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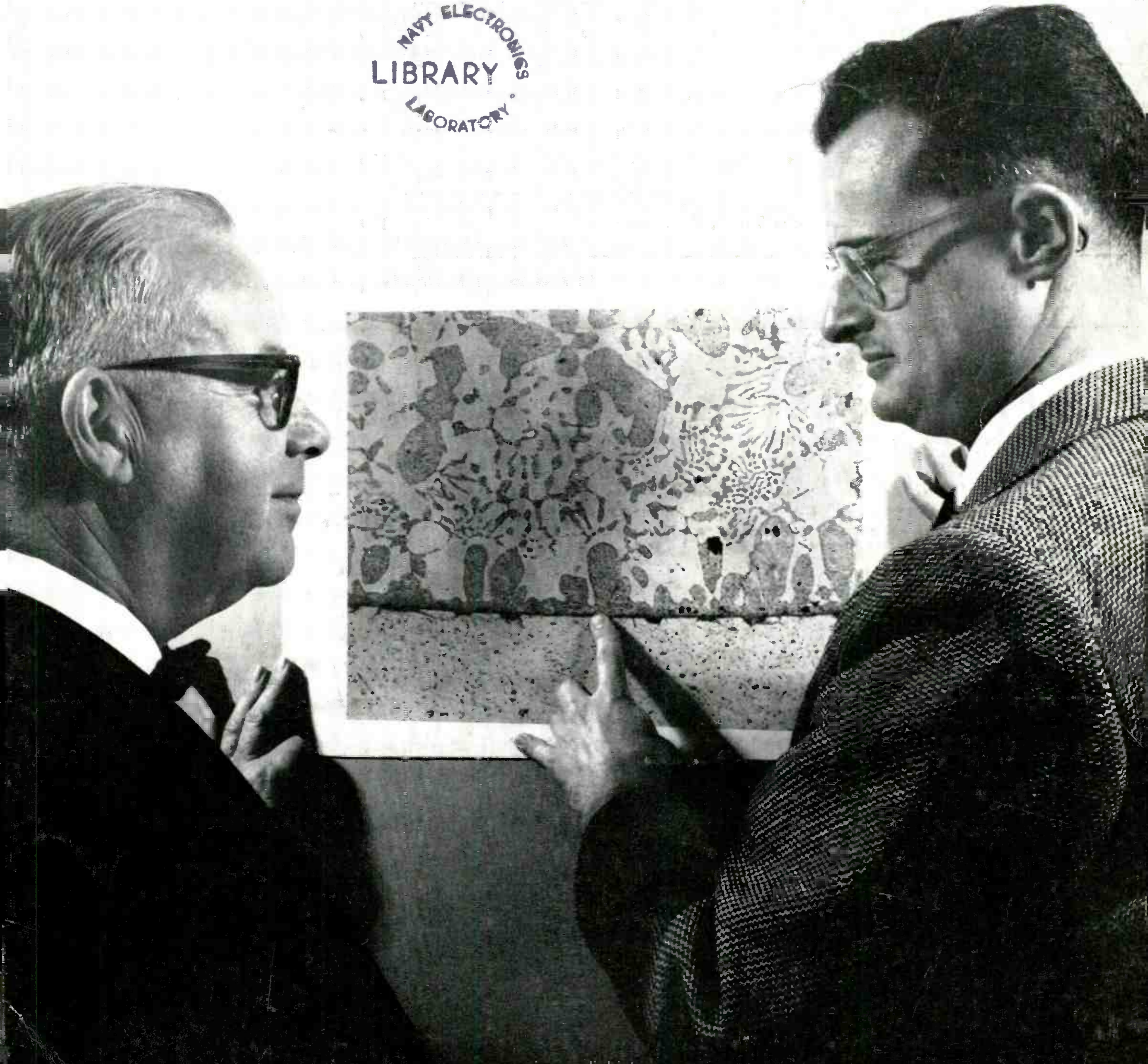

Bell Laboratories RECORD

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THE COVER: G. M. Bouton, left, and P. R. White examine a photomicrograph of the junction between aluminum and its zinc-base solder. (See story on page 157.)

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The Concept of Automatic Number Identification

A. E. VITALO *Systems Engineering III*

Two important goals of the Bell System are direct-distance customer dialing and automatic billing of all extra-charge calls. To help realize these goals, Bell Laboratories has developed an automatic number identification (ANI) system. ANI will mechanize the process, now requiring the services of operators, of obtaining the calling customer's number and will also forward the number to the centralized automatic message accounting (CAMA) office.

Getting paid for goods or services rendered is of prime importance in the conduct of any successful business. Before payment can be collected, however, a procedure must be established for accumulating charging information and for processing this information so that accurate, regular customer bills may be prepared. In the telephone business, billing is a monumental task, representing a substantial portion of the expense of each service item. It is easy to understand the size of this job when one considers that nearly fifty million telephone customers purchase about 250 million individual service items daily. Naturally, Bell Laboratories and the entire Bell System have directed considerable attention toward the development of economical ways to record and process charging information.

When commercial telephone service first began, customers were charged a *flat rate* for an unlimited number of calls within a specified local area. Subsequently, a *message rate* service was made available. This service entitled customers to a fixed number of "message units" at a base rate, with one message unit recorded for each call within the local area. Initially, the record of such calls was prepared by operators who made out tickets; later, this procedure was supplemented by automatic message registers. Both the flat rate and message rate methods of charging for calls are still used.

With the development of "zone registration" and automatic ticketing,* the automatic recording of charging information steadily expanded. Little progress was made in processing techniques, however, so the task of manually processing the large volume of message-register counts, automatically printed tickets and tickets prepared by operators remained an enormous one. In answer to this processing problem, the Laboratories developed the automatic message accounting (AMA) system.† The AMA system provides equipment in No. 1 and No. 5 crossbar local offices for automatically recording charge data on a paper tape and equipment at an accounting center for automatically processing this tape. Automatic message accounting has recently been extended to step-by-step offices with automatic ticketing equipment, through a large conversion project still under way in Los Angeles and San Francisco.

As planning for the Bell System program for direct distance dialing progressed, the need for an automatic charging method applicable to *all* local

* Record, *July*, 1944, *page* 445. † Record, *January*, 1949, *page* 2.

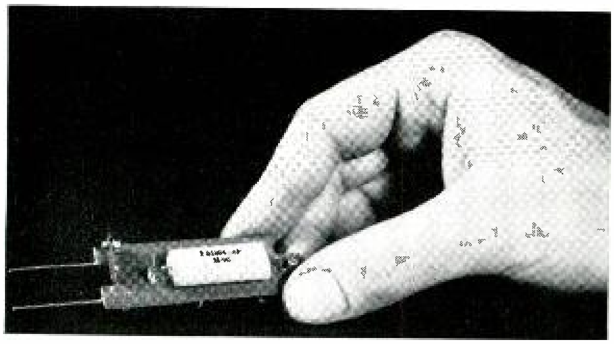


Fig. 1 — Prototype capacitor-resistor networks, mounted on rear of distributive-circuit frames, connect to customer-directory numbers in the office.

switching systems became apparent. To make available such a system, and at the same time take advantage of the proven automatic features of AMA, plans were formulated for centralizing AMA facilities. With centralized automatic message accounting (CAMA),‡ AMA recording equipment would be located at a central switching point through which extra-charge calls from neighboring local offices would normally be completed.

One great advantage of this arrangement was that information necessary for billing, such as the destination of the call and its duration, would be available to the CAMA office, since this information is integral to the completion and supervision of the call. The identity of the calling customer, however, is obtainable only in the originating office. In the early phases of planning, this difficulty was recognized as one of the obstacles in the over-all CAMA program. In fact, preliminary investigations indicated that a considerable period of development and testing would be required before a workable automatic arrangement could be developed for obtaining at the CAMA office the number of the calling customer.

‡ RECORD, *July*, 1954, *page* 241.

At the same time, increases in the demand for CAMA facilities emphasized the importance of expediting the commercial availability of CAMA. Rather than wait for the development of an automatic number identification system and delay the over-all project unnecessarily, the system plans were changed slightly so that operators could obtain the calling customer's number. In this arrangement, an operator at the CAMA point is brought in on the dialed connection just long enough to ask the calling customer his number and key this number into the AMA equipment. As soon as she has done this, the operator is released, allowing the connection to be set up to the called station.

In the meantime, an extensive program has been carried on at the Laboratories to supply the missing link in automatic CAMA. The Automatic Number Identification system (ANI), now well along in development, is currently undergoing a field trial in Newark, N. J. Specifically, the system is designed to mechanize most manual procedures now required in "operator-identified" CAMA.

Although the ANI development represents an impressive step toward relieving the critical shortage of operators, it will not at all obviate the need for them. For instance, operators will still be required for "assistance" and person-to-person calls. In addition, a group of some 5.5 million customers will still require operator-identification on extra-charge calls. Of the total of 27,400,000 directory numbers, about 66 per cent can be identified by this ANI method. Making up the group not presently scheduled to be identified by this method are numbers assigned to four-party and rural customers, and numbers served by small step-by-step offices where the installation of ANI would be uneconomical. Local AMA systems do not require ANI, and a different ANI method is being developed for No. 5 crossbar offices.

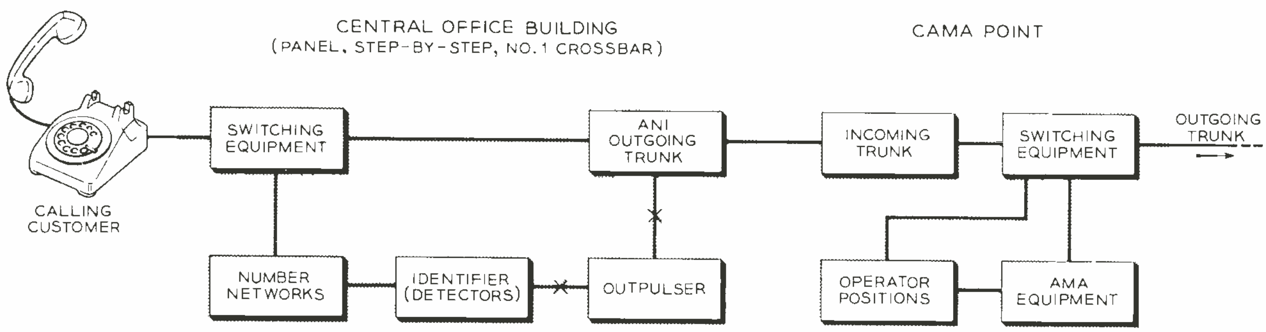


Fig. 2 — Diagram of ANI equipment in central office and connecting equipment at CAMA point.

As previously mentioned, all the necessary items of charge information are readily obtainable at the CAMA office except the directory number of the calling customer, which is available only at the originating local office. Obtaining this item of information and passing it forward to the CAMA point posed a rather complex problem to the ANI designers. Even more complex, however, was the problem of economically providing ANI in existing step-by-step, panel, and No. 1 crossbar offices.

Many methods of identification were studied, and all of the proposed arrangements fit into one of the following categories: (1) Arrangements whereby a telephone would transmit its own directory number. (2) Methods for deriving the directory number from the location of the customer-line equipment in the originating office, similar to the AMA identification arrangement. (3) Provision of a simple network for each customer line which would be "interrogated" by a distinctive signal to determine the directory number. This network-interrogation scheme is similar to the identification method used in step-by-step automatic ticketing.

After an extensive evaluating process, a plan was selected from the third classification. Stated briefly, ANI uses a capacitor-resistor network for each directory number, plus some associated common circuitry for identifying and forwarding the number to the CAMA office. The field-trial model of one of these number networks is shown in Figure 1.

The ANI system, applicable to step-by-step, panel, and No. 1 crossbar, is shown in simplified form in Figure 2. The large bulk of extra-charge calls — those originated by individual, two-party, and PBX customers — will be identified automatically. The calling customer's number will be identified in the local office after the dialed digits of the called number have been transmitted to the CAMA office. Completion of the call is withheld temporarily while the CAMA office requests the ANI equipment in the originating office to obtain the directory number of the calling customer. To do this, the ANI system uses the established connection through the switching equipment in the local central office.

Fig. 3 — The author, left, and J. Dietz, switching development engineer, work at experimental test center at trial installation in Newark, New Jersey.

Fig. 4 — B. Pollack, left, and author check measurements on number-network frames. M. Bertelo of the New Jersey Bell Telephone Company, on ladder, makes directory number change with the new hand-squeeze grip wire-wrapping tool.

The ANI equipment transmits an ac signal over the local-office switching path to the capacitor-resistor network associated with the calling number. This network is connected in numerical sequence to a distributive circuit, as are all of the other capacitor-resistor networks in the office. Detectors scanning this distributive circuit detect the presence of an ac signal and translate this information into the four digits of the directory number. After registration and checking, the calling customer's directory number and the three-digit, calling-office code — derived automatically by the ANI common-control equipment — are transmitted to the CAMA office by MF pulsing.* At the same time, another item of information is passed to the CAMA office. This is a one-digit number known as the "information digit," and is used by the CAMA equipment in handling the call. At the CAMA point, an AMA entry of the calling number is made, and the switching operations to complete the path through the CAMA office are resumed.

From the above description, it probably sounds as though our typical toll call has been held at the CAMA point for some time. Actually, the identifying and outpulsing equipment is designed to make, check and transmit an identification in about two seconds. The speed of identification eliminates the need for furnishing large groups of identifying equipment. In fact, one group of identifying and outpulsing equipment will be used for all the offices in a telephone building, and this equipment will be arranged to perform only one identification at a time.

To insure a high degree of accuracy in performing an identification, self-checking features have been built into the ANI equipment. In the event of a failure during identification, a trouble ticketer prints a trouble ticket. The information in this trouble ticket will be useful in many cases in directing the trouble-locating measures. Calls encountering failures during the identification process will not be blocked, but will be routed to the CAMA office and identified there by a CAMA operator. This arrangement has the advantage of maintaining continuity of service during minor trouble conditions.

The ANI system will also simplify some maintenance and testing procedures in the local dial offices. In panel and No. 1 crossbar offices, for instance, lines routed to permanent signal-holding trunks because of "receiver off-hook" or line-trouble conditions may be automatically identified by ANI equipment. At present this is done by having maintenance personnel manually trace the troubled line through the office and out over the trunks.

ANI will also make line-verification tests. These tests check the validity of the connections of new and changed numbers to insure that charges for calls from a particular directory number will be billed correctly.

When ANI is introduced into the telephone system, another important step will be taken to consummate the program of complete mechanization of customer dialing of extra-charge calls. But more important than this is the improvement in service to Bell System customers. Telephone service will be faster, operator intervention will be unnecessary, and calls will be billed with the human-error factor further reduced.

* RECORD, *December*, 1945, *page* 466; *June*, 1954, *page* 221.

THE AUTHOR

A. E. VITALO, a native of Brooklyn, New York, joined the Labortories in 1954 after completing the advanced technology course at the R.C.A. Institutes. Since that time, Mr. Vitalo has been associated with the switching systems engineering group responsible for local dial-telephone systems. He is currently attending the evening session of the Polytechnic Institute of Brooklyn working towards the B.S. in E.E. degree.

A Method for Soldering Aluminum

G. M. BOUTON and P. R. WHITE   *Metallurgical Research*

Ordinary methods for affixing two pieces of aluminum have presented a number of difficulties. Recently, however, a soldering technique using zinc-base solders has been evaluated in the Laboratories Metallurgical Research Department. This technique has proved feasible and, furthermore, it is expected to expand greatly the possibilities for aluminum construction.

The joining of aluminum has been the subject of investigations in the metallurgical field for many years. A major problem has existed, however, because of the oxide film that instantaneously forms on aluminum when it is exposed to air. This oxide confers excellent weathering characteristics on the material. However, it also constitutes a serious barrier to soldering and has hindered the widespread use of solders in fabrication.

Metallurgists have proposed a number of methods to remove the aluminum oxide during the soldering process. As in other soldering operations, fluxes have been used. Fluxes are materials that reduce oxides, prevent reoxidation, and promote flowing of the solder. For aluminum they must be very active chemically because aluminum oxide is not readily attacked by mild fluxes. Also, most fluxes in practice give off copious fumes and leave residues that are corrosive and hard to remove completely from the aluminum surface.

Another way to remove aluminum oxide is to apply ultrasonic vibration to the molten solder while it is in contact with aluminum. This causes cavitation and rupturing of the oxide, permitting the solder to "wet" the aluminum. Unfortunately the equipment required is relatively expensive, and the rapid attenuation of the ultrasonic impulses limits the scope of this procedure.

A third way to obtain wetting is to apply molten solder to the area of aluminum to be joined, and vigorously scratch the aluminum oxide beneath the solder with a wire brush or a sharp instrument. Once the surface is wet, soldering is readily accomplished. All of these procedures have found some limited usage.

At Bell Laboratories, critical evaluation of aluminum soldering methods has shown that for many applications a simple, effective process is available. In this method no flux, vigorous abrasion or ultrasonic vibration is used. The aluminum oxide layer is punctured by the solder stick; a noteworthy factor in the process is the ease with which this is accomplished. It is only necessary to heat the aluminum to a temperature that will melt the end of the solder stick. A very slight motion of the stick against the hot surface, then, is sufficient to wet the aluminum.

Figure 1 shows a spot on a hard aluminum alloy, grade 2024, which has been so contacted while hot with a stick of zinc-rich solder. The dark ring around the center spot of solder shows where the molten solder has crept under the oxide and wet the aluminum alloy. It has not dissolved but merely floated the oxide so that it may be swept away readily with the end of the solder stick (or other means) while the solder is molten. The understanding and control of this behavior permit many

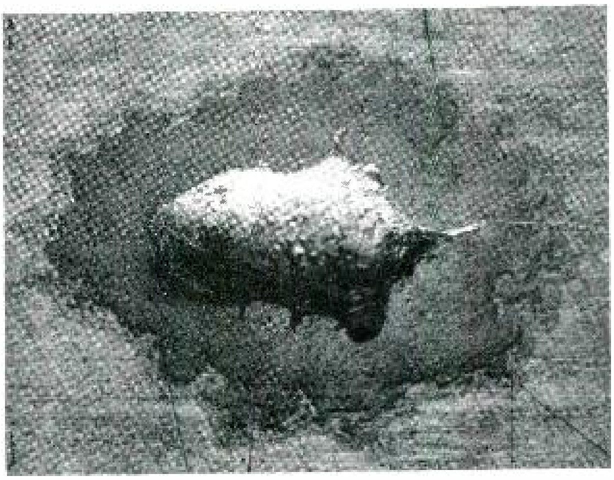


Fig. 1 — A spot of zinc-base solder on an aluminum alloy causes the oxide to loosen and allows the solder to creep underneath (note the dark ring).

