The Role of Quality Assurance in the Bell System

R. B. MURPHY *Quality Assurance*

Even with the strict manufacturing quality-control measures imposed by Western Electric, the Operating Companies want assurance that merchandise they purchase conforms to specifications. The Quality Assurance Department of the Laboratories acts in this capacity as their representative, with activities in three broad areas. Inspection engineering deals with inspection requirements and quality evaluation of the product. Complaints of defective product are evaluated and appropriate action recommended. Also, together with Western Electric personnel, the Department conducts quality surveys on individual telephone items.

Of the technical departments in the Laboratories, the Quality Assurance Department is one of the few not principally engaged in research or development. To understand the objectives of this department, it is necessary to regard the Bell System, exclusive of the general departments of the American Telephone and Telegraph Company, as composed of three parts: Bell Telephone Laboratories as the designer, Western Electric as the supplier, and the aggregate of the Operating Companies and Long Lines as the consumer.

Granted that the consumer – in this Bell System sense – knows the kind and quantity of goods he wishes to purchase, he needs assurance when he buys that the purchased product will for a specified time perform as the designer intended and that the cost, including future maintenance, is not excessive. This assurance is necessary to satisfy the consumer that he is paying a reasonable amount for equipment that will provide the ultimate telephone customer with the expected standard of service.

The interests of the Bell System as a whole temper these desires of the consumer in two ways. First, economy for the consumer – and for the telephone customer – means system-wide economy. If any part of the system should operate uneconomically, the telephone customer would eventually pay for it. Thus, the designer's, supplier's, and consumer's costs must all be considered. It is possible, for instance, that the supplier, in an effort to introduce economies in manufacture, might inadvertently increase the system-wide cost of a given product by shortening its life, increasing maintenance, or affecting interchangeability. On the other hand, the designer may be unaware that a specification may lead to a higher over-all cost than necessary to achieve his design intent. Second, the means of gaining assurance should be as inexpensive as possible. If each Operating Company acted for itself, there would be extensive duplication of effort. For instance, at a supplier's plant, every company might have its own representative. These men would do the same kind of work even though fewer people might be able to do it better. Therefore, A. T. & T. has delegated the Quality Assurance Department, as a central agency, to see that the interests of system-wide economy are observed in quality matters.

In the Bell System, quality assurance is a judicial function and is not synonymous with either quality control or statistical quality control. Quality

Fig. 5 — R. H. Gertz, second from left, and H. C. Curl, second from right, watch the manufacturing process with Western Electric Quality Control and Inspection Control representatives during a quality survey on the 1A telephone answering set.

concerned, based on data collected by the appropriate inspection group. A typical quality index is that for TD microwave equipment, Figure 6. The "standard quality level" represented by the solid line is considered by the Quality Assurance Department to signify an economic compromise between the need of the consumer to receive high quality product and the need of the supplier to operate at tolerable cost. The dotted lines in Figure 6 represent the extent to which individual index points may depart from the standard quality level without being judged significantly different from it. This allowance is necessary because the information on which the index is based is only a sample, and chance variations are to be expected even when the prevailing quality is nearly standard.

Finally, inspection engineering includes passing judgment on lots of product calling for special consideration under the terms of inspection specifications. This is called the *nonconformance* procedure. Under its provisions, nonconforming lots are shipped to the consumer only with the knowledge and agreement of the Quality Assurance Department after discussion, when appropriate, with the purchasing company. Nonconforming lots with serious defects are rarely considered for acceptance. Of all nonconforming lots submitted for Quality Assurance Department approval in 1954, about 98 per cent in dollar value were eventually shipped to the Operating Companies. These shipped lots constituted only about 1 per cent in dollar value of all apparatus and equipment purchased.

Naturally, the inspection engineering function applies not only to goods manufactured by Western Electric, but to goods purchased for the Bell System by Western Electric from outside manufacturers, to central-office equipment installed by Western Electric, and to used apparatus repaired by Western Electric Repair Shops.

The second broad area of quality assurance work is the handling of engineering complaints from the Operating Companies. Around 5,000 such complaints are received yearly, of which about one-half arise from the ordinary amount of defectiveness economically tolerable in manufacture, and recommendations to Western Electric for settlement are quickly made. Ten per cent more involve only cursory checking, but the remaining 40 per cent require more thorough engineering investigation, including close examination of individual units or samples of defective lots usually accompanying complaints. The technical cooperation of Western Electric and various departments of the Laboratories has been vital to the successful conduct of many such investigations. The Laboratories' effort is largely devoted to seeking for any conditions requiring changes in the production process or in the design itself. Substantial savings in maintenance and replacement costs have been obtained from this complaint program. As a by-product, the volume

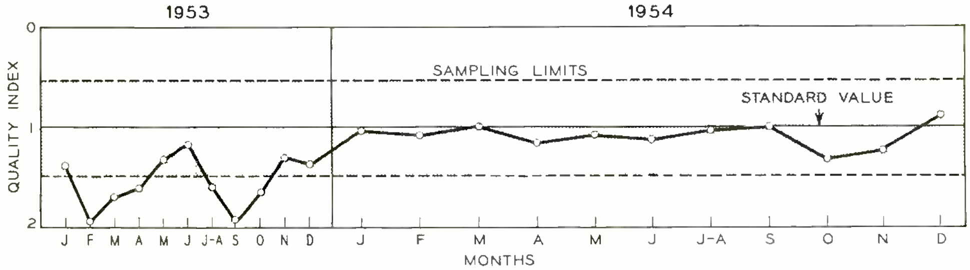


Fig. 6 — Quality index for TD microwave equipment.

and variety of complaints serve as a check on the standards set by the department.

The third and most unusual area of quality assurance activity is the program of quality surveys. Each year, about forty or fifty products are selected out of the hundreds available for quality surveys. Among the considerations governing the selection of products are any unusual quality history of the product in the factory or in the field and the economic importance of the product in the Bell System. After a product is chosen for a quality survey, the appropriate quality specialist carefully examines a specimen of recent manufacture and reviews all the information available to him pertaining to the quality of the product such as that derived from complaint and inspection records, special studies, or informal field reports. At the same time, a similar review is made by a representative of the group that regularly inspects it on behalf of the Quality Assurance Department, and a representative of the manufacturer also conducts a review.

Together, the reports of these three men form a Preliminary Survey Report, and this is followed by a meeting of the three men at the manufacturing location, where the production process is observed. The committee of three then jointly consider any pertinent matters relating to the quality of the product that have appeared in their reports and observations. These might concern the necessity and sufficiency of Laboratories engineering specifications, of inspection specifications, of quality standards, or of test information and procedures. They might deal with agreement of manufacturing, installation, or repair specifications with those of the designer, the acceptability of the production process, test-set accuracy and calibration, recent nonconformance and complaint history of the product, or comments from the field. The outcome of this meeting is a joint Final Survey Report, recommending appropriate action and who is to take it. Such recommendations may be directed to the designer, the producer, the inspection group, or Quality Assurance itself. Action on the recommendations is closely watched by the quality specialist.

