.

Kelley, D. P., *Patent Law at Bell Telephone Laboratories,* University of Illinois, Urbana, Ill.

Lowry, W. K., *Technical Information Services at the Bell Telephone Laboratories,* Annual Meeting of the American Documentation Institute, Chicago, Ill.

Madsen, R. L., *Feedback Made Easy,* Student Branch, I.R.E., Newark College of Engineering, Newark, N. J.

McMillan, B., *Operations Research and the Planning of Communication Systems,* 12th National Meeting of Operations Research Society of America, Pittsburgh, Pa.

O'Connor, T. J., *Dimensioning and Notes Section Y14.5 — 1957 of the American Drafting Standards Manual,* American Ordnance Association, Atlantic City, N. J.

Pearson, G. L., *Silicon in Modern Communications,* Joint Symposium of Physics and Chemistry Dept., University of North Carolina, Chapel Hill, N. C.

Pearson, G. L., *Mechanical Properties of Small Silicon Crystals,* Solid State Seminar, University of North Carolina, Chapel Hill, N. C.

Pfann, W. G., *Solute Redistribution During Freezing,* American Society for Metals Seminar on Liquid Metals, Chicago, Ill.

Pierce, J. R., *Transistors — The Seven League Boots of Modern Communication,* Royal Canadian Institute and Toronto Section A.I.E.E., Toronto, Canada.

Pierce, J. R., *Fancies and Fallacies of Space Travel,* Long Island Section, I.R.E., Garden City, L. I.; Whippany Auditorium, Murray Hill Auditorium and West Street Auditorium, Bell Telephone Laboratories.

Ryder, R. M., *Transistors: New Developments from the Laboratory,* I.R.E., Detroit, Mich., and American Society for Testing Materials, Detroit, Mich.

Schormann, W. W., *The Technician from the Viewpoint of Research, Development, and Design Engineering,* North Atlantic Regional Conference on Technical Education, Asbury Park, N. J.

Schulz DuBois, E. O., *The Three Level Solid State Maser,* Department of Electrical Engineering, Syracuse University, Syracuse, N. Y.

Scovil, H. E. D., *The Solid State Maser,* Northeast Electronics Research and Engineering Meeting, I.R.E., Boston, Mass., and National Security Agency, Washington, D. C.

Slepian, D., *The Coding Problem of Information Theory*, Oliver Mathematics Club, Cornell University, Ithaca, N. Y.

Slichter, W. P., *Molecular Motion in Polyamides*, Joint Meeting of American Crystallographic Association, Pittsburgh Diffraction Conference, Pittsburgh, Pa.

Smith, K. D., *Silicon Solar Energy Converter*, Ohio State University, Columbus, Ohio.

Suhl, H., *Ferromagnetic Resonance*, Radio and Microwave Spectroscopy Conference, Duke University, Durham, N. C.

Upthegrove, H. N., and Gretter, R. W., *Mechanical Problems in Laying and Repairing Submarine Cables*, Mid-Jersey Section, American Society of Mechanical Engineers Meeting, Arnold Auditorium, Murray Hill, N. J.

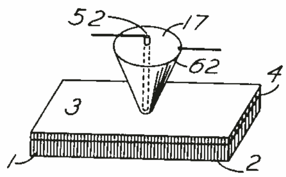
Wadlow, H. V., *Microchemical Laboratory Techniques*, Annual Convention, New Jersey Science Teachers Association, Atlantic City, N. J.

Wallace, R. L., Jr., *Digital Transmission and Transistor Techniques*, North Texas Section, A.I.E.E., Dallas, Texas.

Wernick, J. H., *Effects of Crystal Orientation, Temperature, and Molten Zone Thickness in Temperature Gradient Zone Melting*, Am. Institute Mining Metallurgical, and Petroleum Engineers, Chicago, Ill.

Wilk, M. B., *Empirical Models*, Central New Jersey Chapter of Am. Statistical Association, Princeton, N. J.