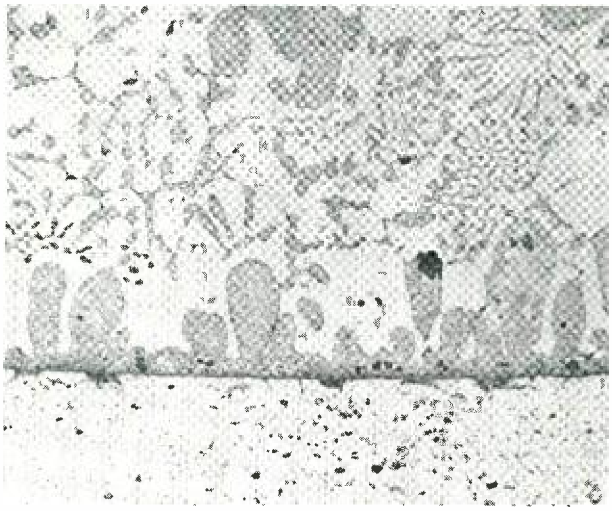


Fig. 2 — Photomicrograph of a joint showing complete wetting of the aluminum (bottom) by the zinc-base solder (top). Original magnification 500x.

useful soldering operations to be performed.

Many alloys having zinc as the major constituent will perform in the manner described. To obtain maximum joint stability, however, recourse has been made to the years of experience with die-casting alloys having a zinc base. Metallurgists found long ago that even traces of such elements as lead, tin, cadmium, or bismuth resulted in swelling and cracking of zinc-aluminum alloys that are aged over a period of years. They also found that 0.03 to 0.06 per cent magnesium conferred additional stability on the zinc-aluminum alloys. Accordingly, a grade of zinc – known as "Special High Grade" – was used in making the zinc-aluminum solders, to which 0.05 per cent magnesium was added. The range of aluminum contents is under further study to determine the most favorable percentage of aluminum. Pending the outcome of this study, the widely used die casting alloy containing 3.5 to 4.3 per cent aluminum is being successfully used.

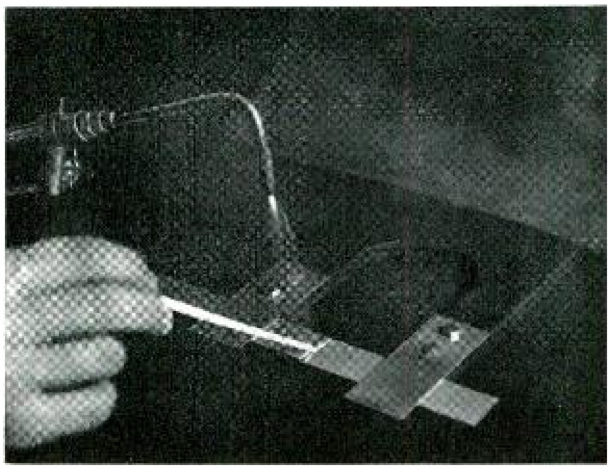


Fig. 3 — Applying the new soldering technique to two beveled surfaces. The oxy-hydrogen torch shown is only one of a number of common torches that may be used for this type of soldering.

One type of joint suitable for the new soldering operation is shown in Figure 3. The ends of strips of commercially pure aluminum (grade 1100) – 1 inch wide by 0.032 inch thick – are beveled and brought together. They are beveled so that both surfaces of the joint may be touched with the solder stick and the resultant loosened oxide swept away. At this stage it is important for the operator to be certain that the surface of the aluminum is truly wet rather than covered superficially with molten solder. One way to determine this is to remove the excess solder, conveniently with the solder stick, and play the torch flames on the residual thin coating. If wetting has not taken place, surface tension will cause the solder film to draw back at the edges. Complete wetting allows the groove formed at the junction to be filled with solder which, when solidified, forms a joint that is stronger than the members (made of grade 1100 aluminum) which are being joined.

Table I – Tensile Test Results on "T" Joints

Aluminum Alloy	Breaking Load in Pounds		
	A*	B*	C*
"T" joints–as made	370†	1250	870
"T" joints–after 29 days in humidity	390†	1060	910
"T" joints–after 73 days in humidity	380†	1290	740

* Aluminum alloys:
A–grade 1100–99.0% aluminum
B–grade 2024–4.5% copper, 1.5% magnesium, 0.6% manganese, balance aluminum
C–grade 5052–2.5% magnesium, 0.25% chromium, balance aluminum

† All of these joints broke in the aluminum stock away from the joint. In the remainder of the tests, failures occurred in both the metal stock and the joints. Some of the variations in the breaking loads of these hand-soldered joints were caused by non-uniform fillet dimensions.

Any class of joints may be easily made if the two surfaces intersect at a reasonably large angle – permitting the joint area to be stroked by the solder stick. Where maximum strength is required, both members to be joined should be precoated with solder before they are brought together. After assembly, the operator heats the parts and flows a fillet of solder into the junction. While the solder at the joint is still molten, he passes the end of the solder stick through the liquid solder once or twice to break up any entrapped oxide films and to skim oxide from the surface. A smooth and exceptionally strong joint results. Joints with strengths adequate for most purposes, however, may be made without prewetting the parts. In this case the solder fillets themselves support the load since the bottom area of the vertical member will not be bonded to the horizontal member.

Figure 4 shows a "T" joint that was tested by holding the horizontal member in a slotted plate and applying a tensile load to the vertical member. Failure occurred away from the joint. A few of the other types of joints that may be made are shown in Figure 5.

For lap joints, the parts can be prewet and slid together while the solder is molten. In many instances it is sufficient to apply a generous fillet of solder to the two exposed edges of a lap joint. The solder will not flow by itself between two closely spaced surfaces to make a good joint. Even though it flowed along the metal surface beneath the aluminum oxide, the presence of this oxide film would prevent bonding of the molten layers.

The soldering process has been applied to a number of commercial aluminum alloys. No difficulty has been encountered in wetting the wrought aluminum alloy grades. Cast aluminum alloys containing high silicon can also be wet by this procedure, using slightly more of a stroking action. However, since the melting point of the solder is quite high (approximately 720 degrees F.) some decrease in strength of the aluminum material being joined may occur.

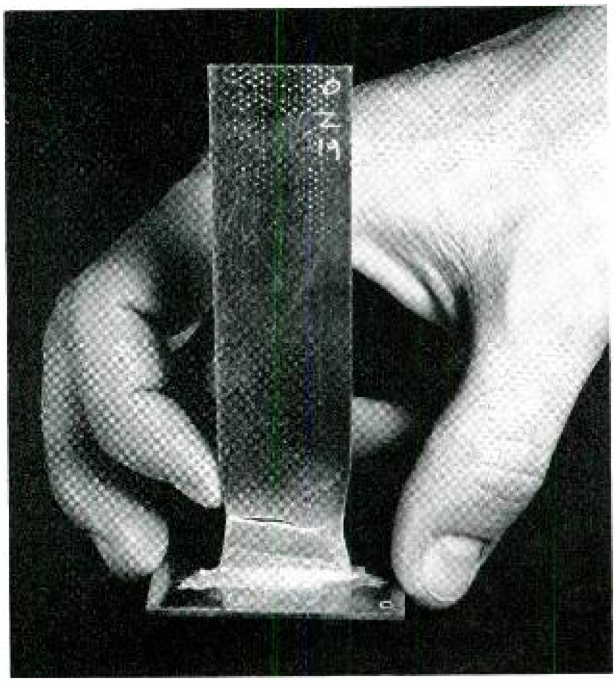


Fig. 4 — A tensile test of this "T" joint proved the strength of the soldered joint to be greater than that of the aluminum stock, as shown by the failure.

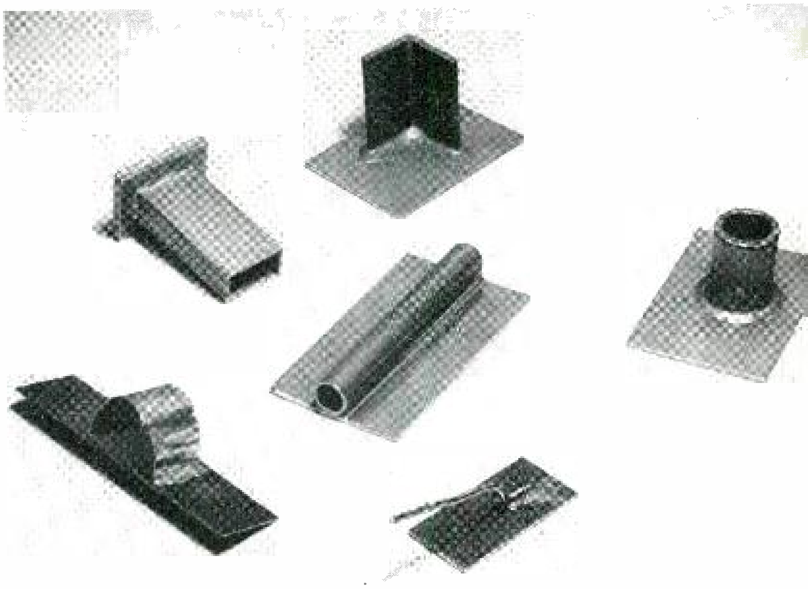


Fig. 5 — A number of constructions are possible with the application of the recently evaluated procedure for the efficient soldering of aluminum.

Table I shows average values of breaking load obtained from tensile tests on "T" joints made with the 3.5 to 4.3 per cent aluminum alloy solder on three wrought grades of aluminum. The stem material in each case was one inch by 0.032 inch in cross section. "T" joints made from many other aluminum solders lost up to 80 per cent of their strength after 73 days in these humidity conditions.

The technique of applying this solder alloy has also been used successfully on galvanized surfaces. A strong flux had been normally used when soldering galvanized steel with soft solders. With the new procedure no flux is required, and joints can be made that are much stronger than soft-soldered joints. "T" joints made with hot-dip galvanized steel, in which the stem material was one inch by 0.026 to 0.030 inch, required in a tensile test an average of 1068 pounds to break the joint. One sample failed in the galvanized steel stock.

The form of the solder stick has been found to be important. For ease in handling, best results have been obtained by using a solder stick 1/16 inch by 3/16 inch in cross section. The narrow edge permits the bar to touch the surfaces close to their intersection and break up oxide films within the fillet. The wide edge of the solder stick is better suited to finish off the fillets and produce smooth and clean surfaces.

Applications of this new joining method may be found in sheet-metal fabrications such as chassis, panel and duct work, and in numerous constructions such as frames, supports, housings, and waveguide assemblies. Another important application might be in model-shop work where complex designs could be fabricated easily and at relatively low cost. Further applications would be in the repair of aluminum assemblies to seal cracks and holes, to make containers water tight, to fill in dents and to reinforce structures.

An important aspect of the aluminum-soldering technique should be re-emphasized. The heated aluminum surface has to be touched and stroked slightly with the solder stick to wet the aluminum; the solder will not flow by itself into a capillary joint. Two important advantages of this soldering process are: joints made on aluminum and galvanized parts are stronger than joints made with other solders; and these joints are stable in the presence of humidity.

THE AUTHORS

G. M. BOUTON, a native of Cleveland, Ohio, joined the Laboratories in 1926 after receiving the Ch. E. degree from Polytechnic Institute of Brooklyn. At the Laboratories he has been engaged primarily in research and development studies on metals and alloys. He has had published several technical articles on cable sheath alloys, and has been granted a number of patents on cable sheath alloys and solders. Mr. Bouton is a member of the American Society for Metals and the American Institute of Mining, Metallurgical and Petroleum Engineers.

P. R. WHITE, a native of New York City, returned from Army service in World War II to attend Columbia University, from where he received the B.S. degree in Metallurgical Engineering in 1948 and the M.S. degree in 1949. After employment at the research laboratories of General Motors, where he was a research metallurgist on ferrous and non-ferrous alloy development problems, he joined the Laboratories in 1955. Since that time, he has specialized in metal joining, solderability, and research on low-melting alloys, solders and related material. Mr. White is a member of the American Society for Metals and the American Institute of Mining, Metallurgical and Petroleum Engineers.

Continuous Process for Etching Copper

P. D. Garn and L. H. Sharpe of the Chemical Research Department inspecting a copper plate after etching it in newly developed chemical solutions.

A new technique for continuously regenerating copper etching solutions was described on April 14 by P. D. Garn and L. H. Sharpe of Bell Laboratories. Speaking at the 133rd National Meeting of the American Chemical Society in San Francisco, the inventors said their process will eliminate "downtime" of equipment such as that used in the manufacture of printed circuits. It will also do away with the dangers inherent in changing the corrosive spent etchants, and make it possible to salvage the etched copper.

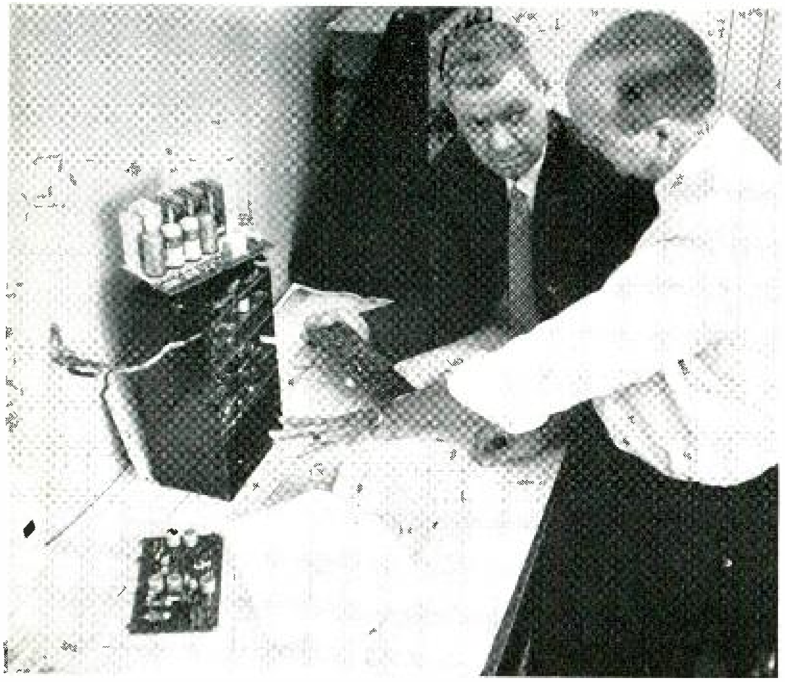
The etching solutions used in the new process are composed of cupric chloride in the presence of excess chloride ions. They can be regenerated electrolytically while etching operations continue, either on a self-regulating basis or on a time cycle, depending on the type of etching equipment involved. Electrical costs in the regeneration process are low, which adds to its economy. For instance, the cost of electricity to regenerate the solution for etching 200 square feet of 2-ounce copper would be about twenty cents, assuming an efficiency of 50 per cent in current rectification and an initial cost of one cent per kilowatt hour. Copper worth about $5 is recovered in the regeneration. To etch the same amount of copper would require about $70 worth of ferric chloride and there would be additional handling and disposal costs. This new process, because of the return from the recovered copper, may well be self-supporting.

According to Garn and Sharpe, the new etching solutions dissolve copper because the chloride forms a more stable complex with cuprous than with cupric ions. Hydrochloric acid, sodium chloride, and ammonium chloride have all been investigated as sources of the excess chloride ions. (In the absence of excess chloride, the cuprous chloride forms a film on the copper, which inhibits any further attack.)

Hydrochloric acid-cupric chloride baths will etch copper more rapidly than the presently used ferric chloride etchants. Sodium chloride baths show approximately the same improvement in etching time. In addition, the sodium chloride baths show an increased capacity for dissolved copper of nearly 50 per cent over the hydrochloric acid baths. They also have the advantage of low vapor pressure compared to hydrochloric acid baths, with a resulting lack of corrosive fumes. Some further benefits are indicated when ammonium chloride is used.

Special attention to the shape and size of the cathode is essential in the electrolytic regeneration of the etchant. The normal reaction on electrolysis is for cuprous ions to be oxidized to cupric at the anode, but for cupric to be reduced to cuprous at the cathode, leaving no net reaction. (This is due to the greater stability of the chloro-cuprous complex.)

If, however, the cathode area is decreased with no change in the current flow, the current density at the cathode will obviously be increased. As this current density increases, a point is reached where the cupric ions are reduced to cuprous as fast as they reach the cathode surface. A second electrode reaction must then take place, and this is the reduction of cuprous ion to metallic copper. At some appropriately high current density, all the cupric and cuprous ions which diffuse to the cathode surface will be reduced to copper. This gives a net reaction of the oxidation of one part cuprous ion to cupric, and the reduction of an equal part of cuprous to copper. This forced "disproportionation" is simply the reverse of the etching process, and thus regenerates the etching bath.



Repair

Philosophy and Documentation

F. S. WOLPERT *Specifications Engineering*

Repair or replace? Bell Laboratories helps the Operating Companies to answer this question by establishing the requirements that repaired equipment should meet. These Bell System Repair Specifications set forth the many important technical considerations in this vital economic question.

If some item of essential equipment in your home breaks or wears out, you can either fix it or replace it. Generally, your decision is based on such questions as: do I have the tools and facilities required to fix it; can I make it perform well enough to do its job; and, in view of its age and previous wear, could new equipment do the same job better? Even more basic to the problem is the question, what is the most economical thing to do?

Businessmen are faced with this same problem continually, on a considerably magnified scale. It would be impossible in most business situations to consider each case of repair individually, so some philosophy or standard system governing repair is generally adopted. Such is the case in the Bell System. Repair in the Bell System, when measured by any industrial standards, is a big enterprise. The value of the equipment repaired in Western Electric distributing houses in 1957 was about $244,000,000, and the price of this repair work currently runs to about $82,000,000 a year. Equipmentwise, more than 8,500,000 used telephones were repaired during 1957. This is more than double the quantity repaired in 1951, and exceeds the total number of new telephones manufactured in 1957.