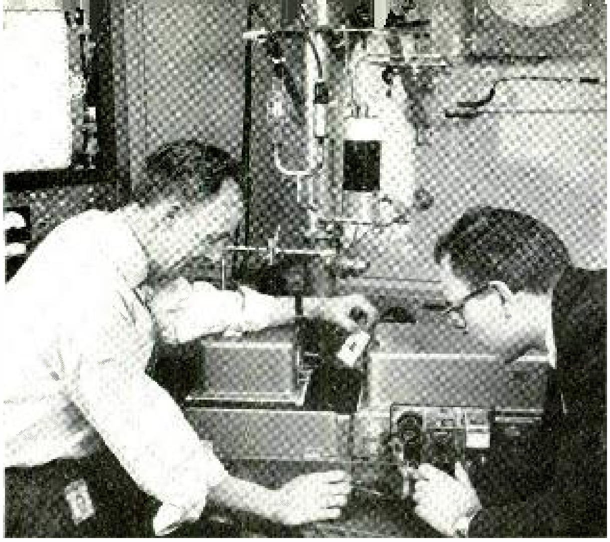
In addition to the approximately 55 quality specialists, there is a force of about 15 Field Engineers located from coast to coast who are the liaison with the Operating Companies. These men investigate about 60 per cent of the complaints themselves; the rest are forwarded to the Laboratories. Field comments also pass through the Field Engineers and are valuable in assessing the soundness of the department's quality standards.

About 10 people form the quality results group. Their work is largely statistical and covers the preparation of general inspection specifications, planning and editing the Quality Report, informal consulting on statistical problems, and research into those problems of industrial statistics involved in the department's operations. Important contributions to the theory and practice of industrial quality control have come from past and present members of this group, including the control chart and various forms of the attribute sampling plan widely used in industry today.

The Quality Assurance Department has worked closely with the U. S. Army, preparing inspection tables and procedures for the Ordnance Corps during World War II, to be used in inspecting material before purchase. During the Korean War, the department undertook an Ordnance contract for quality control on the 105-millimeter Howitzer shell. At present, the department is working on an Ordnance contract, the first of its kind, for quality assurance on the Nike guided missile. Finally, the Atomic Energy Commission is developing a quality assurance plan along lines suggested by the department after extensive study of their problems.

THE AUTHOR

R. B. Murphy received the degree of A.B. in 1943 and a Ph.D. in 1951 from Princeton University. He was on the teaching staff of Carnegie Institute of Technology from 1949 to 1952, reaching the position of Assistant Professor. He joined the Quality Assurance Department of the Laboratories in 1952, and has specialized in the statistical aspects of quality assurance since that time. During World War II, Dr. Murphy served as radar officer in the U. S. Marine Corps. He holds membership in the Institute of Mathematical Statistics, the American Statistical Association, The Econometric Society, the Institute for Computing Machinery and the American Mathematical Society.



Intermetallic Semiconductors

H. J. HROSTOWSKI *Semiconductor Research*

We now have a fairly complete knowledge of the semiconductors silicon and germanium, but there is another class of semiconductors — the intermetallic compounds — about which our knowledge is as yet incomplete. Recent investigations have shown, however, that we can make intermetallic compounds with a wider range of electrical properties than is obtainable with silicon and germanium, and thus it may be possible to produce more versatile transistors and other semiconductor devices.

Within the past decade, such rapid progress has been made in the study of silicon and germanium, that there is now a great interest in other semiconducting materials. Among the more promising types are the intermetallic compounds – a new class of semiconductors distinctly different chemically from silicon and germanium. This new class of materials exhibits diversified electrical properties which should be useful in constructing a broader variety of transistors and transistor-like devices.

The chemical difference between a semiconductor like silicon and an intermetallic compound can be seen from an inspection of the familiar periodic table of the atoms. Carbon, silicon, germanium and a few other chemical elements all lie in group IV of the periodic chart. Each has four valence electrons in its outer or chemically active ring. In the solid state, the atoms share the outer electrons to form "bonds" which constitute the cohesive forces that give the material its crystalline character. The materials discussed here, however, do not consist of single elements in crystalline form, but of crystal structures of compounds – chemical compounds of two different metallic elements.

Perhaps the most promising of these new semiconductors are the so-called group III – group V compounds. One of the combining elements is taken from group III of the periodic table (three valence electrons per atom) and the second is taken from group V (five valence electrons). Equal numbers of the two atoms are used. Since in the periodic table these elements bracket the group containing germanium and silicon, and since a III-V compound "averages" four electrons per atom, we may expect that these compounds will undoubtedly have many semiconducting properties of interest to communications technology.

One of the fundamental electrical properties of a semiconductor is the energy required to free an electron from the bond formed when two atoms share a pair of electrons. When such bonds are broken, electrons become free to travel about in the crystal and thus to conduct electricity. The "hole" left by a departed electron is also considered as a conductor of a positive charge and is similarly free to travel about. The energy required to create an electron-hole pair is called the "forbidden energy gap." This quantity varies for different semiconductors and is one way of distinguishing among them and of determining how likely they are to be of practical use. One of the most significant features of the intermetallic compounds is that by using different combinations of group III and group V elements, we can achieve a very wide range of

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In the illustration at the top of the page R. H. Kaiser (left) and the author engage in an experiment to determine infra-red transmission of the intermetallics.

energy gaps. Another property studied closely in semiconductors is mobility, or the speed with which electrons or holes move through a crystal in an electric field of one volt per cm. Intermetallic compounds exhibit the high electron and hole mobilities observed previously only in germanium and silicon. For these reasons, it may be possible to construct transistors or semiconductor diodes with a broader choice of such properties as current or power-handling capacity, rectification ratio, and wide range of frequency.

As with the single-element semiconductors, the electrical properties of the intermetallics are greatly affected by very small concentrations of free carriers of electrical charge. In a particular crystal, the concentration of charge carriers may be increased by adding small amounts of impurities which contribute excess electrons or holes. Also, increasing the temperature of the crystal has the effect of freeing more electrons and holes for conducting electrical current. Because of the importance of these carriers in the semiconductor, charge-carrier concentrations must therefore be measured with great accuracy by determination of the Hall coefficient.* In the Hall experiment, the deflection of a current by a magnetic field is used to measure impurity concentrations with much greater accuracy than is possible with conventional analytical procedures.

Inspection of the periodic table of the chemical elements suggests that many group III – group V (III-V) compounds exist. Examples are indium antimonide (InSb), gallium arsenide (GaAs) and indium phosphide (InP). Since InSb has been investigated most extensively, we choose it to demonstrate some of the semiconducting properties of the III-V compounds. Although indium and antimony are both metals, InSb is a semiconductor with a cubic crystal structure which would become the diamond structure of silicon or germanium if all the atoms were alike. Figure 1 shows samples of metallic indium and antimony and a single crystal of InSb pulled from the melt. With three valence electrons for each indium atom and five for each antimony, there is an "average" of four electrons per atom in InSb. Thus, between each atom and its four nearest neighbors we have four electron-pair bonds. Since the forbidden energy gap is only 0.16 electron-volts, ordinary thermal agitation at room temperature produces 2 x 10^{16} electron-hole pairs per cm^3. These are free to conduct electricity in an applied field. Figure 2 shows the conductivities of two relatively pure InSb samples plotted as a function of temperature. Above 250°K, increasing thermal agitation ruptures more In-Sb bonds as the

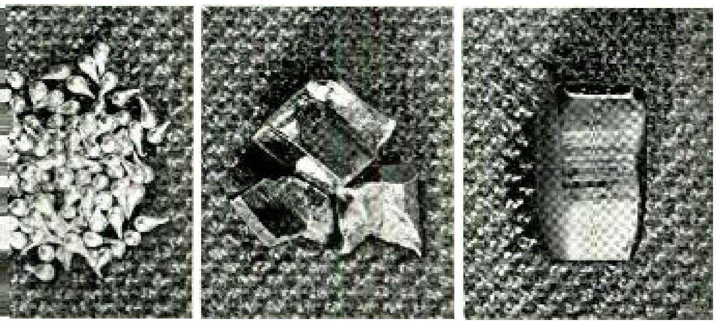

Fig. 1 — Left to right: indium, antimony, and a single crystal of indium antimonide, an intermetallic semiconductor.