Wood, E. A. (Mrs.), *The Work of the U.S.A. Delegates at the General Assembly of the International Union of Crystallography*, Meeting of American Crystallographic Association, Mellon Institute, Pittsburgh, Pa.



Patents Issued to Members of Bell Telephone Laboratories During October

Barlow, D. S., and Crofutt, G. B., Jr. – *Identifier-Translator* – 2,808,459.

Belek, E., and Riederer, C. A. – *Combination Wire Stripping, Cutting and Wrapping Tool* – 2,807,810.

Bemski, G. – *Processing of Silicon* – 2,808,315.

Bonner, A. L. – *Coaxial Switching Arrangement for Two Way Amplifiers* – 2,811,589.

Crofutt, G. B., Jr., see Barlow, D. S.

Cutler, C. C. – *Magnetron Oscillator* – 2,808,538.

Cutler, C. C. – *Serpentine Traveling Wave Tube* – 2,810,854.

Drexler, J. – *Automatic Level Control* – 2,811,695.

Felch, E. P., Israel, J. O., and Kummer, O. – *Frequency Controlled Variable Oscillator* – 2,808,509.

Frosch, C. J. – *Manufacture of Silicon Carbide Varistors* – 2,807,856.

Galbreath, R. R. – *Intercommunication System* – 2,811,586.

Glass, M. S., Molnar, J. P., Och, H. G., and Thatcher, W. H. – *High Frequency Oscillator* – 2,810,830.

Henning, H. A., and Murphy, O. J. – *Matching Circuit* – 2,811,707.

Hogan, C. L. – *Magnetoelectric Induction Devices* – 2,811,697.

Israel, J. O., see Felch, E. P.

Jakielski, C. E. – *Cross Coupling for Astable Circuits.* – 2,810,831.

Jenkins, R. T., and Polk, R. E. – *Telephone Signaling Device* – 2,808,463.

Knapp, H. M., and Koehler, D. C. – *Method of Manufacture of Contact Springs* – 2,807,868.

Kock, W. E. – *Directional Radiator* – 2,808,584.

Koehler, D. C., See Knapp, H. M.

Kompfner, R. – *Traveling Wave Tube* – 2,811,673.

Kuch, F. C. – *Electrical Connector for Printed Wiring Board* – 2,811,700.

Kummer, O., see Felch, E. P.

MacNair, D. – *Cathodes for Electron Discharge Devices* – 2,810,088.

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Meacham, L. A. – *Subscriber Telephone Set* – 2,808,462.

Molnar, J. P., see Glass, M. S.

Murphy, O. J., see Henning, H. A.

Och, H. G., see Glass, M. S.

Pearson, G. L., *Silicon Power Rectifier* – 2,811,682.

Polk, R. E., see Jenkins, R. T.

Reynolds, F. W., and Stilwell, G. R. – *Fabrication of Laminated Transmission Lines* – 2,810,663.

Riederer, C. A., see Belek, E.

Rieke, J. W. – *Television Band Width Reducing System* – 2,811,578.

Robertson, G. H. – *Electron Discharge Devices* – 2,808,533.

Sargent, G. A. – *Method for Testing Helix Pitch* – 2,811,690.

Smith, K. D. – *Electro-Optical System* – 2,810,863.

Stilwell, G. R., see Reynolds, F. W.

Stryker, N. R. – *Loudness Indicator* – 2,808,475.

Thatcher, W. H., see Glass, M. S.

Theuerer, H. C. – *Purification of Germanium Tetrachloride* – 2,811,418.

Thomas, U. B., Jr., and Wood, E. A. – *Stable Liquid Electrodes for Piezoelectric Crystals* – 2,811,655.

Thulin, C. W. – *Pulse Generators with Pulse Shaping* – 2,808,511.

Walker, L. R. – *Method and Apparatus for Measuring Saturation Magnetization of Small Ferromagnetic Specimens* – 2,810,882.

Weber, L. A. – *Carrier Ringing Circuit* – 2,808,464.

Wood, E. A., see Thomas, U. B., Jr.