A large percentage of the apparatus recovered through repair is station apparatus, although a wide variety of other types of equipment is processed every year in the Western Electric repair shops. This includes switching apparatus, PBX switchboards, teletypewriter equipment, outside plant tools, and electronic equipment. The last includes such things as mobile-radio equipment, transmission test equipment and transistorized plug-in units for rural carrier systems – see photograph above. The repair of electronic equipment is a rapidly growing field. Specifically, the dollar value of electronic equipment repaired yearly has increased from $3,700,000 in 1953 to over $26,000,000 in 1957.

Since nearly all of the equipment used by the Operating Companies was designed or specified by Bell Laboratories, the requirements covering the condition and performance of equipment after it has been repaired are established by the Laboratories. The requirements for a specific item are incorporated in a "Bell System Repair Specification." This specification tells what the performance capabilities of equipment should be after repair, not how to repair it. The actual repair work is usually done in Western Electric distributing house shops such as the one illustrated in Figure 1, and the detailed repair methods and tests are prepared by Western's Engineer of Shops organization.

Repair requirements can be conveniently grouped in three categories, which will be defined and discussed separately. The first group concerns the permissible "let-downs" or departures, if any, from the requirements for new apparatus. This usually takes the form of a complete restatement of the original requirement. Generally, a great deal of original testing and study goes into determining whether requirements for new equipment can or should apply, or if departures are advisable.

Many factors enter into the determination of such departures; mentioned here are the two principal factors. The first of these is the importance of the repair requirements in the operation of the apparatus – the obvious things an item of equipment was designed to do. Next is the question of what consideration should be given to wear and deterioration of the apparatus in service, inasmuch as any piece of used equipment has lost some part of its original, potential life.

A simple example of equipment whose requirements (except for the non-essential "new" appearance) must be the same for used as for new are steel measuring tapes. Likewise, the jaw, spring and load tests for repaired cable-strand pullers – used to string cable from pole-to-pole – must be the same as specified for new pullers. By contrast, a requirement which differs because of the natural wear of parts is the thickness of plunger springs for the 6000-type keys used on switchboards and key telephones. For repaired keys, the area of contact of the spring with the roller or plunger may be worn to as much as one-half of its original thickness and still be satisfactory for re-use.

A further example of deviation from new requirements is the refinishing of metal parts. Here, lacquers are widely used for a quick-drying finish that requires no baking and can be applied without dismantling and reassembling the equipment.

The next category is repair requirements which are not necessary for new apparatus but which are necessary for used apparatus because of the inevitable exposure, corrosion and general aging that result from service in the field. Specifically, these deal with freedom from dirt, rust, corrosion and other foreign matter. On the kerosene and propane furnaces for melting lead and solder, for example, the flues and top grid plates are originally finished with black paint and aluminum paint respectively. Here, specifications permit covering firmly adhering rust on otherwise clean flues and top plates with a coat of light oil or anti-rust liquid, since these parts would normally become discolored upon first use anyway.

Repair requirements in the third group cover changes in the construction of the apparatus. In many cases, this means the addition of features that have come into use subsequent to the original manufacture of the equipment, such as conversions to later codes or types. This would include such changes as modifying coin telephones to operate on ten cents rather than five cents.

These three categories – permissible departures from the specifications for new equipment, requirements for worn or deteriorated items, and changes in the original design of equipment – separate the

Fig. 1 — Telephone sets being repaired in the Western Electric distributing house shop at Boston, Mass.

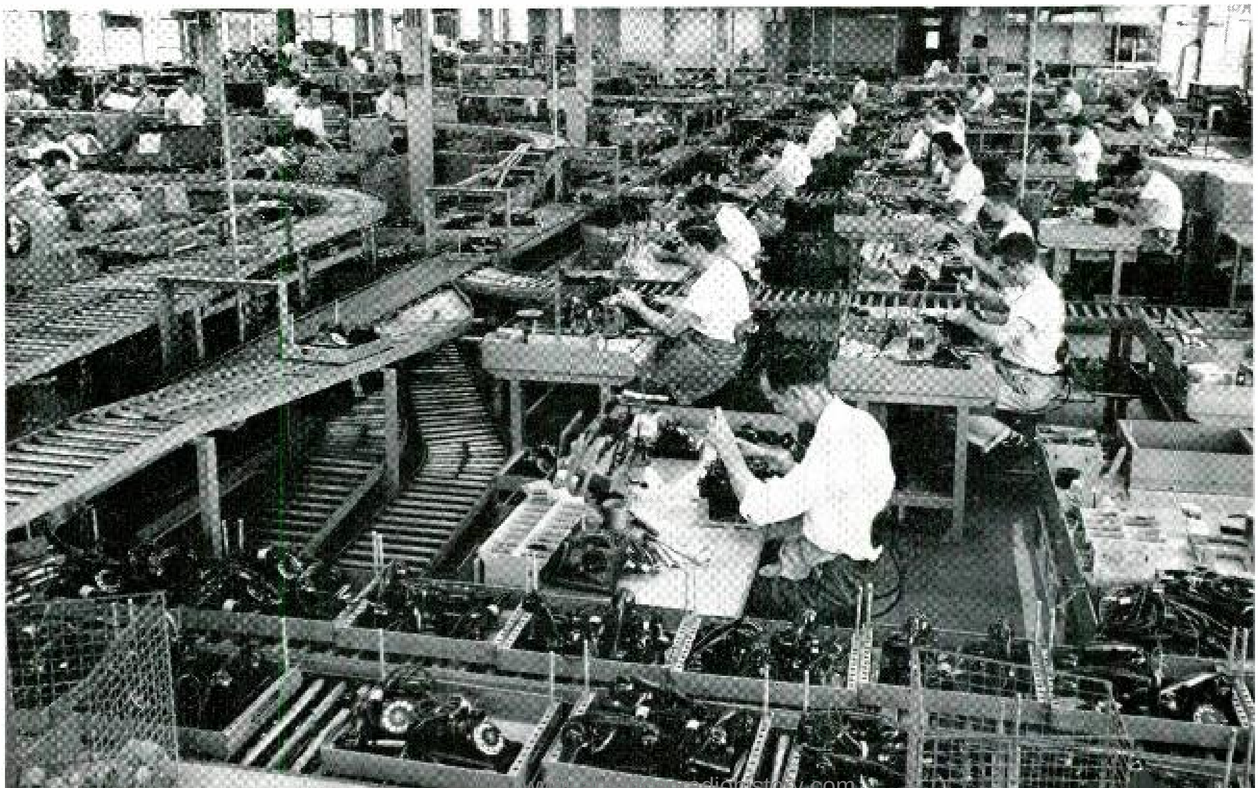


Fig. 2 — Program planning conference, Western Electric conference room, 220 Church Street, N. Y. C.

over-all problem of repair into three well defined segments. The logical next step is to explain how the problem is solved; or in this case, how the requirements for repaired equipment are established.

The objective of a Bell System Repair Specification is to present a set of requirements which will ensure satisfactory, dependable and economical products for the Operating Companies. These requirements must also consider the capabilities of the repair facilities available in the Western Electric shops. Much of what is covered in the specifications is based on technical and business decisions made by engineers specifically trained for this work. The factors that these engineers consider are primarily technical, however, and involve such things as the original intent of the design, future field-maintenance costs, safety, appearance, administrative aspects, and repair-shop economics.

The need for repair information comes from such sources as the development of a new item, design changes affecting equipment in service, and specific requests from Western or A.T.&T. Specifications are prepared in accordance with priority ratings jointly established by Western Electric, A.T.&T. and the Laboratories at quarterly program-planning conferences (Figure 2). This method has been found very effective in coordinating the efforts of the engineering groups concerned. It also ensures that the repair specification and the "Western Electric Methods Specification" may proceed simultaneously. The priority system also serves to minimize delays in getting repair information on urgently needed items into the field.

After appropriate study, tests and planning, repair engineers at Bell Laboratories prepare a draft of the specifications for an item or related group of items. This draft is then discussed at informal conferences (1) with members of development groups at the Laboratories (Figure 3) on design and related repair considerations; (2) with the Western Electric Engineer of Shops organization on questions concerning economics and repair-shop facilities; and (3) with the A.T.&T. Company on operating, engineering and policy matters. The Quality Assurance Department at the Laboratories is also consulted to benefit from its knowledge of the equipment gained from investigating engineering evaluations and from conducting quality surveys of repaired products.

Because of the many different viewpoints of all of these organizations, it is not difficult to appreciate that additions to and changes in the original draft are frequently necessary before the final repair requirements are formulated. Once they are firmly established, these requirements are published in a Bell System Repair Specification. This document is basically a recommendation to the Operating Companies by Bell Laboratories and the A.T.&T. Company, with the concurrence of Western Electric. This recommendation defines the requirements that the Operating Companies can expect repaired equipment to meet..

For twenty-five years, these repair requirements took the form of the "D-series" Bell System Practices. Following a System-wide survey about five years ago, the present specification procedures were adopted because they seemed better suited to both the presentation and dissemination of repair information. A new format was also devised which considerably expedited the preparation, revision, printing and distribution of repair requirements. This change in format has also made it possible to eliminate a backlog of long standing. Current needs for repair information are being realized in a much shorter time than under the old procedures.

Repair prices — a concept that has been mentioned frequently — average about thirty per cent of the purchase price paid by the Operating Companies for the product during the last ten years. In a few cases, however, the cost of repair is as high as fifty per cent of the average purchase-price. Such a high cost-ratio would probably mean that replacement parts and the price of new equipment were high and the availability of both low. Other factors which Operating Companies must consider if repair costs are this high are the immediate demand for repaired equipment, and the amount of money available for investment in new equipment.

The repair costs are submitted by the various distributing house shops to Western's Engineer of Shops cost control engineer, who must approve them before they are adopted. These costs are usually in the form of a detailed analysis (for billing purposes) of material, labor and overhead based on lots of 100 units. In compiling these averages, the various shops also consider the local options and deviations of the Operating Companies. In general, however, where Bell System Repair Specification requirements are followed, each shop performs repair work in accordance with standard methods, thereby making the costs comparable and as economical as possible. Approved costs are published in price lists released to each Operating Company. These lists are also used by Laboratories' repair engineers in their economic studies.

Holding repair costs at a level satisfactory to the Operating Companies is, of course, one of the prime requisites of the repair specification. Closely allied to this is the fact that repair requirements must be based on facilities that can be reasonably and economically provided in the repair shops.

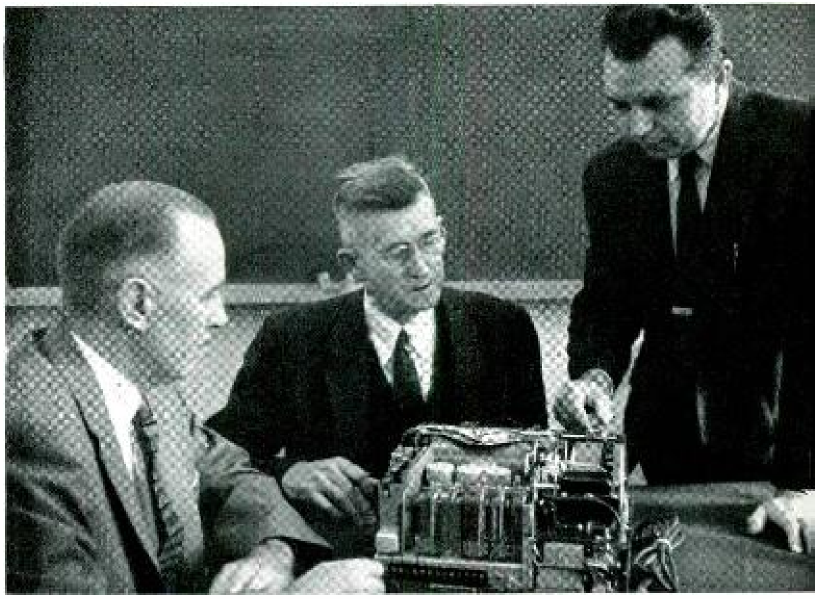


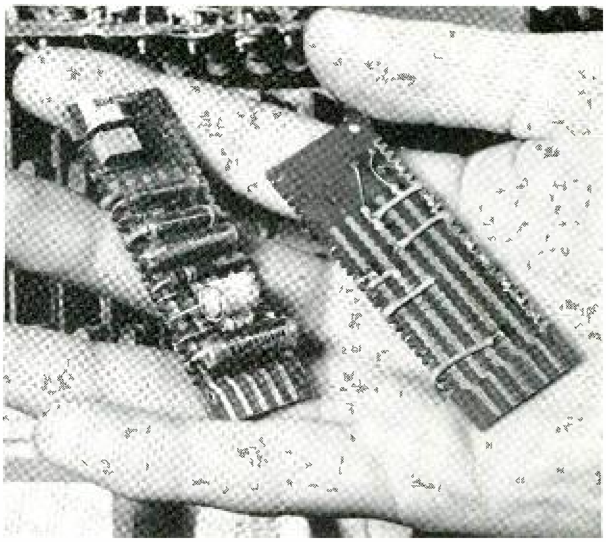
Fig. 3 — Informal conference at the Laboratories on repair requirements for the telephone answering set. From the left, C. F. Benner, development engineer, A. B. Reynolds, repair specification supervisor, C. D. Stulga, repair engineer.

One of the most interesting and challenging new facets of repair is the increasing use of electronic "packages" or plug-in units. These printed wiring "cards" are still not very prevalent in the Bell System, but the repair philosophy on such equipment is receiving considerable study by all of the organizations concerned. "New art" apparatus is the special province of the electronic repair engineers, who keep abreast of the new technology and at the same time draft requirements for the repair of "old art" electronic equipment.

THE AUTHOR

F. S. Wolpert, a resident of Short Hills, N. J., received the B.S. degree in E.E. from Newark College of Engineering and, after a year with the Weston Electrical Instrument Corporation, joined the Laboratories in 1928. His early work at the Laboratories was in the development and design of station apparatus transmission instruments. During World War II, he was engaged in the manufacturing information aspects of military communications instruments. He is presently Specifications Engineer in charge of the preparation of engineering specifications on new and repaired stations, outside plant, and electronic apparatus and equipment.

Coordinate Data Sets for Military Use



WALTER KOENIG
Military Systems Development

In antiaircraft fire coordination systems, the data obtained by radar must often be transmitted for long distances to processing centers. Laboratories' engineers have developed transistorized units to do this rapidly and accurately over telephone circuits. This military equipment converts analog data to digital form for transmission and then returns the data (binary numbers) to the original analog form at the receiving end of the system.

Bell Laboratories' engineers recently completed the development of two new data-transmission sets for military use. Transistorized to as high a degree as the state of the art at the time permitted, this is the first military equipment actually in production that uses transistors in such large numbers. The sets were developed under the sponsorship of the Signal Corps and are formally designated AN/TSQ-7 and AN/TSQ-8. In this article the term TSQ refers to a system using either or both of these pieces of equipment.

The primary purpose of TSQ is the transmission of radar data over ordinary telephone circuits. These data consist of three dc voltages, known as analog voltages, that represent the three rectangular coordinates of an aircraft in space with respect to the radar site. One voltage is proportional to the distance of the aircraft east or west of the station, the second is proportional to the distance north or south, and the third is proportional to the height of the aircraft above sea level. Two additional voltages representing velocity components are used with TSQ-7. It might be possible to transmit these slowly varying dc voltages over very short distances by using a separate circuit for each, but most voice circuits of any length do not transmit dc at all, because such circuits include transformers, amplifiers, signaling facilities, and other elements that present an open circuit to dc signals. Transmission of analog signals with low-frequency ac components over voice circuits is also subject to varying amounts of attenuation and noise that would tend to obscure the transmitted signal and make it hard to interpret at the far end.

To surmount these difficulties, the TSQ transmitter accepts the analog voltages, converts them to binary digital form, and uses the binary digits to control spurts of a carrier frequency that are applied to the line. The binary numbers corresponding to the original dc voltages are used in a definite time sequence, thus allowing all the information to be sent over a single telephone circuit. Since binary numbers contain only "ones" and "zeros," each "one" can be represented by a spurt of carrier and each "zero" by the absence of carrier. The TSQ receiver detects the spurts of carrier and converts the binary numbers to the original dc voltages that they represent. No type of distortion or noise can affect the precision of the system unless it is severe enough to prevent distinguishing the presence of carrier from the absence of carrier at the receiving end. Precision is limited only by the encoding process (the conversion of dc voltages to binary digits) and the decoding process (the conversion of binary digits to dc voltages). The overall precision obtained with the AN/TSQ-7 and

AN/TSQ-8 systems is approximately one in 1000.

The history of TSQ goes back to 1949, when the development of TSQ-1 was started. This was a single-target system of very high precision — one part in 8,000 — that used some 370 electron tubes. About 200 units of TSQ-1 were manufactured and are now in service. In developing TSQ-7 and TSQ-8, the main objectives were: (1) a more compact system using less power — achieved by using transistors instead of electron tubes; (2) lower precision because the newer applications do not require as high precision as that obtained with TSQ-1; (3) high-speed encoding and decoding so that the systems could be multiplexed; and (4) provision for the transmission of additional data other than the positional coordinates of the aircraft. These goals were to be met without appreciably increasing the time required for transmission of a message.

If all stations in a TSQ system are to send data to each other and to interpret received data, they must all speak a common coordinate language. This is achieved by referring all targets to the left and bottom edges of a reference square (a type of map) that is large enough to include all stations and their areas of radar coverage.

To understand some of the arithmetic of the method, consider, for example, the X coordinate alone. If X_T is the distance of a target east of the transmitter and P_T is the distance of the transmitter east of the left edge of the reference square, then X_T plus P_T is the distance of the target from the left edge of the square. This distance will also be equal to X_R plus P_R, the subscript R referring to the receiver. Now, since X_R plus P_R equals X_T plus P_T, X_R will be equal to X_T plus P_T minus P_R.

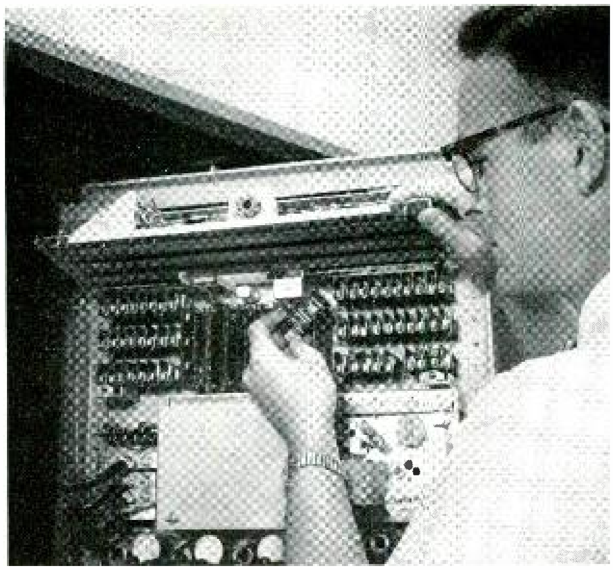


Fig. 1 — L. M. Smith examining one of many plug-in circuit units used in AN/TSQ-7 transmitter.