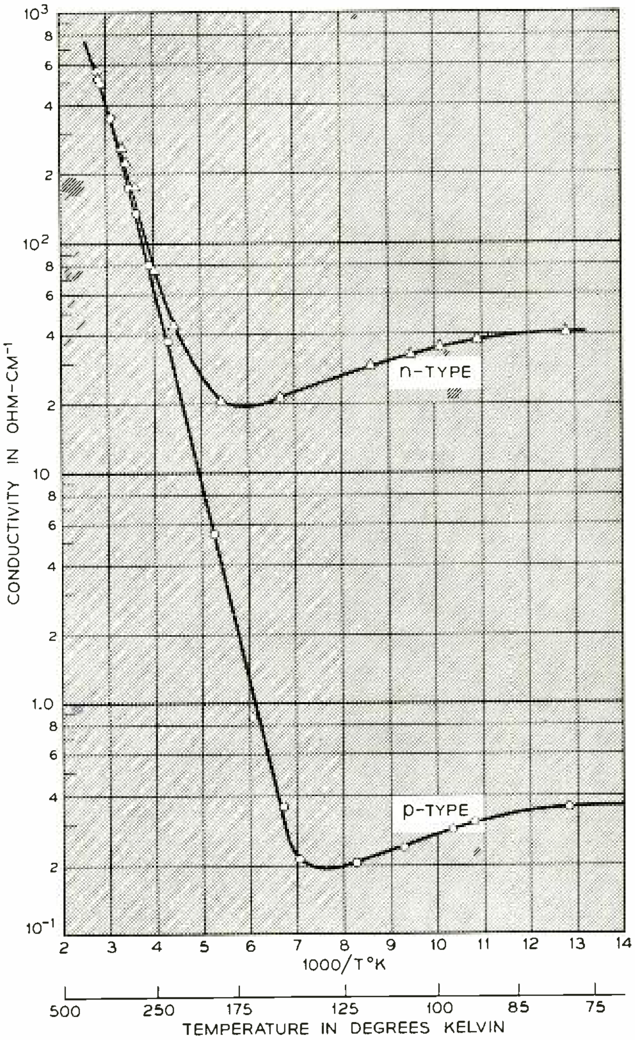

Fig. 2 — Conductivities of n- and p-types of indium antimonide, showing high-temperaure intrinsic region and low-temperature impurity region.

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* Record, *March*, 1955, *page* 85.

temperature rises. The number of charge carriers now depends primarily on the numerical value of the energy gap; the impurity effects are negligible. This is the "intrinsic" region where the properties are nearly identical to those of an absolutely pure crystal. Below 250°K, the electrical activity of impurities is much greater than that of the intrinsic electrons and holes, and we observe impurity conduction, which is discussed below.

It is a well known empirical fact that the energy gaps of the group IV elements decrease, going down the periodic table from diamond to gray tin. The same trend applies to the III-V compounds, although the situation is more complex here because of the possibility of "diagonal" compounds (compounds of a light and a heavy element) such as aluminum antimonide (AlSb). Table I lists energy gaps at room temperature and melting points of the III-V semiconductors along with similar data for the group IV semiconductors. The energy gaps of the compounds range from a few tenths of an electron volt to several electron volts. Comparing these to 0.75 e.v. for Ge and 1.1 e.v. for Si, it is readily apparent that we now have available a large number of cubic semiconducting materials with a wide range of forbidden energy gaps. It seems that only the inevitable lag in technology prevents us from selecting a "tailor-made" semiconductor most suitable for a particular application.

Table I also lists the room temperature values of electron and hole mobilities for the III-V compounds. These values have been obtained from Hall effect and conductivity measurements on samples exhibiting impurity conduction. N-type conduction occurs when we introduce impurity atoms which have electrons in excess of those needed for bond formation. If, for instance, an antimony atom in InSb is replaced by one of tellurium, we have six valence electrons of which only five are needed to complete the bond structure. The extra electron wanders about the lattice and drifts toward the positive terminal of an applied electric field. P-type samples may be produced by substituting zinc atoms for indium. Now we have only two electrons where three are needed, and the result is a positive hole which drifts toward the negative terminal in an applied field. The excess electrons (or positive holes) are normally bound to their respective impurity atoms at 0°K. However, the binding energies are very small and thermal agitation ionizes these carriers much below room temperature. In general, we produce n-type conduction by substituting group VI elements for antimony and p-type conduction by replacing indium with group II elements.

TABLE I

	Melting Point (°C)	*Energy-Gap* (electron-volts)*	*Electron Mobility (cm^2/volt-sec)*	*Hole Mobility (cm^2/volt-sec)*
InSb	523	0.17	70,000	~500
InAs	936	0.4	23,000	~100
InP	1070	1.25	34,000	650
GaSb	720	0.75	4,000	700
GaAs	1240	1.35	4,000	200
GaP	–	2.2	–	–
AlSb	1080	1.6	~100	200
AlAs	–	–	–	–
AlP	–	3†	–	–
Ge	936	0.75	3600	1800
Si	1420	1.1	1900	425

* Values obtained primarily from optical data.
† Estimated from color of material.

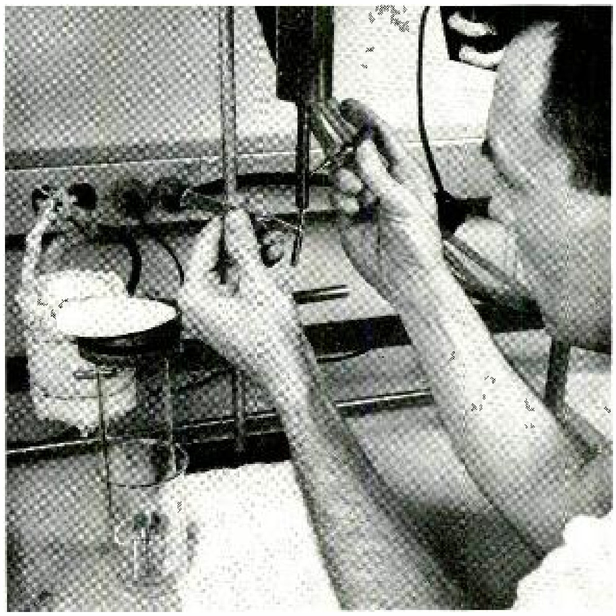

Fig. 3 — G. H. Wheatley attaching seed crystal to drawing bar, preparatory to growing single crystal of indium antimonide.

Although these compounds are remarkably similar to silicon and germanium in physical appearance, crystal structure, and over-all electrical properties, there is a major difference in chemical bonding. An In-Sb bond, for instance, is more complicated than an Si-Si bond in the respect that the two ends of the former are not identical. The formation of four electron-pair bonds around an indium atom in InSb requires the transfer of one electron from the antimony to the indium atom. Thus the In-Sb bond is not truly an electron-pair (covalent) bond since it contains a certain amount of ionic character or electrical charge separation. This results in a bond strength (and forbidden energy gap) higher than would be otherwise expected. For instance, in GaAs we might expect an energy gap very similar to germanium, because gallium and arsenic bracket germanium in the fourth row of the periodic table. Yet the energy gap of germanium is only 0.75 e.v., while GaAs has an energy gap higher than silicon. AlSb and InP, which bracket germanium diagonally in the periodic table, are further examples of this effect, as shown in Table I. Another consequence of the complex mixture of covalent and ionic bonding is the higher mobility of the III-V compounds, also seen in Table I. It should be remembered here that the mobility values quoted are in many cases limited by effects of impurities and thus represent only lower bounds to the true values.