The quantities P_T and P_R are known as the parallax of the transmitter and receiver, respectively, with reference to the left edge of the reference square. Similar parallax quantities are used to refer targets to the bottom edge of the reference square. By having the transmitter add its parallax to the transmitted data and the receiver subtract its parallax from the received data, all targets are referred to the receiver's own location. With this system, any transmitter can send to any receiver without announcing its identity, and any receiver can interpret the message without knowing where it originated. The quantity called parallax may be many times larger than the coordinate data, but since the

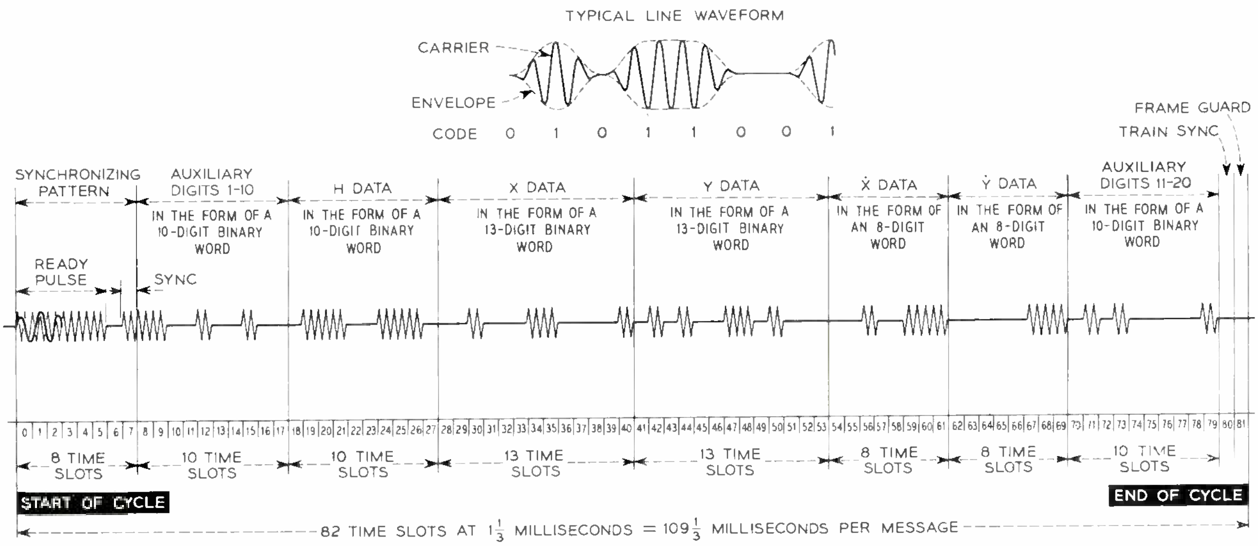


Fig. 2 — Typical transmitted AN/TSQ-7 message. Inset shows the line waveform for eight digits.

addition and subtraction are performed digitally, there is no loss of precision.

In addition to the correction made for parallax, the data must be corrected for the curvature of the earth. Some of the distances involved are so great that simple parallax corrections are not valid. Both the transmitter and the receiver, therefore, correct for this effect. This correction is made by changing the operation of the encoder and decoder so that a given voltage results in a slightly different code, and vice versa. The earth-curvature correction is made only on the X and Y coordinates.

TSQ can also transmit auxiliary data. These consist of a number of binary digits that may be used singly or in combination to convey information other than coordinate data. The auxiliary data can be thought of as a telemetering system whereby a closed switch at the transmitter results in an operated relay at the receiver. There is one switch, and one relay, for each of ten such digits in TSQ-8

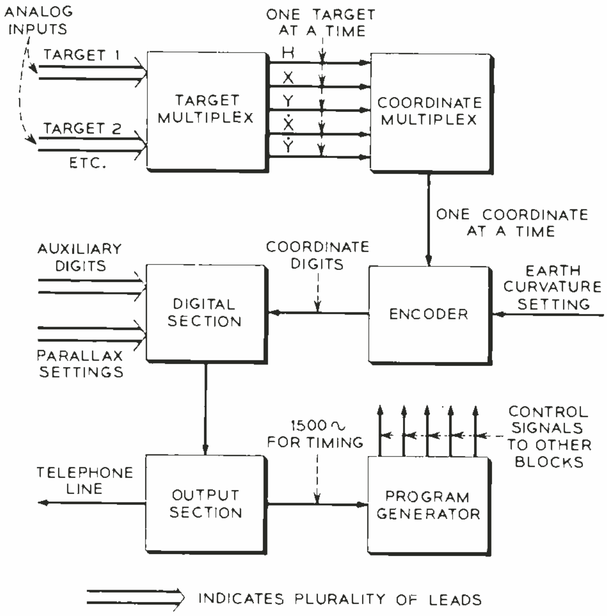


Fig. 3 — Block diagram of AN/TSQ-7 transmitter.

and for each of twenty digits in TSQ-7. These digits can be used for identification numbers, status information, or commands.

Let us now examine a typical message as sent by TSQ-7. The complete message, or frame, consists of 82 time slots, each 1-1/3 milliseconds long. Each time slot is just long enough for two complete cycles of the 1500-cps carrier. The first eight slots are called the synchronizing pattern, because they are used to put the receiver in step with the transmitter. The "ready pulse" consists of six of these eight time slots with a spurt of 600-cps tone superimposed on the first six cycles of the 1500-cps carrier. The receiver recognizes this combination as the beginning of a new frame. After a one-slot blank, carrier is transmitted for the duration of one time slot. This pulse of carrier is called the "sync" digit. The receiver uses the leading edge of the "sync" digit as a timing reference.

The body of the message follows the synchronizing pattern. The first ten slots immediately after the "sync" digit are devoted to auxiliary data. Then come 52 time slots devoted to coordinate data. Of these 52 slots, the first ten make up the H (height above sea level) data, followed by two thirteen-digit binary words for the X and Y data. Then come two eight-digit words for the Ẋ and Ẏ velocities. The number of digits devoted to each of the coordinate data words is a measure of its precision. Following the coordinate data digits, ten more time slots are devoted to auxiliary data.

The message frame to this point has used 80 of the 82 time slots. The next slot, known as the "train sync," is vacant unless the frame is the last of the series concerning the targets being reported. The last slot is the "frame guard" and is always vacant. After the "frame guard," the transmitter immediately sends similar frames of data on each of the other targets in sequence. For the last target of the series, a spurt of carrier is injected into the "train-sync" slot. This resets the receiver and keeps it in step with the transmitter, regardless of the number of targets in the train.

When TSQ-8 is used, successive frames pertain to the same target. The line signal is exactly the same, however, as for TSQ-7, except that slot 54, the 55th slot, is the "frame guard" and the succeeding slots are omitted. TSQ-7 and TSQ-8 are compatible in the sense that TSQ-8 can send to TSQ-7 (each "ready pulse" resets the receiver), and TSQ-7 can send to TSQ-8 (the receiver ignores the last part of the frame).

If we refer to the block diagram for the TSQ-7 transmitter, we see that the five analog voltages for each of the targets appear at the input to the target-multiplex section. This is a chain of glass-enclosed dry-reed relays that are fast, silent, and dustproof.* A relay picks up one target and when it has been processed, drops it. The next relay picks up the next target, and the process continues until all targets have been processed. The output of the target-multiplex section appears at the input of the coordinate-multiplex section, which also consists of dry-reed relays. These pick up one coordinate

* RECORD, *September*, 1947, *page* 342; *September*, 1956, *page* 356.

at a time and apply the coordinate voltages to the encoder in sequence. TSQ-8, being a single-target system, does not contain a target-multiplex section. The radar data, instead, appear directly at the input of the coordinate-multiplex section. Fewer relays are required in this section because TSQ-8 handles only three analog voltages.

The encoder operates on each voltage and converts it to a corresponding binary number. The digital section accepts this binary number and adds to it the appropriate parallax number, which has been preset (permanently for a given installation) by means of keys. The auxiliary-digit inputs are also accepted by this section and handled, at appropriate times, just like data digits.

The output section generates the 1,500-cycle carrier frequency with a very precise tuning-fork oscillator. The digits coming from the digital section control the application of the carrier to the line. The program generator derives 750-cycle timing pulses from this same carrier, and using a "double-ring" circuit, generates control signals that govern the operations occurring in the other sections.

At the receiver, the incoming signals are amplified to a uniform level, then detected and sliced. Starting with a tuning fork which matches the one in the transmitter, pulses are derived at a 750-cycle rate, but so phased as to occur in the middle of the incoming digits. Each time one of these pulses occurs, the receiver decides whether the incoming digit is a "one" or a "zero," and passes this information on to the digital section. The digital section subtracts the appropriate parallax numbers (permanently set in by means of keys, as in the transmitter) from the coordinate data numbers, and passes the resulting binary numbers on to the decoder. The digital section also recognizes each "one" among the auxiliary digits, and locks up the corresponding relay for the duration of the frame.

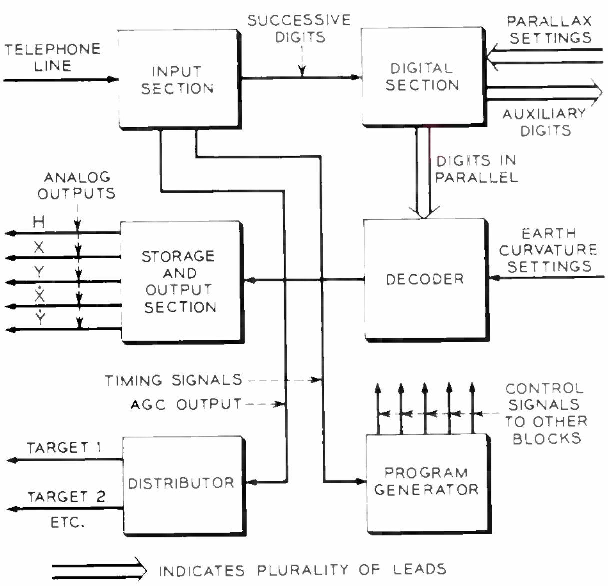


Fig. 4 — Block diagram of AN/TSQ-7 receiver.

Fig. 5 — The author sets in parallax figures on the receiver of the AN/TSQ-7 system equipment.

The decoder converts the binary numbers into corresponding voltages. The five voltages are then stored on five separate analog storage circuits in the output section. The five voltages corresponding to one target are thereby made simultaneously available; in the next frame these same output leads carry voltages corresponding to the next target. With TSQ-8, the outputs pertain to the same target in successive frames but change in value as the target moves. As in the transmitter, these operations are all controlled by the program generator.

The block labeled "distributor" in the block diagram of the receiver is a relay chain similar to the one in the transmitter. With this chain, the incoming line signals (after being amplified to a uniform level, but before detection) can be separated so that target-1 data goes out on line 1, target-2 data on line 2, etc. Data on different targets can thus be routed to different destinations, where they can be decoded by TSQ-8 receivers.

Let us now consider the operation of the encoder in the transmitter. A "ramp generator" in the encoder produces a voltage whose value decreases linearly at a precisely controlled rate. At one instant of time, the output voltage of this generator will have a certain reference value that corresponds to the highest input voltage which can be handled. The voltage decreases until at some later time it is identical to the analog voltage whose value is to be encoded. The interval between these two times is a measure of the value of the analog voltage. The circuits are so arranged that the "beginning" and "end" voltages of the ramp generator trigger the passage of a 100-kc tone, the length of which effectively "counts" the value of the analog voltage.

Suppose, for instance, that it takes 1/2000 of a second for the ramp voltage to drop from the "beginning" to the "end" value. During this time, 50 cycles of the 100-kc energy are allowed to pass through the triggering devices. The number 50 is a discrete decimal representation of the analog voltage. Since we do not want a decimal representation, however, the 100-kc tone is applied to a binary counter located in the digital section. This converts the number 50 to binary form.

The decoder in the receiver operates in an entirely different manner. Here we wish to convert a binary number back to an analog voltage. A ladder network of precision resistors with a relay in each leg of the ladder accomplishes this. A reference voltage is applied to the network, and the circuit is such that the output voltage depends on which relays are operated and which are unoperated. There is one relay for each binary digit. The relay corresponding to the smallest binary digit (if operated) contributes one unit of voltage, the next relay two units, the next four units, and so on. The summation of all these contributions is a voltage corresponding uniquely to the binary number applied to the relays.

TSQ-7 and TSQ-8 are contained in metal cabinets 6 feet high, 2 feet wide, and 16 inches deep. TSQ-8 uses only one cabinet to hold transmitter, receiver, and power supplies, while TSQ-7 uses two cabinets – one for the transmitter and its power units and the other for the receiver and its power units. Each cabinet has folding doors. Within each cabinet, the apparatus is mounted on a swinging-frame type gate. With the gate closed, the controls are accessible from the front of the cabinet; with the gate open, the apparatus can be inspected and serviced.

Development of the TSQ system has resulted in a highly reliable method of transmitting radar data over telephone circuits, and is a good example of how transistors can be used to design more compact and efficient equipment. It is also an illustration of how this solid-state device is playing an important part in our nation's defense.

THE AUTHOR

Walter Koenig, a native of Pitcairn, Pennsylvania received his A.B. degree from Harvard in 1923. After an additional year as instructor and laboratory assistant to Dr. P. W. Bridgman, who was engaged in pioneer research in extremely high pressures, Mr. Koenig joined the Development and Research Department of A.T.&T. Co. This was merged with the Laboratories in 1934. Following work with physiological acoustics, he undertook several projects during World War II—including development of the Sound Spectrograph. Since 1950, he has been associated with the AN/TSQ projects. He has been awarded some 25 patents, is a member of the I.R.E., and is a Charter Member and Fellow of the Acoustical Society of America.

Laboratories Awards Fourteen Graduate Fellowships

Bell Laboratories announced on April 7 the names of fourteen nationwide winners of its 1958-59 university graduate fellowships. Outstanding students working toward Doctor of Philosophy degrees in sciences relating to communications were selected for the annual awards.

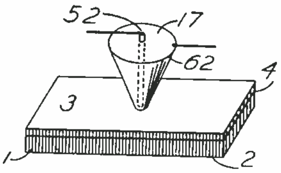
Each Bell Laboratories Graduate Fellowship carries a grant of $2000 to the recipient and an additional $2000 to cover tuition, fees and other costs at the college he has selected for his doctoral work.

The recipients of the fellowships will do their advanced graduate studies at thirteen universities across the nation. The winners were selected by a Laboratories committee of H. A. Affel, chairman, R. L. Dietzold, K. E. Gould, J. A. Hornbeck, S. B. Ingram, W. D. Lewis, F. B. Llewellyn, B. McMillan, H. E. Mendenhall and S. Millman.

During the three years in which fellowships have been granted by Bell Laboratories, a total of 39 outstanding doctoral candidates have received grants. A total of 49 fellowships have been awarded; ten individuals have been named twice.

Six winners are being honored a second time this year with the fellowships. These six, their home towns, the universities they attend, and their fields of specialization are: Sivert H. Glarum, Wyncote, Pa., Brown University, physical chemistry; Eugene Levine, Brooklyn, N. Y., New York University, higher algebra; Bede Liu, New York City, Polytechnic Institute of Brooklyn, active networks (electrical communications); Werner A. Mehlhop, Hamburg, Germany, Washington University at St. Louis, Beta and Gamma ray spectroscopy; William H. Orttung, Narberth, Pa., University of California, electrical and optical properties of macromolecular solutions; and Sukeyasu Yamamoto, Tokyo, Japan, Yale University, experimental nuclear physics.

The eight other fellowship winners, their home towns, the schools they have selected for their advanced studies and their fields of specialization are: Manuel Cardona, Cadiz, Spain, Harvard University, semiconductors; Robert N. D'heedene, New Vernon, N. J., Harvard University, applied mathematics; Howard D. Helms, Winnetka, Ill., Princeton University, communication and information theory; Jagadishwar Mahanty, Cuttack, India, University of Maryland, solid-state physics; Ivars Melngailis, Pittsburgh, Pa., Carnegie Institute of Technology, semiconductors at low temperatures; George E. Smith, Upper Darby, Pa., University of Chicago, experimental solid-state physics; Donald W. Tufts, Boston, Massachusetts Institute of Technology, mathematical aspects of communication theory; and Kenneth G. Wilson, Concord, Mass., California Institute of Technology, who will study theoretical physics.



Patents Issued to Members of Bell Telephone Laboratories During February

Carmichael, R. L. — *Pulse Train Modification Circuits* — 2,824,228.

Cutler, C. C. — *Direct View Storage Tube* — 2,824,260.

Feinstein, J., and Turrell, G. C. — *Magnetrons* — 2,824,231.

Fletcher, R. C. — *Microwave Amplifier Device* — 2,833,332.

Franz, E. E. — *Mass Soldering of Electrical Assemblies* — 2,821,959.

Holman, E. W. — *Selective Ringing Circuit Using a Transistor* — 2,824,174.

Krantz, H. K. — *Relays* — 2,824,266.

Lynch, R. T. — *Cathodes for Electron Discharge Devices* — 2,822,499.

Meacham, L. A. — *Delay Circuit for Amplifying Device* — 2,823,267.

Meacham, L. A. — *Transistor Selecting Ringing, Dialing and Party Identification Circuit* — 2,824,173.

Meacham, L. A., and West, F. — *Selective Ringing Circuits* — 2,824,175.

Means, W. J., and Slonczewski, T. — *Coaxial Switches* — 2,823,358.

Miller, R. L. — *Transmission and Reconstruction of Artificial Speech* — 2,824,906.

Miller, S. E. — *Frequency Selective High Frequency Power Dividing Networks* — 2,823,356.

Molnar, J. P. — *Magnetrons* — 2,824,998.

Oestreicher, J. J. — *Programmer* — 2,823,370.

Ohl, R. S. — *Silicon Translating Devices and Silicon Alloys Therefor* — 2,824,269.