On the whole, our knowledge of these materials lags far behind that of silicon and germanium. This is due in part to the great difficulties involved in purification and in growing single crystals. Large single crystals of InSb and GaSb have been produced at the Laboratories by the standard pulling techniques. However, all of the arsenides and phosphides are unstable at their melting points, and special techniques are required to prevent evolution of arsenic or phosphorous. Usually, a compound such as GaAs is prepared in a sealed quartz tube by diffusing arsenic at low pressures into molten gallium maintained at a temperature above the melting point of GaAs. Recently, the German scientist H. Welker has grown single crystals of GaAs using a pulling technique in which the crystal is grown in a sealed quartz tube. The pulling is accomplished by a magnetic drive coupled to the seed. This is one of the techniques being explored at the Laboratories by J. M. Whelan. Figure 4 shows an experimental pulling machine in operation. High melting-point materials like GaP have as yet been prepared only by slow precipitation of the compound from solutions of excess gallium. In all cases, starting materials are purified extensively by chemical means and zone-refined* if possible. The compounds also must be zone-refined after preparation in order to obtain reasonably low impurity concentrations.

InSb is the most thoroughly investigated compound at present. It has been purified to such an extent that only one atom in less than ten million is an electrically active impurity. This is the only compound which has been extensively studied at temperatures low enough so that total impurity concentrations have been obtained. Although the energy gap is low, this material has attracted much attention because of its exceptionally high electron mobility (70,000 cm^2/volt sec at room temperature and 1,000,000 cm^2/volt sec at liquid nitrogen temperature), which results in a very large change in resistance in a magnetic field. Several devices such as magnetic switches have been based on this effect. InAs is much like InSb with a somewhat higher energy gap and lower electron mobility.

GaAs and InP have aroused considerable interest because both have energy gaps slightly higher than that of silicon. Electron and hole mobilities also are somewhat higher in these materials. Good rectification has been observed with both compounds. Because of their instability at the melting point, however, it is difficult to make grown junctions, but it seems certain that new diffusion techniques can produce workable transistors from both compounds. AlSb is quite similar to these, although most material produced so far is more or less readily attacked by atmospheric water vapor at room temperature and decomposes on standing.

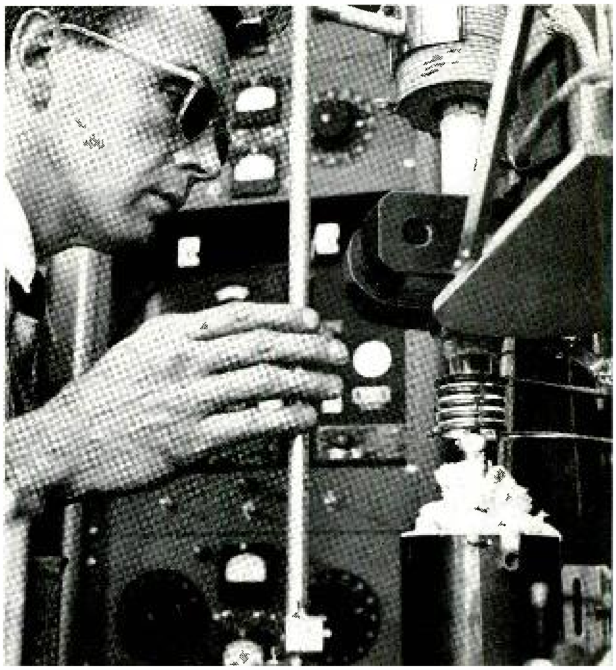

Fig. 4 — G. H. Wheatley using experimental apparatus for growing single crystals of gallium arsenide.

Very little can be said about the remaining group III – group V compounds. Although GaSb is very similar to germanium, it has not been purified sufficiently for reliable measurement of its semicon-

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* Record, *June*, 1955, *page* 201.

ducting properties. GaP, AlAs and AlP are unstable under ordinary conditions and have not yet been investigated to any great extent.

Recently, some attention has been focused on a new class of compounds somewhat similar to the III-V compounds. These are chalcopyrites of which $AgInTe_2$ is an example. With one valence electron from the silver atom, three from indium and twelve from two tellurium atoms, there is an "average" of four electrons per atom. These form "covalent" bonds resulting in a cubic crystal structure. Obviously, there are many possible compounds of this type. Preliminary data on some of these show that they are semiconductors with energy gaps and mobilities comparable to the compounds discussed above. Our present knowledge of these is extremely limited since they are even more difficult to purify than the binary compounds we have discussed here.

THE AUTHOR

H. J. Hrostowski, after service in the armed forces from 1944 to 1946, received the B.A. degree with a major in Chemistry from Wesleyan University in 1947. In 1949 he received the M.S. degree in Physical Chemistry from Oregon State College, and the Ph.D. degree, also in Physical Chemistry, from the University of California at Berkeley in 1952. Dr. Hrostowski joined the Semiconductor Research Department of the Laboratories in 1952, where he conducted research studies of the semiconducting properties of the III-V intermetallic compounds. More recently, he has been engaged in studies of the optical properties of semiconductors in the infra-red region. He is a member of the American Physical Society, of the American Chemical Society and of Sigma Xi.

Twenty-four Million Dollar Expansion Planned

The Long Lines Department of American Telephone and Telegraph Company and nine associated telephone companies recently asked the Federal Communications Commission to approve an expenditure of almost $24,000,000 for new facilities.

Ralph L. Helmreich, Long Lines Director of Operations, said projects included in the application were but part of the company's over-all construction program for 1956. Long Lines expects to spend more than $200,000,000 this year. A previous application calling for $33,000,000 worth of facilities has already been approved.

Costs itemized in the recently submitted application were for communications pathways along existing as well as proposed routes. The additional facilities covered in the application would provide about 3,000 telephone circuits and 1,900 telegraph channels. Fulfillment of the outlined plans would adequately take care of increases in telephone traffic estimated for the remainder of 1956 and early 1957.

The program contemplates construction of cable systems in the vicinity of Dallas, Texas, and Omaha, Nebraska. The application also disclosed plans for several new microwave routes. The principal one would extend from Denver, Colorado, to Great Falls, Montana, traveling through Billings and Helena, Montana. It was stated that although the Denver-Great Falls route would be needed for telephone growth, it could be equipped to carry network television to the area.

Long Lines would bear $21,000,000 of the cost outlined in the program. Other companies participating are: The Chesapeake and Potomac Telephone Company of Virginia; Illinois Bell Telephone Company; Michigan Bell Telephone Company; The Mountain States Telephone and Telegraph Company; New Jersey Bell Telephone Company; New York Telephone Company; Northwestern Bell Telephone Company; The Pacific Telephone and Telegraph Company and Southern Bell Telephone and Telegraph Company.

Color-Coded Rural Wire

Fig. 1 — A. P. Jahn of Outside Plant Development demonstrates how any one of the six pairs of conductors is easily identified by color.

Rural wire* is a lusty newcomer to the telephone outside plant and has already displayed phenomenal possibilities. In 1954, its first full year of Bell System service, a half billion conductor feet of this wire (designated as B Rural Wire) were produced by the Western Electric Company and this figure approached one billion conductor feet in 1955. Now rural wire has blossomed out in color.

The wire consists of six pairs of insulated copper conductors stranded around a steel support wire. The steel core wire is insulated with polyethylene, and the 19-gauge copper conductors are first insulated with polyethylene plastic, and then jacketed with polyvinyl chloride compound to improve their abrasion resistance qualities.