Pierce, J. R., and Yocom, W. H. — *Backward Wave Tube* — 2,824,256.

Quate, C. F. — *Traveling Wave Tube* — 2,823,333.

Slonczewski, T., see Means, W. J.

Smith, K. D. — *Electro-Optical System* — 2,824,975.

Turrell, G. C., see Feinstein, J.

West, F., see Meacham, L. A.

Yocom, W. H., see Pierce, J. R.

Beam Focusing in Microwave Amplifiers

P. P. CIOFFI
Electron Device Development

The traveling-wave tube, now finding many uses in the Bell System, has an important element located outside the glass envelope. Though mechanically simple, this exterior structure — the beam-focusing magnet — must be precisely designed and its field accurately aligned with the tube axis to insure satisfactory operating efficiency and long life in microwave amplifiers.

Microwave radio-relay transmission is the backbone of the Bell System transcontinental communications network. Present radio-relay systems can transmit simultaneously as many as 720 telephone conversations on a single broadband channel using the multiplex technique. A very important part of the repeaters for one of the latest microwave transmission systems — TH — is a traveling-wave tube* which is essentially a microwave amplifier.

High-frequency waves are amplified by interaction with a beam of electrons projected from an electron gun down the center of a helical conductor. The waves to be amplified are put on this helical path to slow them down so that they will receive the full "boosting" power of the electron beam. The amplified microwave signal is then taken off the end of the helix by an output waveguide or coaxial cable, and the stream of electrons is collected at the end of the tube.

This brief explanation of how a traveling-wave tube operates gives no indication of the electrical and mechanical precision necessary for efficient operation. If the electrons in the beam stray too far from the axis of the helix, they impinge on the helix and cause serious deterioration of both the efficiency and life of the tube. The simplest and most efficient method for holding the electron beam together against repulsive electrostatic forces, and also for directing it down the helix axis, is an axially-directed magnetic field of the proper intensity. Since the earliest days of traveling-wave tube development, many types of electro- and permanent-magnet arrangements for beam focusing have been used, both at the Laboratories and elsewhere.

* Record, *December*, 1946, *page* 439.

Beam focusing can be broken down into two separate but interrelated considerations: creating the magnetic field and precisely aligning this field with the electron beam. These, then, are the two problems concerning beam focusing which confront the tube designer:

1) what magnetic materials and magnet shapes will give a uniform field of the required strength;

2) given such a magnet structure, how can its axial magnetic field be analyzed and then aligned with the electron beam of the tube?

Taking the two problems separately, let us consider first some basic facts about magnets. The relatively long, high-intensity field required for electron-beam focusing can be developed most economically with a permanent magnet. An ellipsoid of permanent-magnet material has uniform magnetization and is the most efficient configuration, in terms of volume, for developing a magnetic field. A field equal in intensity and distribution to the field within the permanent-magnet material is also developed within a cylindrical hole along the principal axis of an ellipsoidal magnet. In designing a magnet for a given tube, the length of the major axis (L), of the ellipsoid is fixed by the length of field required for beam focusing. The minor axis (D) can then be determined from the magnetization necessary to develop the required field intensity in the magnet.

Magnetic materials vary widely with respect to magnetization, but the material which operates with the highest flux-density (B) at the required field (H) will have the smallest volume. Every material has a characteristic demagnetization-curve, such as the one shown in Figure 1 (inset). The point P on this curve, given by the coordinates (B) and (-H) is called the "operating point" and, for an ellipsoid, it depends on the ratio of the major axis to the minor axis. This dimensional ratio, L/D, and the ratio of B/H at the operating point of the material, as well as the factor of self-demagnetization of a magnetic body, N, have a known relationship which is plotted in Figure 1. Since the principal axis of the ellipsoid (L) is fixed, the minor axis (D) can be uniquely determined from such a plot.

The practical beam-focusing structure, however, must of necessity deviate considerably from the ideal ellipsoid. In addition to the axial hole required for the tube envelope, large transverse openings are required for the input and output waveguides, and "pole pieces" must also be added for shaping the magnetic field near the poles. The flux leakage due to these structural requirements means that the magnet volume must be substantially increased to furnish the required magnetization. In fact, the volume of a practical structure is approximately three times larger than that of the ideal ellipsoid. To illustrate this deviation from the ideal shape, two magnets and the field-distribution curves inside their axial holes are illustrated in Figure 2.

The traveling-wave tube is mounted in the magnet structure with the tube axis coincident with the mechanical axis of the magnet. If the axis of the magnetic field were also coincident with these axes, ideal focusing conditions would prevail and the radial field components on the common axis would be zero. However, because the magnetic field builds up to its full value over a finite distance, and because this field may vary somewhat along the axis, there will be radial field components *off* the axis even under ideal conditions. These radial components occur where the lines of force tilt toward the axis, as illustrated in Figure 3. But because of complete axial symmetry in the ideal case, the resultant of these radial components in any perpendicular plane must be zero.

In practice, however, it is impossible to achieve complete coincidence of the magnetic and mechanical axes of the focusing system. This lack of coincidence, caused primarily by inhomogeneities within the magnetic material, prevents complete cancellation of radial field components. The resultant of these radial components in any plane perpendicular to the axis, is defined as the *transverse field* at that point. By this definition, an axially symmetric field would have no transverse component on the axis of symmetry.

In focusing traveling-wave tubes, we are concerned with transverse field of the order of one oersted when the longitudinal field is 600 oersteds. This corresponds to a deviation in the axial field of about 0.005 inch in three inches. These quantities imply an extraordinary degree of precision in the location and orientation within the magnetic field of a device for taking the transverse-field measurements. Small errors in both positioning the magnetic center and aligning the magnetic axis of the measurement device with respect to the axis of the magnet would result in large errors of measurement. Precise determinations can be made, however, despite errors of positioning and alignment, by a method which is essentially an exploration of the field for axial symmetry.

Up to this point, we have been dealing with the broad considerations a tube designer takes into account when he sets out to design a beam-focusing magnet. We have also been dealing with this design problem in a general way — any magnet for any tube. In going now to the second half of the beam-focusing problem — analysis and alignment of the field — we are concerned with specific magnets, each with individual field characteristics. Worth mentioning, too, is the fact that these magnets are for manufactured rather than experimental tubes, and both the analysis and aligning of their fields will be done in a manufacturing situation.

A test probe, or search coil, must be used to explore the air-gap field of a magnet. The coil is fixed

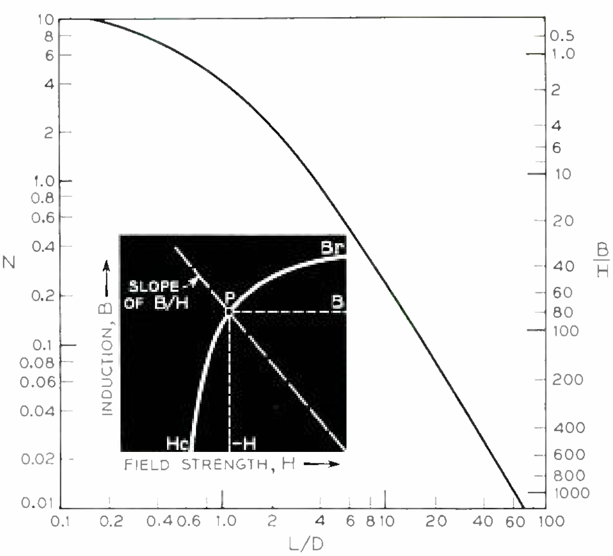


Fig. 1 — Plot of relationships of B/H, L/D and N. Inset shows part of typical demagnetization curve.

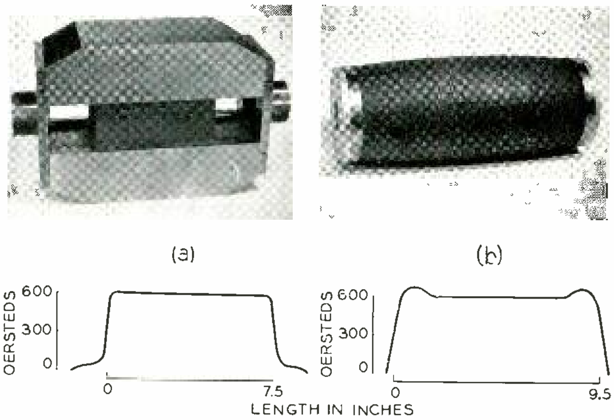


Fig. 2 — Beam-focusing magnet developed for power TWT in TH system (a), and (b) magnet structure for TWT in a military application. Air-gap curves for respective magnets are shown below.

on a non-magnetic mandrel so that the coil axis and the mandrel axis are mutually perpendicular. The axis of the mandrel — made coincident with the mechanical axis of the magnet — is the axis of reference. The search coil is connected to a fluxmeter which detects changes in the magnetic flux interlinking the coil. This flux is due to radial components of the axial magnetic field and to field components resulting from errors in positioning the probe with respect to the mandrel axis.

Thus the relative position of the probe to the axis remains fixed for all mandrel orientations. The field is axially symmetric if there is no change in flux interlinking the probe when the mandrel orientation is changed by 180°. This is true even for large errors of positioning and alignment of the test probe. A resultant change in flux interlinkage, therefore, is a direct measure of the transverse field

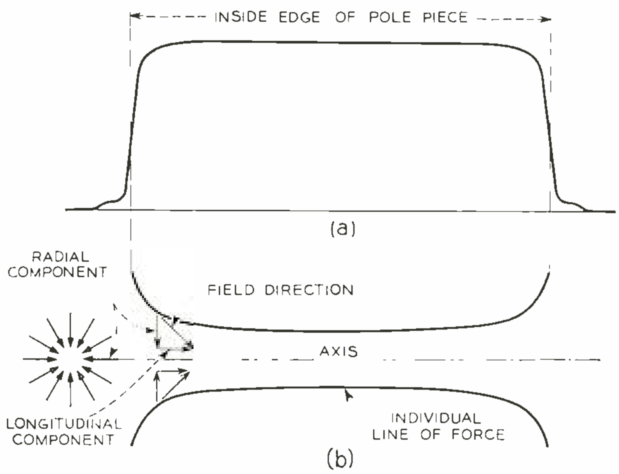


Fig. 3 — (a) Axial field distribution and (b) radial components of the individual lines of force in regions of non-uniform field in a beam-focusing magnet.

at any point on the reference axis in the plane determined by the mandrel and probe axes. As the photograph on page 172 shows, the arrangement for doing this is fairly elaborate. A schematic diagram appears below.

A recording fluxmeter* of high accuracy and sensitivity was used in these measurements. This instrument can record field intensities of the order of a tenth of an oersted with a small probe. Originally developed for tracing magnetization curves and hysteresis loops, the fluxmeter has since been adapted to tracing transverse-field patterns.

The test probe is wound on a brass bobbin 0.25 inch in diameter and 0.2-inch long with approximately 2000 turns of 1.5-mil, Formex-insulated copper wire. The probe is mounted in a transverse hole in a 3/8-inch diameter bronze rod. This non-magnetic mandrel is in turn supported in accurately fitted bushings, with its axis coincident with the mechanical axis of the magnet. The orientation of

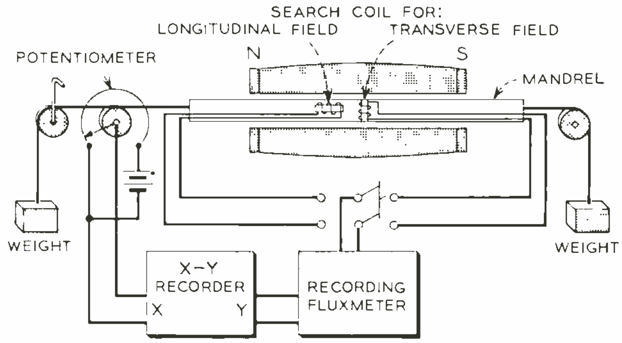


Fig. 4 — Schematic diagram of the field-exploration method showing arrangement of components.

the test probe within the air-gap is read on an index head keyed to a slot in the mandrel. The mandrel is linked to a potentiometer and crank so that turning the crank produces simultaneously a longitudinal motion of the rod and a voltage output from the potentiometer. This output indicates the position of the search coil, and when applied to the X-Y recorder of the recording fluxmeter, moves the pen proportionally. The search coil is directly connected to the fluxmeter, and its output due to a change in inter-linking flux moves the paper drum in proportion to the changes in field intensity.

The recorder thus traces a curve of the variation of the resultant of the longitudinal and radial field components parallel to the probe axis. The variation for every point along this axis is recorded as the probe moves with fixed orientation from pole to pole. If the search coil makes the same traversal with a 180° change in mandrel orientation, the

* Record, *June*, 1952, *page* 247.

recorder traces a curve of similar field components parallel to the new probe orientation. The difference in amplitude between these two opposing curves at any point along the axis is a measure of the resultant radial field — defined earlier as the transverse field. If there were no transverse-field components, the two curves would coincide. To get a complete picture of the transverse-field components present in the air-gap, the distribution patterns in two right-angle planes are generally plotted for each magnet. Patterns of transverse-field distribution can be traced by this method in about thirty seconds.

In addition to the transverse field, longitudinal field-distribution curves, similar to those shown in Figure 2, can also be traced automatically using this exploration method. For plotting the longitudinal field, a second coil is mounted on the mandrel with its axis coincident with the mandrel axis. Longitudinal-or transverse-field distribution curves can then be taken by simply switching the fluxmeter to the appropriate coil.

This method of recognizing and measuring transverse fields has been a great help in developing small, efficient magnets for high-precision, electron-beam focusing. The principal cause of transverse-field components is inhomogeneity of the permanent-magnet material. Field misalignments corresponding to transverse fields of thirty oersteds are not unusual, as illustrated by the patterns in Figure 5. Transverse components of this magnitude would cause complete interception of the electron beam by the helix of the traveling-wave tube.

Although manufactured to very strict specifications and from the best obtainable permanent-magnet materials, beam-focusing magnets cannot be used "as manufactured" because of serious field misalignment. This condition, however, can be counteracted by "field straightening." A very effective field-straightening device has been developed by C. C. Cutler of Bell Laboratories. This relatively simple device consists of an assembly of permalloy discs and aluminum spacers. The field-straightening assembly is inserted in the air-gap along the axis of the magnet. The discs shield the space between them from transverse fields and, as plane-perpendicular, equipotential surfaces, they direct the longitudinal field parallel to the axis. The effectiveness of a permalloy-disc field-straightener is illustrated by a comparison of the transverse-field patterns before and after correction shown in Figure 5. These patterns are for the permanent-magnet structure on the right in Figure 2.

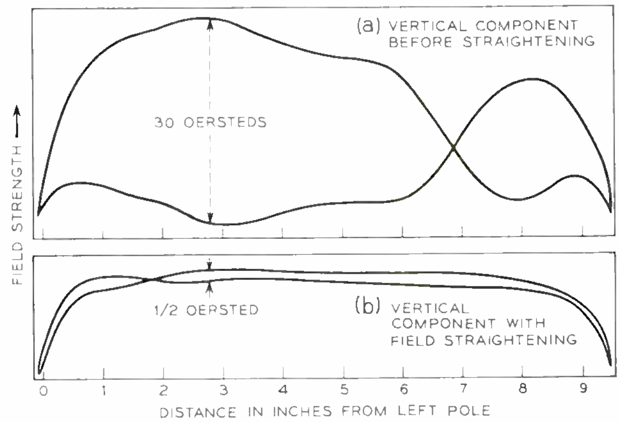
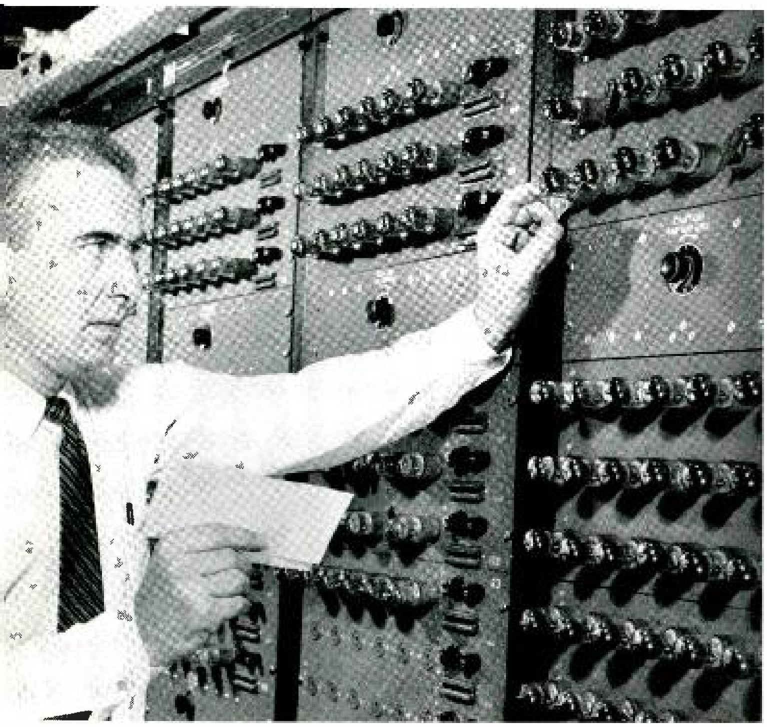


Fig. 5 — Transverse-field patterns of (top) field before straightening, and (bottom) field after installation of field-straightener in the air-gap.

The reduction in transverse field from thirty oersteds to about one-half oersted is indicative of the precise field alignment that can be achieved in a relatively simple manner. With such precisely aligned fields, greater than 99.9 per cent of the electrons emitted from the cathode are reproducibly transmitted to the collector.

THE AUTHOR

P. P. Cioffi, a native of Cervinara, Italy, joined the Laboratories in 1917. He received the B.S. and E.E. degrees from Cooper Union in 1919 and 1922, respectively, and the M.S. degree in Physics from Columbia University in 1924. He has been concerned principally with fundamental investigations in magnetics and magnetic materials and with their application in communication apparatus. His important contributions in this field have been in the development of materials with greatly improved magnetic properties and the development of a recording fluxmeter for tracing magnetization curves and hysteresis loops. Mr. Cioffi is currently engaged in the development of ellipsoidal-type, permanent-magnet structures and the analysis of magnetic-field distributions for the magnetic circuits for electron-beam focusing in traveling-wave tubes. He is a member of the A.I.E.E. and a Fellow of the American Physical Society.