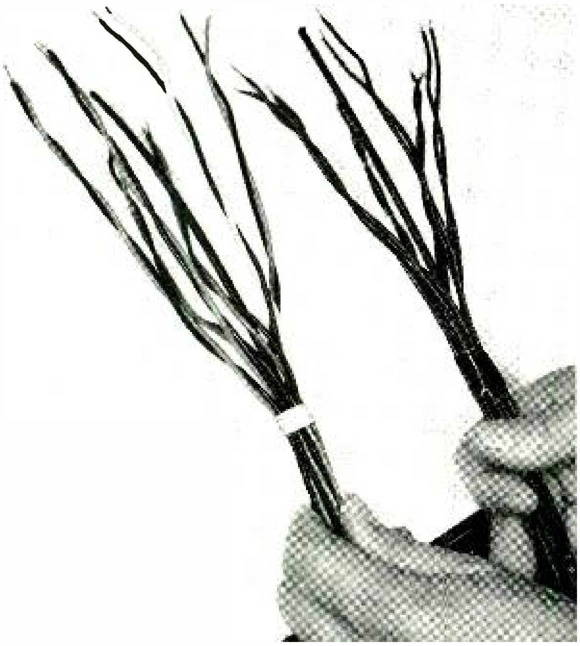

Fig. 2 — The new color-coded B Rural Wire (left) and its all-black predecessor.

Until recently, this polyvinyl chloride jacket has been black. One conductor of one pair had a raised tracer and it was therefore possible to identify each pair by counting from this tracer conductor. Of course, the count was clockwise or counter-clockwise depending on which end of the wire was being viewed, and in some instances this led to confusion.

To simplify identification of conductors, rural wire is now made in color. The polyvinyl chloride jackets on the polyethylene insulated conductors are specially compounded and colored so that identification is possible at sight. Pair No. 1 has one blue and one black conductor. Pair No. 2 has one red and one black conductor, and so on through green, brown, slate and yellow to complete the six pairs.

Rural wire has found many applications for providing communication circuits to customers in remote areas at lower cost than has been possible with cable and open wire facilities. Its outstanding advantages have been low installed cost, ease of placement and attachment, and the ready accessibility of each pair. Color coding further simplifies handling of the wire at terminations, at loading points, and at splicing points, and aids materially in locating troubles.

A. P. Jahn
Outside Plant Development

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* Record, *May*, 1954, *page* 167.

Telephone Sets in Color

G. A. WAHL *Station Apparatus Development*

The author (left) and E. C. McDermott checking pigmentation of the new 500-type color sets.

Today's color-conscious homemakers can now choose a telephone that blends or contrasts effectively with the general decor. Eight colors are presently available, and are meeting with widespread approval. The engineering of these new telephone sets involved several interesting problems, both in the matter of color preference and in the use of materials.

The demand for telephone sets in color has grown rapidly because customers have found them to be attractive as well as useful instruments to have in the home. Supplying color sets has become possible because the needs for telephone service are now being met substantially on a current basis.

The latest telephone set, the 500 type, has been made available in eight colors which have met with quite widespread approval by the telephone customer. This is not to imply, however, that color is something new in telephone sets. Actually, colored telephones of the handset type are almost as old as that kind of telephone instrument itself. In 1930, shortly after the introduction of the handset, a small group of artists and decorators was consulted to obtain suggestions for suitable colors. This group, among whom were Virginia Hamill, Harvey Wiley Corbett, Ralph Walker, Lee Simonson, Norman Bell Geddes and John Vassos, selected five colors: ivory, gray-green, old rose, Pekin red, and dark blue. In addition, several so-called metallic finishes – old brass, dark gold, statuary bronze and oxidized silver – were also provided.

All of these finishes were obtained by the use of suitable paints or lacquers applied to the handset and base of the original hand telephone set. This is the type that required a separate bell box. The finishes were also applied to the early "combined" set (302 type), in which the bell and all necessary components were assembled in one metallic housing. With the advent of thermo-plastic materials and their subsequent use in the housing of the 302-type set, the five basic colors were reproduced in these materials in 1941. Since no practical method of reproducing the metallic colors in plastic had been developed, these finishes continued to be supplied on a more or less special basis. No particular effort was expended during the years immediately following the war to promote sales of color sets, since the Bell System was directing most of its efforts toward furnishing basic telephone service to fulfill customers' demands. During these years, however, the development of the new 500 set was undertaken with the knowledge that it would ultimately be provided in color. Consequently, the design of the set was engineered to permit its economical manufacture either in the conventional black or in color.

With the launching of the 500-type set into full scale production in 1950 and with the anticipation of a greater demand for color, it appeared desirable to review the field of color. Inspection of the production reports of the previous years revealed that ivory sets represented 70 per cent of the sales, green 12 per cent, with the other three colors making up most of the remainder. In view of this and the known changing of color preference with time, it was decided to obtain the services of a specialist in color styling. Through the office of Henry Dreyfuss, the industrial designer retained by the Laboratories for appearance design of apparatus, the services of Howard Ketcham were obtained. Mr. Ketcham has worked with American industry for over twenty years to make products more appealing to more people by the scientific use of color. His color recommendations have been used for automobiles, airplane interiors, trains, marine equipment and for more than one hundred industrial and home furnishing products, ranging from fountain pens to prefabricated houses.

Mr. Ketcham was asked to recommend a line of colors for the telephone which would be appropriate for present-day trends in interior decoration, and would also have a reasonably long-range appeal. In other words, instead of high-style colors that go out of fashion rapidly, good basic colors that would wear well over the years were desired. Originally, six colors were proposed: ivory, green, beige, red, gray, and brown. At the same time, a poll of the telephone companies as to what colors customers requested indicated that a blue and yellow should also be made available, and these two colors were added to the line. Telephone sets in these eight colors comprise the full color series of sets, with handset, housing and dial in color, a clear plastic finger wheel on the dial, and matching or harmonizing cords. A supplementary line of two-tone sets has also been made available in which a color housing in any of the eight colors replaces the standard black housing, with handset, dial and cords remaining black.

To permit economical manufacture of color sets, a number of interesting problems had to be solved. For example, the handle of the 500 set requires special treatment in design, because, for economical molding, its wall sections should be fairly uniform in thickness. Thus it is necessary that the handle be essentially hollow. With the black 500 set, this handle is compression molded from a phenol-formaldehyde compound. Compression molding is employed because the compound is thermosetting; it is molded into the correct handle shape at high pressure and high temperature, and the subsequent chemical change causes the material to harden. The basic resin of the phenol-formaldehyde material, however, is a rather dark amber and does not permit pigmentation to light colors. Even though some pigmentation is possible, the nature of the material is such that it soon becomes darker on aging. The handset handle for the color telephones is therefore made from cellulose acetate butyrate, the basic materials of which are essentially water-white. It can be provided in any color by adding suitable dyes and pigments. This material is thermoplastic, which permits molding by the injection technique. The material is heated to a plastic state and then is injected into a relatively cool, closed mold, where the plastic hardens essentially on contact and can be removed with little time needed for cooling.

The housing, the dial number plate, and the transmitter and receiver caps of the set are also


Fig. 1 — E. C. McDermott testing the transmission characteristics of the 500-type color set.