Automatically Recording Tube-Life Data

A. T. ROSS *Electron Device Development*

While the electron tubes for Bell System undersea cables are "aging," a dossier is kept on each tube. In seeking a way to make this record more accurate, uniform and useful, Laboratories engineers have developed a system for automatically recording aging data on business machine cards.

Most electron tubes, no matter how carefully designed or how precisely manufactured, are "aged" for a period of time to stabilize their characteristics. For tubes used in the Bell System undersea cables, the aging period is normally a few thousand hours. During this time, data on various operating voltages and currents are collected and analyzed. This important part of the history of each tube is then carefully considered in the final selection of tubes for use in the cable repeaters.

Until recently, the number of tubes required for cable applications has been small enough to permit taking aging information manually. Future cable programs such as the recently announced second transatlantic cable,* however, may require the construction of larger numbers of tubes. To demonstrate the feasibility of automating the aging facilities for such tube manufacturing programs, the Electron Device Development Department at Bell Laboratories has designed and built equipment that automatically reads data from the aging panels and records it directly on punched cards. Aside from savings in time and labor, this equipment minimizes errors in reading data and yields uniform information in a form suitable for processing on high-speed equipment.

*Record, *November*, 1957, *page* 454.

The automatic recording system is diagrammed simply in Figure 1. The arrangement consists of three basic elements. The first of these is the information source — the individual tubes. Thousands of tubes can be arrayed in bays consisting of twelve racks. Each rack is divided into six panels, and each panel contains 18 tubes. One rack is represented in Figure 1. The second basic element is the control center. The brain of the control center is a unique switching scheme that scans the tube sockets sequentially, and simultaneously coordinates the recording of data. Measurement and recording of data — the third system element — consists of an automatic voltmeter and an analog-to-digital conversion system that enables the business machine to "read-out" data directly onto punched cards. Figure 3 shows the general ar-

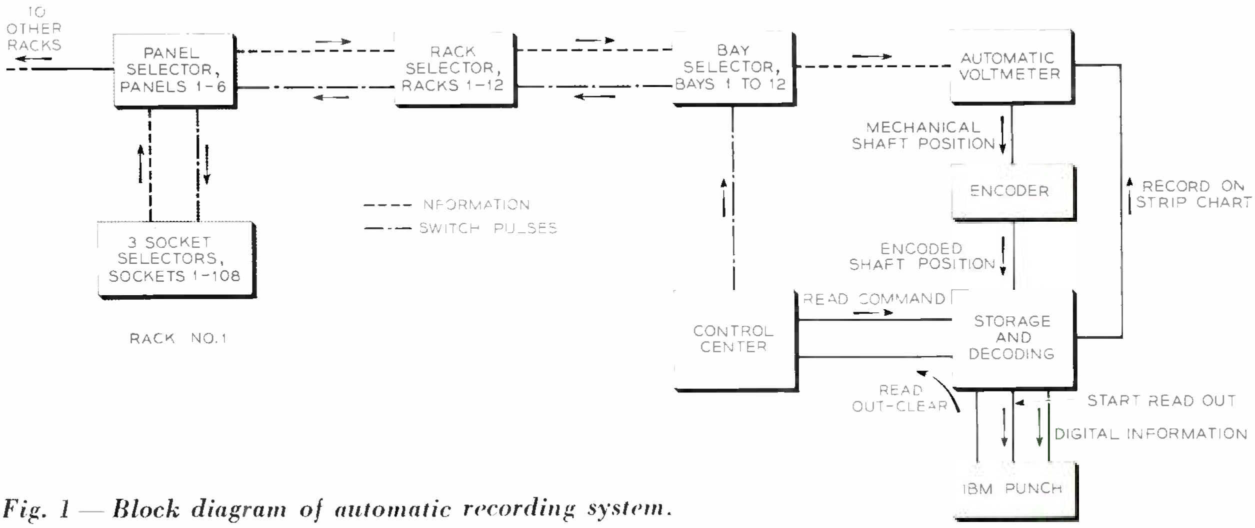


Fig. 1 — Block diagram of automatic recording system.

rangement of these three elements of the system.

The information read by the recording equipment is in the form of low-level dc voltages (zero to ten millivolts). These voltages are generated at the tube sockets by the current in a tube element flowing through low values of resistance. No "signal," or grid voltage, is applied during aging. The information from the tube sockets represents plate voltage, screen voltage, heater current and plate current, and is sent to the automatic voltmeter which presents a high-impedance at balance.

A measurement cycle begins at the control center, where there is a fixed program of pulses — "read," "read-out-clear" and "switch" — repeated every 1.2 seconds. During each of these cycles, three numbers are printed and punched on the card. The short "read" pulse causes information sent to the voltmeter from the tube sockets to be held and decoded by the storage section. This same information is also pen-recorded on a strip chart at the automatic voltmeter. The storage equipment — also stimulated by the "read" pulse — initiates a "read-out" operation by the recording machine.

The program of the business machine is such that it stops operating after three digits have been punched and sends a "clear" signal back to the storage section. This, in turn, permits the control center to clear. The entire recording sequence takes about 0.15 second. When the control center is clear, a pulse is generated to "switch" the system to the next data position. A new voltage then comes to the automatic voltmeter from the next data position, and there is a 1.05-second interval to allow the automatic voltmeter sufficient time to make an accurate balance on the new quantity. The control center then starts the process of generating the next

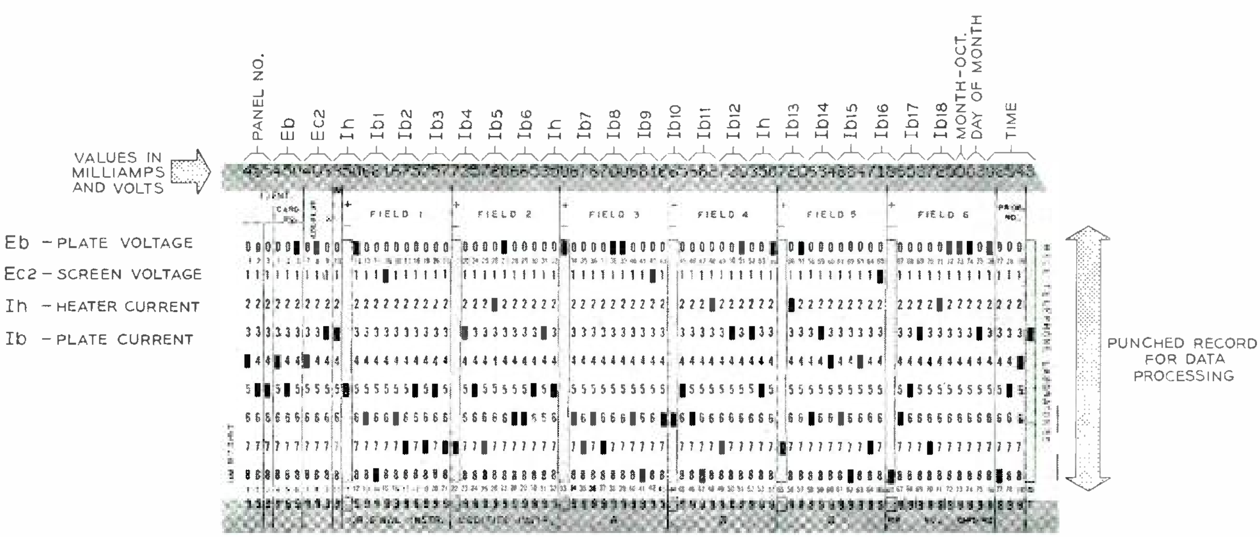


Fig. 2—Business machine card showing printed and punched data and designations of columns.

"read" pulse which initiates the next data cycle.

In each rack, the pertinent data are selected by four stepping switches with silver-alloy contacts. These switches automatically "step-down" from the highest to the lowest of twelve positions. The "panel selector" (switch) on each rack controls the three "socket selectors" (switches) on a rack in sequence. The circuit here is arranged so that each socket selector makes four complete traverses while the panel selector makes only one. To make this possible, the twelfth position on an active switch is used to supply regeneration in two forms: advancing the system to the next data point, and, at the same time, restoring the switch to normal (highest of the twelve positions). For example, socket selectors are regenerated on the twelfth position so that in two traverses they can sample 24 data points on a panel.

One card with eighty columns, as shown in Figure 2, is used to store the following information for each panel: panel number, plate voltage, screen voltage, heater current for each of three rows of tubes, plate current for each of the 18 tubes, date and elapsed time. Aging information, both printed and punched, is listed for a maximum of 18 tubes per card – the normal complement of each panel in the automatic recording system. The printed data at the top is for visual use.

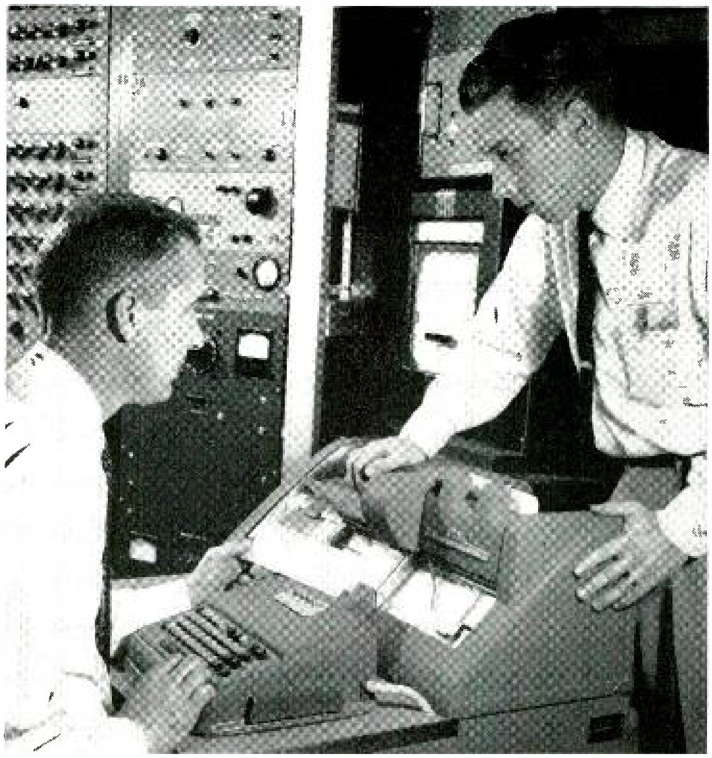
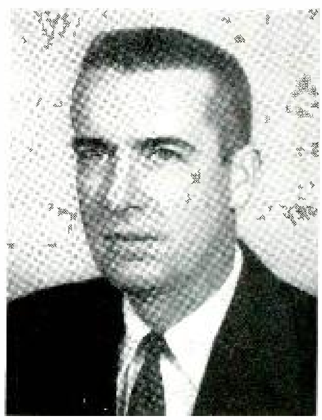


Fig. 3 — The system elements: racks of tube panels extend to left; rack at center contains control elements; author (left) and R. R. Spiwak at recording section of the equipment in the foreground.

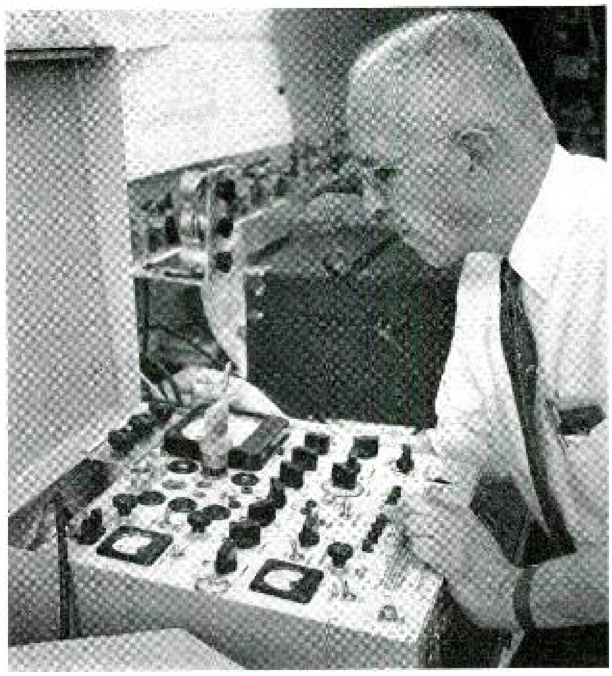
This automatic recording equipment has been in operation for over a year. Its preformance over this period has shown that it is now possible to exercise better control over aging conditions, to obtain a more complete and accurate aging history of each tube, and to obtain data in a form suitable for high-speed, business machine processing.

THE AUTHOR



A. T. Ross, a native of Bedford, New York, received the B.S. degree in E.E. from Lafayette College in 1939. After graduation, he served in the U. S. Navy in the Pacific Theater as a radio material officer, advancing to the rank of Lieutenant Commander. He joined the Laboratories in 1946, where his initial assignment was in the field of high-altitude bombing systems. Subsequently, he transferred to the Electron Device Development Department, where he was concerned with high-power, tunable-magnetron development and later with the production of tubes for the transatlantic cable. He is now engaged in the design of automatic data-recording equipment for use in the development of tubes for broadband submarine cable systems. Mr. Ross is a senior member of the I.R.E.

New Portable Electron Tube Tester



A. A. HEBERLEIN
Transmission Systems Development II

Many key parts of various Bell System communications networks depend on the reliable operation of a wide variety of electron tubes. To help prevent failures and any resulting interruption in service, these tubes are tested from time to time and weak units are replaced. Portable, general-purpose tube testers are often used for performing a variety of these tests.

Among the many types of test equipment in common use in the Bell System, the general-purpose tube tester has become ubiquitous in practically every telephone exchange or repeater office using electron tubes. This widespread use extends from older sets of prewar design to the latest tester to be described in this article (the KS-15750, List 1).

The need for convenient check testing of a wide variety of electron tubes has increased in the last decade, with rapid progress in all aspects of the electronics field. Many applications of tubes in the Bell System permit testing in place with specialized portable test sets designed for this purpose. Supplementing these, the general purpose KS tube test sets must be versatile enough to take care of mobile radio systems, TV terminal equipment, some carrier and signaling equipment, exchange area equipment, as well as varieties of electronic test equipment such as oscilloscopes and transmission measuring and monitoring sets. In addition, tubes in special transmission equipment purchased from outside suppliers for use in the Bell System must be tested. About ninety Western Electric tube codes including the higher transconductance types such as the 404A and 417A are listed on the latest sets, plus hundreds of codes listed for commercial-type electron tubes.

The need for a general-purpose tester was originally met by the adaptation of a commercial set available at that time from the Hickok Electrical Instrument Company. As the need arose for testing more precisely and to take care of new types of tubes outside the capability of the original set, it became necessary to develop new features and improvements from time to time. This resulted in a series of modified designs of increasing complexity which were developed in cooperation with the Hickok Company.

Tube-test features and set operation may be briefly described with reference to the appearance and designation of the panel layout, Figure 1. The electron tube test sockets in the center of the upper panel have their terminals parallel-connected according to common tube base nomenclature. A selector code system is provided to set up any tube type for tests using the seven main selectors. This main selector-switch group includes a lock-out arrangement to minimize possible trouble should duplicate selector code numbers be set up incorrectly. The interconnecting test socket wiring is designed to eliminate possible self-oscillation of tubes under test, using the latest oscillation suppression techniques.

The main selectors connect the proper terminals of a tube under test to the principal functional test circuits of the set through the "shorts test" switch circuit (lower left part of Figure 1). The function selector switch (lower right, Figure 1) controls the various micromho ranges for transconductance measurements. Also included on the function selector switch are a VR test position for metering cold cathode voltage regulator or voltage reference types and a shunt position associated with the shunt potentiometer which provides standard low and high current emission tests for all thermionic diodes. Simple firing point emission tests for small thyratrons by grid voltage control also use this position.

Micromho readings on the GM-VR meter (upper right, Figure 1) are registered on the five ranges designated. The high signal ranges are used for tubes requiring a 5-volt, 60-cps grid signal, and the low signal ranges provide a one-volt signal for the

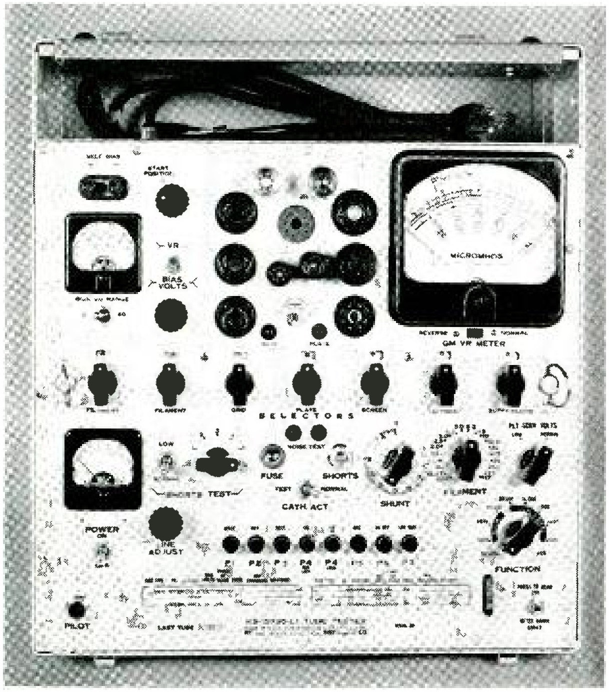


Fig. 1 — Front panel of the improved tube tester.

600, 6,000 and 15,000 micromhos ranges, ½ volt for the 30,000 micromhos range and ¼ volt for the 60,000 range. Indicated transconductance is read on the GM-VR meter as a dynamic measurement derived from the dc unbalance current flowing through a resistor. The dc unbalance condition registered by the GM-VR meter exists when a suitable signal is applied to the grid of a tube under test. This reading is proportional to true transconductance — $G_m = \Delta Ip/\Delta E_g$. Transconductance accuracy as measured in the latest model of this set is in the order of 10 per cent, which is a significant improvement over previous models, particularly in certain micromho ranges. This is reasonable accuracy for the type of maintenance service for which the tester is intended. Test circuit limitations such as the relatively fixed plate and screen test voltages account in part for the limited accuracy. These testers are dependable, however, from the standpoint of reproducibility of measurements with minimum set-to-set deviation errors, important factors where many testers may be in use in large offices.