THE AUTHOR

George A. Wahl received a B.S. degree in Electrical Engineering from New York University in 1934. He joined Bell Telephone Laboratories in 1927 and was concerned with the development of telephone transmitters and receivers from that date until 1930. Until 1941 he worked on the development of handsets and telephone sets and the application of plastics to telephones. During World War II he was engaged in the development of transmitters, receivers and loudspeakers for the military. He was later in charge of a group working on coin collectors for public telephones. Mr. Wahl has since been supervising a group engaged in the development of telephone sets and associated equipment including color telephones and the recently announced Speakerphone. He is a member of the American Standards Association.

fabricated with butyrate by injection molding. So far as the molding processes are concerned, the shapes of these parts are less complex than that of the handle and are therefore more readily adaptable to the injection method.

The color of the characters on the dial number plate, which are white on the standard black set, had to be determined for each of the colors to attain maximum contrast and legibility. A new polyvinyl chloride compound had to be developed for the jacket of the cords so that it could be pigmented and still would wear as well and be as smudge-proof as the neoprene used for black cords. This involved problems of color fastness, perspiration resistance, and marring of furniture finishes.

With the solution of these problems both in design and manufacture, the Western Electric Company undertook the production of the color sets. Limited quantities became available early in 1954, and their ready acceptance by customers is attested to by the fact that Western Electric manufactured over a million sets in color in 1955. The present expectation is that shipments of well over double this quantity will be made in 1956.

Variety of Businesses Help Western Electric Supply Bell System Needs

The town of Southfield, Massachusetts has a unique business — Turner and Cook — a company that has made buggy-whip cores since the middle 1700's. Once these cores, which are wrapped with canvas to form buggy whips, were made from whalebone, but today they are made from water buffalo hide imported from Asia, India and the Philippines. Turner and Cook also make rawhide mallets for the Western Electric Company according to Bell System specifications.

This old firm is only one of some 30,000 suppliers who helped Western Electric meet its commitments to the Bell System and to the U. S. last year. In 1955, Western spent about one billion dollars in payments to suppliers for goods and services. Geographically these suppliers are located in over 3,000 communities in every state in the Union and in 26 foreign countries.

Many of Western's suppliers are leaders in their fields, such as the Gorham Manufacturing Company, one of the country's oldest and foremost silversmiths. Gorham's principal product is its famed silverware, but for many years the firm has manufactured for Western Electric component assemblies for waveguides, used to transmit microwave frequencies in some of Western's U. S. government-contract electronic systems.

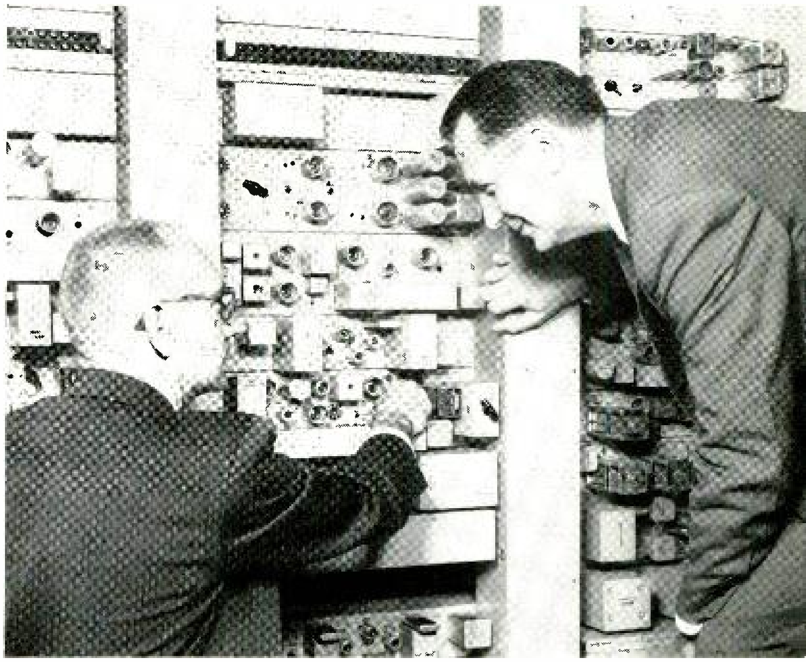
Another example is the Bard Parker Company of Danbury, Conn., which supplies a large percentage of the removable surgical blades used throughout the world. For Western, Bard Parker's 300 people make, among other things, a wide variety of highly precise component parts for the No. 1A card translator used to route calls across the nation in direct distance dialing. The Gilbert Clock Company of Winsted, Conn., also assists Western. Established in 1810, Gilbert makes and adjusts special telephone keys for carrier equipment manufactured by Western Electric.

In a less familiar field is the Ludlow Sales and Manufacturing Company of Needham Heights, Mass., which is one of the prime producers of jute yarn and "roving" in this country. Western uses these materials in the manufacture of cable, and Ludlow, with its large interest in India, is a reliable source of this vital material.

Western buys Bell System supplies, raw materials and equipment from small firms as well as large. In fact, more than 90 per cent of last year's 29,980 individual suppliers are classified as "small business"; that is, less than 500 employees. Washington Machine and Tool Works in Minneapolis is one of these. Its 60 people, of whom 80 per cent are stockholders in the company, do an annual business of some $1,500,000 with Western. Another small supplier is Diecraft, Inc., of Baltimore. This firm began in 1932 with three people in a small walk-up loft in Baltimore as a machine engraving shop. Today the plant employs 350 people. Harry Dundore, the founder and present head, feels that the greatest impetus to his business came when he started producing work for the Western Electric Company some twenty years ago.

One small business which Western is particularly gratified to count as a "partner" in its supply function in the Bell System is the Paraplegics Manufacturing Company located in a remodeled garage in Franklin, Ill. Here some twenty-five paraplegics, persons with spinal core injuries which paralyze their legs, work on jobs for W.E.'s Hawthorne Works. Another "partner" is Chicago's Lighthouse for the Blind, where for some thirty years W.E. and several other firms have been providing work on a subcontract basis for blind people.

Color Television on the L1 Coaxial Carrier System



H. C. HEY *Transmission Systems Development II*

A considerable amount of L1 carrier is in service on coaxial cables throughout the country. The advent of color television, with its more stringent transmission requirements, made it necessary to modify existing L1 television channels so that more viewers could enjoy this new form of entertainment. To fill this need, existing B2 and C2 television terminals have been integrated into Laboratories' developed B3 and C3 color television terminals by the addition of new equipment.

Ever since network television was introduced in the late 1940's, one of the chief transmission media has been the L1 coaxial carrier system.* Although L1 carrier is gradually being replaced for this service by broader-band systems such as TD-2 microwave radio relay† and the new L3 coaxial carrier system,‡ it appears that L1 facilities will provide a substantial fraction of the total intercity television transmission for some time to come. When color television became a reality, the L1 system, which had been developed long before color television was a consideration, had to be adapted for the transmission of color.

Television is broadcast in the VHF and UHF bands because the video or picture signal requires such a wide frequency band. Each television channel is allotted 6 mc with the video signal occupying 4 mc. This video signal is transmitted between cities over Bell System wideband facilities, the sound portion being transmitted separately over other Bell System channels. Although the entire 4-mc band contains video information, the main picture content is contained in the lower frequencies while the higher frequencies, at much lower amplitudes, only provide additional detail. When transmitted over L1 carrier, video frequencies above 2.7 mc are lost but the result to the viewer is equivalent to only a barely perceptible defocusing of the television picture.

For color television, the situation is quite different. A color video signal consists of two separate components, Figure 1, interleaved frequency-wise so as not to interfere with each other.* The "luminance" or low-frequency component is the same as a monochrome signal and can be received on monochrome sets as a black-and-white picture without any modification being needed in the home receiver. This is the feature of compatibility. The "chrominance" or color component is a band of frequencies centered on a sub-carrier frequency of

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* Record, *May*, 1937, *page* 274. † Record, *October*, 1950, *page* 442. ‡ Record, *January*, 1954, *page* 1.