In conjunction with the basic transconductance test, cathode activity — obtained by observing decrease in G_m with a 10 per cent reduction in filament voltage — and a test for grid current are usually made. Provision is included in this tester for making G_m measurements with a self-bias voltage derived from a required resistance value bridged across the jack pair above the bias voltmeter. This is a valuable feature, particularly for checking higher gain electron tubes which have a steep I_b versus Ec_1 characteristic slope.

The "shorts" test circuit functions on 60-cps supply with a low (50-volt peak) and high (100-volt peak) test voltage option using a 1/25 watt neon lamp indicator. This optional test voltage feature is provided to meet the rigid maximum short test voltages permitted. This test will discriminate between a 0.2 megohm short and a 0.47 megohm no-short condition. A special heater-to-cathode insulation test can be made to detect values above 0.75 megohm. It is also possible to make G_m tests at half the fixed value of plate or screen grid voltage normally used, this to facilitate checking lower plate voltage types.

The new tube tester is the latest of three models of postwar design, all with similar basic test circuits. New test features have been added, in successive models, however, without radical changes in panel layout. This has served to minimize operating confusion since many earlier models are sometimes found in larger offices or installations. The original postwar model first incorporated the basic seven-selector switch arrangement with adequate test sockets for all existing tube types. It also had a master range or function selector switch and a 1-volt grid signal. These improvements were lacking in sets of prewar design. Although this set provided much more testing flexibility in handling all tube types, further development was undertaken in 1949-50 to improve the transconductance accuracy with the use of lower (½ and ¼ volts) grid signals for higher gain Western Electric tubes. In addition, a bias voltmeter was introduced to minimize set-to-set measurement errors. The test set was thus developed to meet demands for improved performance.

Although this model met most field tube testing requirements adequately, several supplementary testing features were added in 1955 to provide the current model. Means for testing voltage regulator and cold cathode types, as well as provision for testing a variety of subminiature tubes, were the most important features hitherto unavailable. The VR tube test circuit dc metering was appliqued by calibrating a 200-volt range on the GM-VR meter as well as by adding a VR-MA 50-ma current measuring range to the existing bias voltmeter.

The necessary dc voltage source was derived from the G_m measuring circuit rectifier supply controlled by the VR Test potentiometer. For subminiature tube testing a nine-pin miniature socket mounted below the panel accommodated special adapters for testing inline or circular base subminiature tubes of the short lead type. In later production, a combination dual subminiature socket fixture is permanently mounted and wired to replace this arrangement. Special octal based plug adapters are available for testing long-lead type subminiature tubes.

As a result of large demand in the Bell System, development effort has been directed toward supplying a universal tube test set. In this development program, a number of important factors have been considered: future requirements which may arise from the increasing numbers of electron tube applications have been anticipated where possible; manufacturing costs have been kept as low as possible in the design which includes a careful choice of essential new features, and the test set has been kept as simple as possible to operate and maintain.

THE AUTHOR

A. A. HEBERLEIN, a native of New York City joined the Development and Research Department of the A.T.&T. Co. in 1922 while completing postgraduate work at Polytechnic Institute of Brooklyn obtaining an E.E. degree in 1923, following a Bachelor of Science degree in engineering from C.C.N.Y. in 1921. Until recently a member of transmission systems development at Murray Hill, he is now with a military electronic reliability group at Whippany. In the D. & R. Department at A.T.&T., he was primarily engaged in the earliest carrier telephone system development and vacuum tube testing problems. From 1932 on, he was concerned with special long-range field trials of improved tubes in VF and carrier systems, development of electron tube test sets, and general tube application, testing and field maintenance problems. He is a Senior Member of the I.R.E.

Bell Solar Batteries and Transistors in Vanguard Satellite

One of the radios used to transmit signals from the U. S. Vanguard satellite to the earth is powered by solar batteries of the type invented at Bell Laboratories. Also in the Vanguard satellite are transistors, invented at the Laboratories and manufactured by Western Electric at Laureldale, Pa.

The solar cells were manufactured by Hoffman Electronics Corp., Evanston, Illinois, under license by Western Electric. They were supplied by Hoffman to the Army's Signal Engineering Laboratories which adapted them for use in the satellite. The solar battery consists of a number of individual silicon cells that convert sunlight directly into electrical energy. Invention of the Bell Solar Battery was announced in April, 1954. It was invented by D. M. Chapin, C. S. Fuller and G. L. Pearson of the Laboratories staff (*see* RECORD, *July*, 1955).

The solar batteries furnish power for the radio when the Vanguard is not in the shadow of the earth. Their life should be many months, depending upon how the material holds up against meteorite bombardment and other physical hazards.

A. T. & T. Annual Meeting

Share Owners Hear of Improvements, Service, Sales

A.T.&T. President F. R. Kappel told of plans for continued growth and greater sales effort.

The Bell System is furnishing more service despite the general slowing down of the economy, A.T.&T. President Frederick R. Kappel told 2,500 share owners attending the Company's Annual Meeting in New York on April 16.

Since last September "when general business really started to fall off," the Bell companies have added more than 1,400,000 telephones, and the number of conversations handled has gone up more than 5,000,000 a day, Mr. Kappel said in his talk.

The president expressed confidence in the future, stating "we expect a further increase in business as 1958 proceeds, and are continuing a construction program of more than two billion dollars this year to improve our facilities and service further and take care of growth."

The Board of Directors was re-elected by share owners. Two proposals by groups of share owners were defeated: (1) placing a $25,000 ceiling on all future annual pensions to officers of the Corporation; and (2) giving share owners the right of cumulative voting for election of directors.

Mr. Kappel reviewed the effectiveness of Bell System operations. His talk was illustrated with more than 100 pictures and charts. "In the last 30 years the number of Bell System telephones has increased from about 13 million to more than 52 million," he said. "In the same period the number of Bell System employees has risen from 350,000 to about 770,000. So our telephones have increased four times while the number of people who provide the service has more than doubled.

"What has made this possible? The answer is: We have better equipment. We are always developing better tools. We try constantly to improve our operating methods. These reflect management leadership—effective research—careful training—and

View of Meeting during business proceedings. Share owners heard that Bell Companies added more than 1,400,000 telephones since September, 1957.

the exercise of American ingenuity by countless telephone men and women," he said.

Mr. Kappel listed numerous examples of how the Bell System has combined more attractive service and better methods of providing service to bring us more customers, earn dividends for our share owners, and provide opportunity for telephone employees. Some of these were: improvements in traffic operating; better tools to splice wires; new test apparatus for identifying telephone wires; improved housecleaning in our buildings and for central office equipment; advances in the manufacture and distribution of equipment and supplies; a new centralizing testing system for central offices that saves time and money; the salvage of everything that is of value and can be reclaimed.

More Automatic Machines

Mr. Kappel also discussed the increasing use of machines that automatically perform routine clerical work, and computers that store and analyze information.

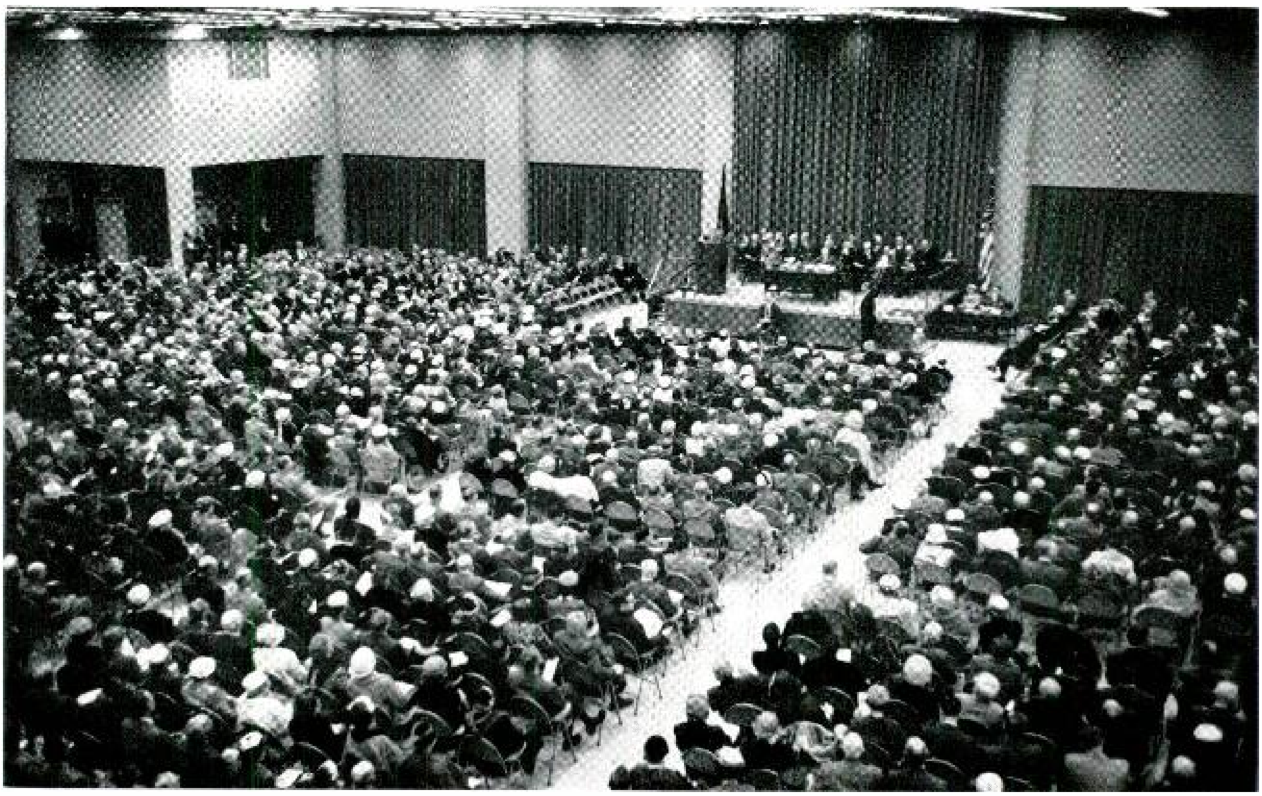
"In years to come, we expect these will not only aid us in providing service more effectively from day to day, they will assist us also in analyzing market conditions—determining what new equipment is needed—engineering the equipment in detail—procuring the necessary materials—and forecasting the manufacturing facilities and the number of people needed to produce the equipment that future service will require.

"All these projects are in close association with the continuous research and development work of Bell Telephone Laboratories," Mr. Kappel said. Technical advances open up the road to progress, and then we go on from there. Research, manufacture and operations all proceed together, and all have a common goal. This is to provide the best possible service to customers, and at the same time earn a satisfactory profit.

The vigorous merchandising, promotion and sale of telephone service were illustrated by several photographs and charts. Mr. Kappel showed the many ways we sell service—by advertising, in business offices, over the telephone, when installers and repairmen visit households. He gave examples of selling complete and convenient local service, and also long-distance service to business firms.

Concluding his talk, Mr. Kappel particularly emphasized the need for obtaining good earnings for investors. "To earn the money we need, we must surely give telephone users the best and most valuable service we know how to provide," he said. "That is the necessary basis—the only basis—for obtaining the rates that will produce good earnings on your investment."

Part of the group of 2,500 share owners attending the April 16 Annual Meeting in New York City.



White Alice Network Completed

An important date in the history of Alaska was recorded when the White Alice Network went into operation on March 26, linking citizens and military personnel of that territory through a reliable long-distance telephone system.

This Air Force communications system, for which Western Electric was the prime contractor, employs the new "beyond-the-horizon" radio technique to furnish telephone and telegraph facilities in an area where terrain, weather and atmospheric conditions formerly made such facilities unreliable at best and non-existent in many cases.

More than this, White Alice represents the successful completion of an Herculean task performed by Western Electric people with the support of groups from Bell Laboratories and the Operating Companies. The new network links Alaskans with their neighbors and provides adequate communication between U. S. air bases and radar stations in Alaska and the remote Distant Early Warning Line radar stations.

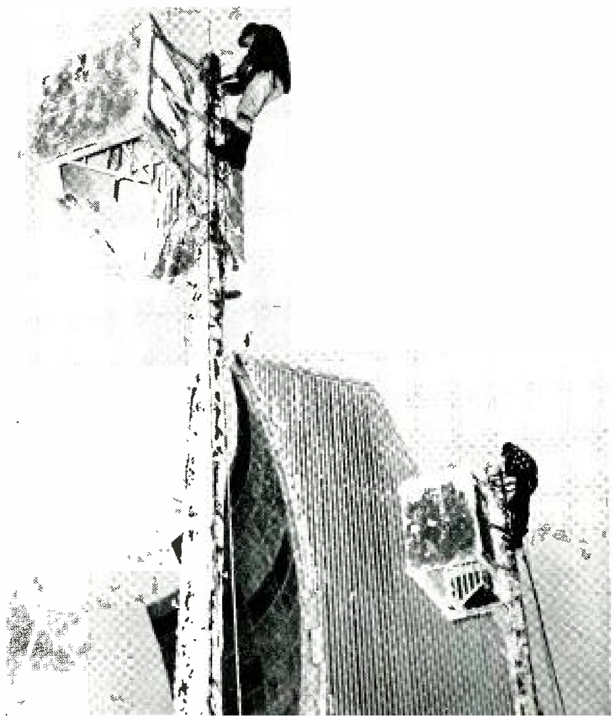
The inauguration of full military use of the system was marked by Brig. Gen. Kenneth H. Gibson, USAF, commander of the Alaskan Air Command, who talked to the more remote aircraft warning posts by means of the network. Mayor Anton Anderson of Anchorage made official calls on behalf of the civilian populace to the mayors of five Alaskan cities over the new system. The official calls were made from the Elmendorf Air Force Base during the acceptance ceremony.

Preceding the calls which inaugurated White Alice service, O. W. Kammerer, White Alice Project Manager for Western Electric, called perimeter points on the network to receive reports on the readiness of the operation. When this was done, William E. Burke, vice president, Defense Projects, presented a certificate of completion to Brig. Gen. Beverly H. Warren, USAF. General Gibson then activated the network. A. Tradup and L. M. Gambrill represented Bell Telephone Laboratories at the ceremonies.

Western Electric, as prime contractor, built the White Alice stations under contracts authorized by the Air Materiel Command of the Air Force. The Alaskan Air Command has assumed military operation of the network and the Federal Electric Corporation will maintain and staff the system.

The acceptance ceremony represented the culmination of three years of work for Western Electric and hundreds of other American industries, large and small, as well as many servicemen and women. The 33-station system was completed despite some of the most challenging problems ever confronted in an undertaking of this size.

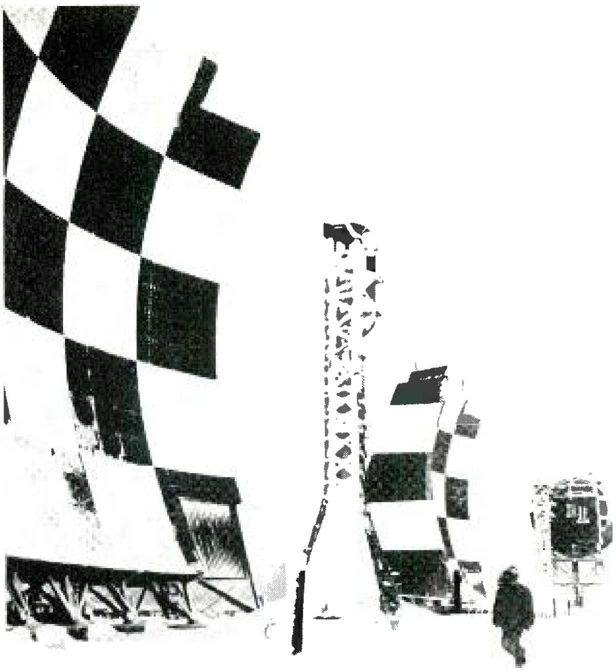
White Alice employs the "beyond-the-horizon" transmission technique to span vast, rugged distances with static-free radio signals. It uses both 30-foot dish-shaped and huge 60-foot 100-ton an-



Western Electric installation experts adjusting "side-leg" antennas at White Alice site. These small antennas provide communications to nearby points; large antenna is used for long distances.

tennas, shaped like outdoor movie screens, to send and receive messages. Under certain circumstances, these devices can be used as both transmitters and receivers. They are aimed with great precision at the next relay station, which may be as much as 200 miles away. Many of the stations are located on remote mountain-tops for maximum effectiveness. They beam their signals above the horizon and the next relay point picks up the faint signal from the troposphere—the upper layer of the air envelope which surrounds the earth. This signal is then amplified and sent along to the next station until the call is routed to its destination.

This construction job would have been a huge task anywhere. When compounded by the rugged terrain and weather of Alaska, it became a job that could be performed only by men and women with skill, ingenuity and courage, such as those from the Bell System who lent their talents to the project. It will stand as a monument to the perseverance of those who created a voice in the wilderness.



"Beyond-the-horizon" antennas transmit and receive over distances up to 200 miles in the network.

Torsional-Wave Delay Lines

A delay line capable of providing a long delay in a small space was described on March 26 at the I.R.E. Annual Convention in a paper prepared by R. N. Thurston and L. M. Tornillo of Bell Laboratories. Known as a delay line of the spiral coiled wire, torsional-wave type, it permits the clear resolution of 10-microsecond pulses spaced 20 microseconds apart.

Delay lines are useful in many applications such as computer memories, trigger delay circuits, range-measurement circuits in radar installations, and in pulse decoding systems for electronic switching. The packaging of these delay lines in a small volume is important.

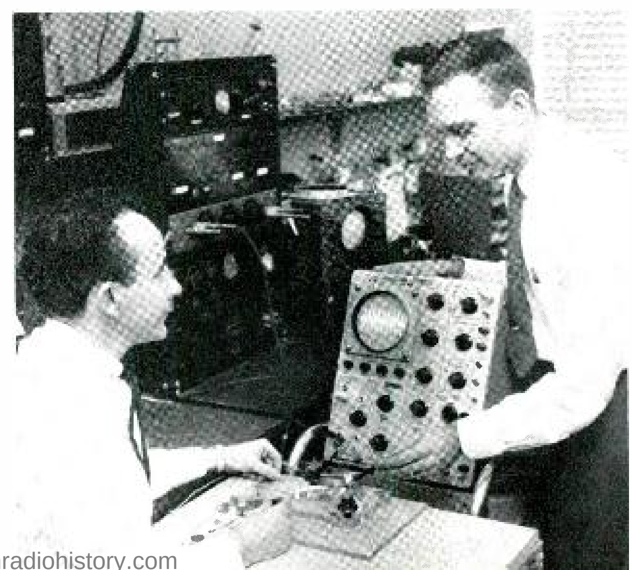
The delay line consists essentially of a length of 0.038-inch diameter wire made of an alloy called vibralloy which has been coiled into a flat spiral to conserve space. Vibralloy, a ferromagnetic alloy developed at Bell Laboratories, is used because it has a high mechanical Q (low losses) and low temperature coefficient of delay.