* Record, *March*, 1954, *page* 81.

3.579 mc. Only the color sidebands are transmitted, the sub-carrier being cancelled out during modulation in the television station. Since, however, it must be reinserted in the television receiver for demodulation, short synchronizing bursts of sub-carrier lasting only a few cycles are transmitted just before the beginning of each picture line.

Because color information is concentrated above the cut-off frequency of the L1 system, a color video signal would lose all of its color information if it were transmitted over an unmodified system. The received picture would be seen in black and white on both monochrome and color receivers. If the color information could be translated to lower frequencies, it could be transmitted over L1. This is accomplished in the B3 transmitting and C3 receiving terminals by modulating the color component with the proper frequency and limiting the bandwidth of both luminance and chrominance components so that they do not overlap and cause interference. The new B3 and C3 terminals include the older B2 and C2 terminals as part of their equipment. Figure 2 shows how the transmission requirements are met by frequency translation and band limiting.

Monochrome video signals, containing frequencies from nearly zero to as high as 4 mc, are translated and frequency limited by the B2 terminal of an unmodified L1 system to the band between 200 kc and 3 mc for transmission over coaxial cable. In a modified L1 system, the luminance component of a color video signal is shifted in exactly the same way by the B2 terminal equipment, but a low-pass filter in the added equipment of the B3 terminal, Figure 3, further reduces the upper frequency limit to 2 mc before passing the luminance component along to a hybrid coil. The original input signal is also fed to a bridging amplifier in the B3 terminal. A band-pass filter in one output of the bridging amplifier permits only color frequencies to reach the color modulator, so that the luminance component will not be shifted by modulation.

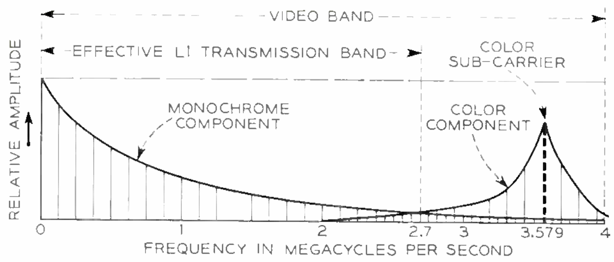


Fig. 1 — Spectral distribution of a color television video signal. The monochrome component that is shown is the same for both color and black-and-white transmission.

In the modulator, the band containing color information is modulated by a carrier at 6.192 mc. This shifts the color sub-carrier frequency from 3.579 to 2.612 mc and, after further frequency discrimination in a high-pass filter, the shifted color band extends only from 2.3 to 2.9 mc. Recombination of the luminance and chrominance components in the hybrid coil results in a signal suitable for transmission over the L1 coaxial line.

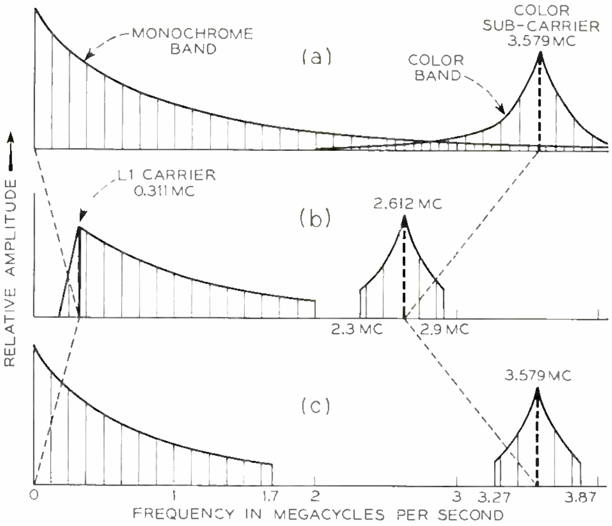


Fig. 2 — Modulation steps in the color terminals.

An inverse process occurs in a C3 receiving terminal, Figure 5. A hybrid coil splits the received signal into two paths. In one path, a low-pass filter passes only the luminance component along to the C2 terminal where it is restored to its original video frequency band, although limited to 1.7 mc at the upper end. A high-pass filter in the other signal path passes only color frequencies along to the color modulator. A 6.192 mc carrier shifts the color band back to its original position in the frequency spectrum, locating the sub-carrier frequency back at 3.579 mc. After being amplified, the chrominance component is recombined with the luminance component in a mixing amplifier to provide a color video signal.

The color video signal derived at the output of a C3 terminal is similar to the original color signal transmitted by the television station, but both the luminance and chrominance components have been reduced in bandwidth. Although the additional band limiting of the luminance component results in slightly degraded picture definition, the addition of color to the television picture tends to compensate for this condition.

A standard monochrome signal transmitted over an L1 system equipped with the new terminals would still encounter the additional frequency limitation of 1.7 mc if it were not for the presence of an automatic switching circuit, Figure 4, that restores the bandwidth to 2.7 mc for monochrome signals. In Figure 3, a second output from the bridging amplifier passes the complete video signal to an automatic switching circuit. The presence of sub-carrier bursts at line repetition frequency tells the circuit that color is being transmitted, and the terminal operates on the signal for color transmission. When a monochrome signal is transmitted, the absence of sub-carrier bursts causes the circuit to automatically switch a loss pad into the circuit instead of the color equipment, and the monochrome signal is then transmitted as on an unmodified L1 television channel. A similar switching circuit in a C3 terminal, Figure 5, uses luminance and chrominance information from the associated C2 terminal equipment and the color modulator output to determine the presence or absence of color and operates a switch accordingly.

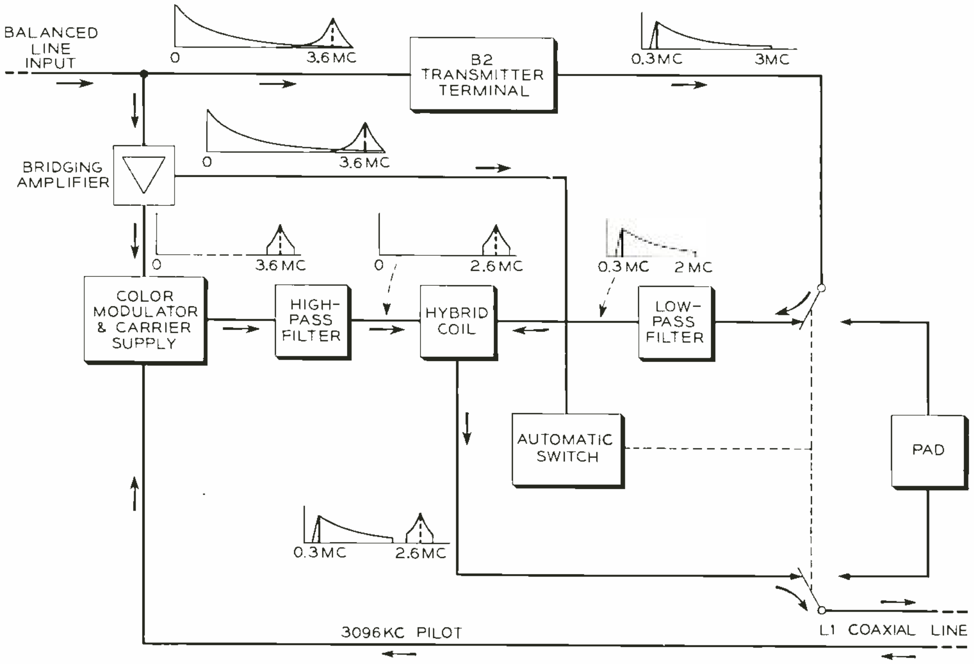


Fig. 3 — Block diagram of a B3 transmitting terminal. The B2 equipment is used without change and becomes a part of the new terminal.