Torsional waves are transmitted through the vibralloy wire at about 2.68×10^5 cm/sec., making the theoretical delay about 3.72 microseconds per cm. In one experimental line, a 15-foot length of wire exhibited a delay of 1.65 milliseconds at 840 kc. The wire was coiled into a spiral about 4 inches in diameter and then heat treated at 500°C for one and one-half hours.

Specially designed ceramic torsional transducers are used to inject and detect the torsional waves. These transducers limit the bandwidth to about 11.5 per cent. Total insertion loss for the 1.65 ms line was 9 db of which 6 db was line loss and 3 db represented conversion loss in the transducers. Bandwidth was about 100 kc.

A number of experimental delay lines have been built using this technique. Results indicate that such delay lines are small, rugged, reliable, and fairly insensitive to moderate changes in temperature.

L. M. Tornillo (left) and R. N. Thurston conducting performance tests of experimental delay line.

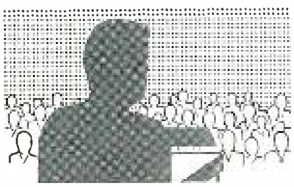


Western Electric Board Elects Two Directors

At a regular meeting of the board of directors of the Western Electric Company on April 18, J. Wilson Newman, president of Dun and Bradstreet, Inc., and Kurtz M. Hanson, president of the Champion-International Company, were elected directors of the Company. They fill vacancies created by the retirement of William B. Joyce and Guy W. Vaughan. Mr. Joyce, president and director of William B. Joyce and Company, insurance brokers, has been a director of Western Electric since 1929. Mr. Vaughan, who has been a director of the Company since 1941, was formerly president and chairman of the board of directors of the Curtiss-Wright Corporation.

Mr. Newman started to work with the Mercantile Agency in 1931 shortly before the merger of R. G. Dun & Company and The Bradstreet Company. Following a wide range of assignments of increasing responsibility he became vice president of the Company in 1946. He was elected president in November, 1952. Mr. Newman is also a director of the Home Life Insurance Company, the Commerce and Industry Association of New York, and the Better Business Bureau of New York and is a trustee of New York University and the New York Institute of Credit.

Mr. Hanson has been president since 1950 of Champion-International, manufacturers of quality coated papers, Lawrence, Massachusetts. Prior to World War II he served in the editorial research and business departments of the National Geographic Society. During the war he was on active duty with the Marine Corps for 43 months. Recently Mr. Hanson completed a two-year term as president of the Associated Industries of Massachusetts. His directorships include the Massachusetts Business Development Corporation, the National Association of Manufacturers, Association of Pulp Consumers, New England Transportation Company, World Trade Center in New England, Inc., and the Massachusetts Higher Education Assistance Corporation.



Talks by Members of the Laboratories

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

American Physical Society, Chicago, Illinois

Batterman, B. W., *Integrated Intensity and Dislocation Content in Germanium.*

Bemski, G., Feher, G., and Gere, E., *Spin Resonance in Electron Irradiated Silicon.*

Boyle, W. S., *Infrared Cyclotron Resonance and Magneto-Plasma Effects in Bismuth at Liquid Helium Temperature.*

Chynoweth, A. G., and Pearson, G. L., *The Effect of Dislocations on Breakdown in Silicon p-n Junctions.*

Dewald, J. F., *A "New" Type of Semiconductor Amplifier.*

Feher, G., see Bemski, G.

Gere, E., see Bemski, G.

Geschwind, G., Walker, L. R., and Linn, D. F., *Observation of Exchange Resonances in Gadolinium Iron Garnet at 24,000 mc.*

Lax, M., *Weisskopf-Wigner Perturbation Theory and the Transport Equation.*

Linn, D. F., see Geschwind, G.

Mandell, E. R., see Slichter, W. P.

Matthias, B. T., *Superconductivity and Ferromagnetism.*

Miller, R. C., *Polarization Reversal in $BaTiO_3$ Samples with Aqueous LiCl Electrodes.*

Pearson, G. L., and Treuting, R. G., *Surface Melt Patterns on Silicon.*

Pearson, G. L., see Chynoweth, A. G.

Phillips, J. C., *An Energy Band Interpolation Scheme Based on a Pseudo Potential.*

Slichter, W. P., and Mandell, E. R., *Molecular Motion in Polypropylene, Isotactic and Atactic.*

Suhl, H., *Amplification of Microwaves by Ferromagnetic Materials.*

Walker, L. R., see Geschwind, G.

Weinreich, G., *The Acoustoelectric Effect.*

Wertheim, G. K., *Neutron Bombardment Damage.*

Wolfe, R., Groves, R. D. and Drabble, J. R. (Groves & Drabble at G.E.), *Anisotropic Hall Effect and Magnetoresistance in N-Type Bismuth Telluride.*

1958 I.R.E. National Convention, New York City

Baldwin, M. W., Jr., *Demonstration of Some Visual Effects of Using Frame Storage in Television Transmission.*

Brown, A. B., and Meyers, S. T., *Evaluation of Some Error Correction Methods Applicable to Digital Data Transmission.*

Graham, R. E., *Subjective Experiments in Visual Communication.*

May, J. E., Jr., *Precise Measurement of Time Delay.*

Meitzler A. H., *Measurement of Frequency and Temperature Dependence of Insertion Loss in Long Delay Lines Made of Fused Silica.*

Meyers, S. T., see Brown, A. B.

Pollak, H. O., *On the Future Mathematical Curriculum for Electrical Engineers.*

Sykes, R. A., *A New Approach to the Design of High Frequency Crystal Filters.*

Thurston, R. N., and Tornillo, L. M., *Coiled Wire Torsional Wave Delay Line.*

Tornillo, L. M., see Thurston, R. N.

Warner, R. M., Jr., *A New Semiconductor Component.*

OTHER TALKS

Baker, P. A., *Transistor Servo Amplifiers,* A.I.E.E.-I.R.E. Student Section, Polytechnic Institute of Brooklyn, N. Y.

Baker, W. O., *Perspectives on Atoms, Bonds and Crystals,* Quartermaster Research and Development Command (RESA), Natick, Mass.

Bommel, H. E., *Some Applications of Ultrasonics to Solid-State Physics,* Department of Physics Colloquium, Iowa State College, Ames, Iowa.

Boyle, W. S., *Infrared Plasma Effects and Cyclotron Resonance in Solids,* McGill University, Montreal, Canada.

Calbick, C. J., *Training of Electron Microscopists in the Development of Techniques,* Symposium on The Human Element in Microscopy, New York Microscopical Society, American Museum of Natural History, N. Y. C.

Chapin, D. M., *Solar Energy and the Bell Solar Battery,* American Society of Mechanical Engineers, Westport, Conn.

Chapin, D. M., *The Bell Solar Battery Moves to Outer Space,* University of Bridgeport, Conn.

David, E. E., Jr., *Hearing and High Fidelity,* Sci-Tech Group of the Special Libraries Association, N. Y. C.

Dransfeld, K., *Sound Absorption in He II,* Fordham University, N. Y. C.

Eckler, A. R., *An Extension of Feller's Method for Calculating Mean Recurrence Times of Complex Events,* Statistics Seminar, Princeton University, New Jersey.

Edson, J. O., Flavin, M. A., and Perry, A. D., *Synchronized Clocks for Data Transmission,* RETMA Conf., RCA., Camden, N. J.

Ferrell, E. B., *Control Charts for Log Normal Universe,* Middle Atlantic Conference, American Society for Quality Control, N. Y. C.

Flaschen, S. S., *New Areas of Inorganic Synthesis Chemistry,* Chemical Engineering Department, C.C.N.Y., N. Y. C.

Flavin, M. A., see Edson, J. O.

Foster, F. G., *Teaching of Industrial Microscopy,* Symposium on the Human Element in Microscopy, New York Microscopical Society, American Museum of Natural History, N. Y. C.

Geballe, T. H., *Thermoelectric, Thermomagnetic and Thermoconduction Processes in Germanium,* Pre-Meeting Symposium of the Division of Solid-State Physics on Phonon-Electron Phenomena, Chicago, Ill.

Geils, J. W., *Research and Development in Industry Today,* Newark College of Engineering, Newark, N. J.

Goldstein, H. L., *Introduction to the Magnetic Amplifier,* New Jersey Division, New York Section, A.I.E.E., Newark, N. J.

Hanna, O. A., *Lightweight Extension Ladder Side Rails,* 1958 Wood Industries Conference Applied Research in Wood Products, Syracuse, N. Y.

Herbert, N. J., *What Can be Done with Transistors Now,* Meeting of the Hampton and Norfolk Sections, I.R.E., Hampton, Va.

Hutson, A. R., *Electronics and Phonons in Zinc Oxide,* Premeeting Symposium of the Division of Solid-State Physics on Phonon-Electron Phenomena, Chicago, Ill.

Jaccarino, V., *Nuclear Magnetic Resonance in Antiferromagnetic Materials,* Newark College of Engineering, Newark, N. J.

Kinsburg, B. J., *Distribution Requirement Specification,* Middle Atlantic Conference, American Society for Quality Control, N. Y. C.

Kuper, A. B., *Physics of Semiconductors,* University of Illinois, Chicago, Ill.

Maas, W. W., *Guided Missiles,* Kiwanis Club, Easton, Pa.

MacKintosh, I. M., *New Developments in Transistor Devices,* PBX Division, New York Telephone Company, N. Y. C.

Maddox, H. D., *Principles of Radar,* Gate City Kiwanis Club, Greensboro, N. C.

Meacham, L. A., *Electronic Telephones,* A.I.E.E.-I.R.E. Sections, University of Washington, Seattle, Wash.; A.I.E.E., University of Idaho, Moscow, Idaho; and A.I.E.E.-I.R.E. Sections, Washington State College, Pullman, Wash.

McClure, B. T., see Pondy, P. R.

Montgomery, H. C., *Relation of Field Effect and Low Frequency Noise in Ge,* Armour Research Foundation, Chicago, Ill.

Moore, E. F., *A General Introductory Survey of Automata,* Columbia University, N. Y. C.

Moore, G. E., *The Dissociation of Solid SrO by Slow Electrons,* Minneapolis Colloquium on Secondary Emission, University of Minnesota, Minneapolis, Minn.

Murphy, R. B., *Stopping Rules for Continuous Production,* Allentown-Bethlehem-Easton Section, American Society for Quality Control, Allentown, Pa.

Perry, A. D., see Edson, J. O.

Pierce, J. R., *Penetration of Space,* Rotary Club of Indianapolis, Indiana.

Pondy, P. R., and McClure, B. T., *Processing Niobium Electrodes for Use in Gas Discharge Tubes,* 19th Physical Electronics Conference, Cambridge, Mass.

Ross, I. C., *Group-Dynamics — What It Is, and What Are Its Potentialities,* Southeastern Personnel Conference, Duke University, Durham, N. C.

Schmidt, P. L., *Rectifier and Core Characteristics,* A.I.E.E. Study Group on Magnetic Amplifiers, Newark, N. J.

Schnettler, F. J., *Ferrites and Their High Frequency Applications,* Regional Meeting, I.R.E., Burlington, N. C.

Schwenker, J. E., *Communications Research at the Bell Telephone Laboratories,* Wichita Section, A.I.E.E., Wichita, Kan., and Little Rock Section, I.R.E., Little Rock, Ark.

Stansel, F. R., *Transistors and Other Semiconductor Devices,* Student Branch, A.I.E.E., Merrimack College, North Andover, Mass.

Terry, M. E., *Rank Order Statistics,* Delaware Section of American Society for Quality Control, Wilmington, Del.

Thatcher, W. H., *NIKE — A Guided Missile System for AA Defense,* Oranges-Maplewood Chapter of the American Red Cross, New Jersey.

Talks by Members of the Laboratories, Continued

Thomas, C. O., and Baker, B. B. (Southern Res. Ins.), *The Detection and Estimation of Atmospheric Proteins by Pyrolysis to Hydrogen Cyanide*, Meeting in Miniature of the American Chemical Society, N. Y. C.

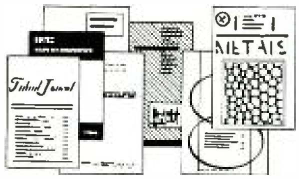
Thomas, C. O., and Smith, H. A. (Univ. of Tenn.), *The Separation of Mixtures of Ordinary and Heavy Water by Zone-Refining*, American Chemical Society, N. Y. C.

Weinreich, G., *The Acoustoelectric Effect*, Solid-State Seminar, Physics Department, University of Illinois, Urban, Ill.

Wilk, M. B., *Reduced Regression Models*, Columbia University, N. Y. C.

Willhite, C. C., *NIKE-AJAX – A Guided Missile System for AA Defense*, US Air Force Eastern Technical Network Military Affiliate Radio System (Radio Network talk).

Wood, Mrs. E. A., *Laves Phase Relationships*, Polytechnic Institute of Brooklyn, N. Y.



Papers by Members of the Laboratories

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

Ballhausen, C. J. see Liehr, A. D.

Benson, K. E., see Wernick, J. H.

Boyle, W. S., Brailsford, A. D., and Galt, J. K., *Dielectric Anomalies and Cyclotron Absorption in the Infrared: Observations on Bismuth*, Phys. Rev., **109**, pp. 1396-1398, Feb. 15, 1958.

Brady, G. W., *Structure in Ionic Solutions, II*, J. Chem. Phys. **28**, pp. 464-469, March, 1958.

Brailsford, A. D., see Boyle, W. S.

Breidt, P., Jr., Hobstetter, J. N., and Ellis, W. C., *Some Effects of Environment on Fracture Stress of Germanium*, J. Appl. Phys., Letter to the Editor, **29**, p. 226, Feb., 1958.

Bridges, T. J., and Churnow, H. J. (Services Electronics Res. Laboratory, England). *Experimental 8-mm Klystron Power Amplifiers*, Proc. of the I.R.E., **46**, pp. 430-432, Feb., 1958.

Burrus, C. A., *Stark Effect from 1.1 to 2.6 Millimeters Wavelength:* PH_3, PD_3, Di and CO, J. Chem. Phys., **28**, pp. 427-429, March, 1958.

Burton, J. A., *Electron Emission from Avalanche Breakdown in Silicon*, Phys. Rev., Letter to the Editor, **108**, pp. 1342-1343, Dec. 1, 1957.

Ellis, W. C., see Breidt, P., Jr.

Fairbanks, G., and Guttman, N., *Effects of Delayed Auditory Feedback Upon Articulation*, J. of Speech and Hearing Research, **1**, pp. 12-22, March, 1958.

Fuller, C. S., see Reiss, H.

Galt, J. K., see Boyle, W. S.

Geller, S., see Wernick, J. H.

Gerard, H. B., and Shapiro, H. N. (NYU), *Determining the Degree of Inconsistency in a Set of Paired Comparisons*, Psychometrika, **23**, pp. 33-46, March, 1958.

Gilleo, M. A., *The Superexchange Interaction Energy for* Fe^{3+}-O^{2-}-Fe^{3+}, *Linkages*, Phys. Rev., **109**, pp. 777-781, Feb. 1, 1958.

Guttman, N., see Fairbanks, G.

Hobstetter, J. N., see Breidt, P.

Jannsen, W. F., and Rigterink, M. D., *Microstructure of Ceramics for Communication Equipment*, Am. Ceramic Society Bulletin, **37**, pp. 152-156, March, 1958.

Krusemeyer, H. J., and Thomas, D. G., *Adsorption and Charge Transfer on Semiconductor Surfaces*, J. Phys. and Chem. of Solids, **4**, Nos. 1/2, 1958, pp. 78-90.

Lander, J. J., see Morrison, J.

Law, J. T., *An Explanation for Some Anomalous Adsorption Effects Attributable to an Ion Gauge*, J. Chem. Phys., Letter to the Editor, **28**, pp. 511-512, March, 1958.

Liehr, A. D., and Ballhausen, C. J., *Inherent Configurational Instability of Octahedral Inorganic Complexes in E_g Electronic States*, Annals of Phys., **3**, pp. 304-319, March, 1958.

Matthias, B. T., see Geller, S.

McDavitt, M. B., *6000 Megacycle Radio Relay System for Broad-Band, Long Haul Service in the Bell System*, Alta Frequenza, **26**, pp. 428-446, Oct., 1957.

Miller, C. E., *A Method for Growing Single Crystals of Potassium Niobate*, J. Appl. Phys., Letter to the Editor, **29**, p. 233, Feb., 1958.

Miranker, W. L., *The L^2 Maximum Principle for Solutions of $\Delta u + k^2 u = 0$ in Unbounded Domains*, Annals of Mathematics, **67**, pp. 72-82, Jan., 1958.

Morrison, J., and Lander, J. J., *The Concentration of Hydrogen in Nickel under Hydrogen Ion Bombardment*, J. Electrochemical Society, **105**, pp. 145-148, March, 1958.

Reiss, H., and Fuller, C. S., *The Effect of Ion Pair and Ion Triplet Formation on the Solubility of Lithium in Germanium – Effect of Gallium and Zinc*, J. of Phys. and Chem. of Solids, **4**, Nos. 1/2, 1958, pp. 58-67.

Rigterink, M. D., see Jannsen, W. F.

Scheinman, A. H., *A Numerical-Graphical Method for Synthesizing Switching Circuits*, Comm., and Electronics, pp. 687-689, Jan., 1958.

Slepian, D., *Noise Output of Balanced Frequency Discriminator*, Proc. of the I.R.E., **46**, p. 614, Correspondence Section, March, 1958.

Thomas, D. G., see Krusemeyer, H. J.

Wernick, J. H., Geller, S., and Benson, K. E., *New Semiconductors*, J. Phys. and Chem. of Solids, **4**, Nos. 1/2, 1958, pp. 154-155.

Wertheim, G. K., *Transient Recombination of Excess Carriers in Semiconductors*, Phys. Rev., **109**, pp. 1086-1091, Feb. 15, 1958.

Westover, R. F., *The Thirty Years of Plastics Impact Testing – Part I*, Plastics Technology, **4**, pp. 223-240, March 31, 1958.