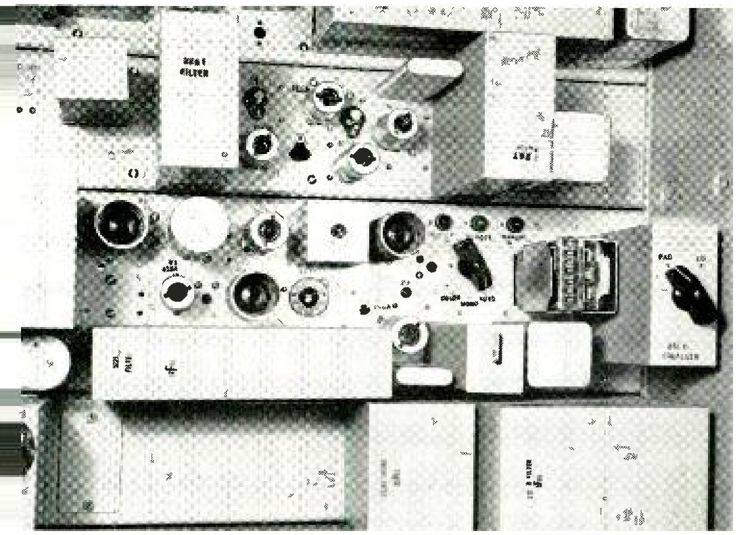


Fig. 4 — The automatic switching circuit. Actual switching is done by the wire-spring relay at the right.

Shifting of the color information down to usable frequencies and back again must not change the color carrier frequency accuracy. This requires that local carriers for the color modulators at both the transmitting and receiving ends of the system be held within very close frequency tolerances. The highly-accurate 3,096-kc line pilot of the L1 system is available at both transmitting and receiving locations. Doubling this frequency and then using it for the generation of the 6.192-mc modulator carrier exploits the excellent frequency stability of the pilot supply.

Another criterion for satisfactory transmission is that the luminance and color components arrive at the output of the receiving terminal bearing the same time relationship to each other that they had at the input to the transmitting terminal. If the transmitting time for one component differed from that of the other, then the received picture would have its luminance and color components misregistered. Careful design of the networks within the terminals has held the time-delay difference between the two paths to approximately 0.05 microseconds. This corresponds to about 0.01-inch misregistration between the color and luminance components as viewed on a 10-inch picture tube in a typical color receiver.

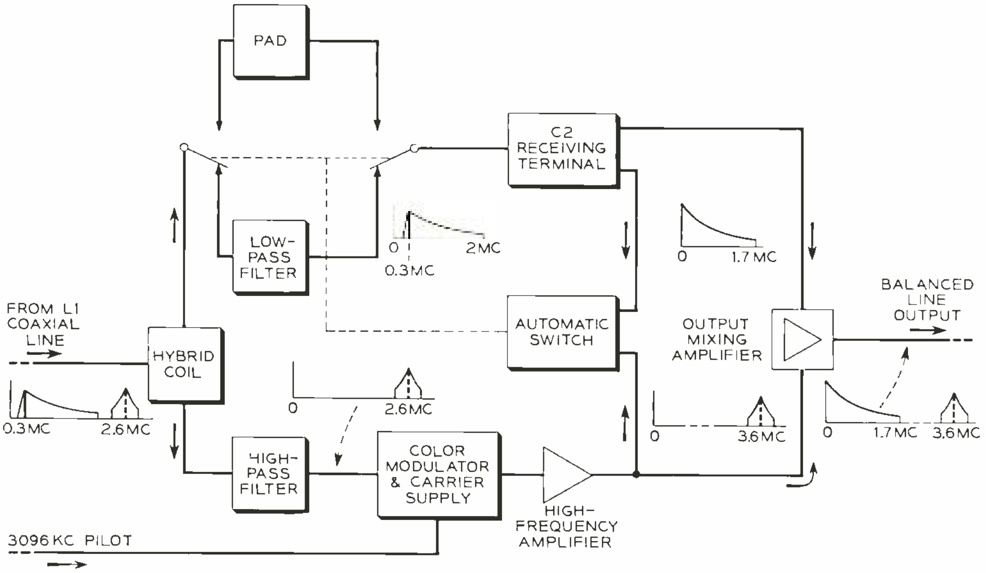
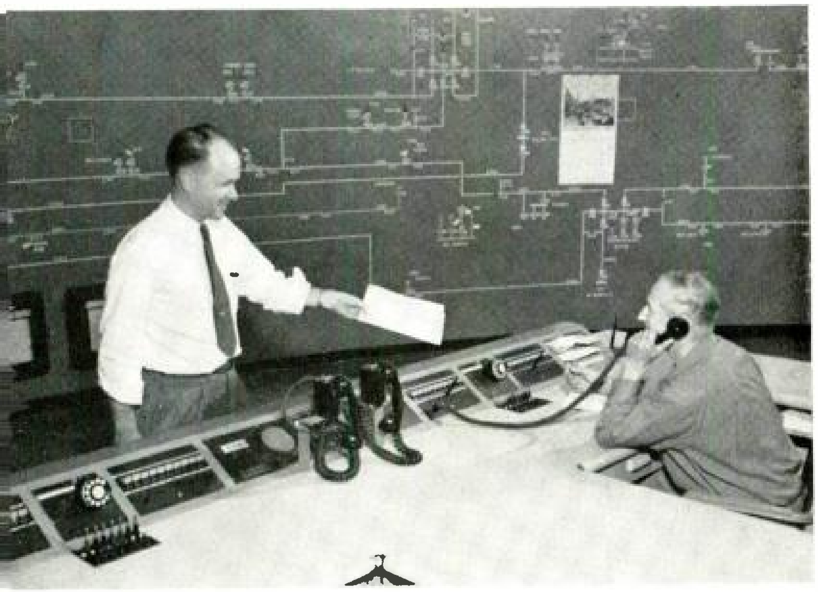


Fig. 5 — Block diagram of a C3 receiving terminal. The two signal components are shifted back to their original places in the frequency spectrum.

The equipment for handling the color information in the new terminals has been so designed that it can be added to existing B2 and C2 terminals without requiring their modification. Approximately 50 of the B3 color transmitting terminals and 100 of the C3 color receiving terminals are now in service, providing color television to viewers in many parts of the country. Some of these areas are not presently served by microwave radio relay or the newer L3 coaxial carrier system, and would therefore not receive color television were it not for the new terminals.

THE AUTHOR

H. C. Hey joined the Laboratories in 1929 and, except for the war years, has been engaged in engineering and development of facsimile and television systems since that time. His early work included facsimile transmission and experimental 72-line and 240-line television transmission. After working on television terminals for the L1 coaxial cable system, he spent the war years on radar systems. Since the war, Mr. Hey has worked on the A2 video transmission system, television terminals for the L3 coaxial cable system and color television terminals for L1. He received the degree of B.E.E. from New York University in 1941.



Dispatcher's PBX Switchboard

C. J. SCHULZ
Telegraph and Special Systems Development

So-called "right-of-way" companies — electric power and pipe-line companies, railroads and similar organizations — maintain vast communication networks linking remote locations. Communication facilities may include such diverse methods of transmission as telephone, radio, and carrier, yet all must be immediately accessible to the dispatcher. The new 508A PBX offers a modern, efficient means of providing such accessibility. It has a number of features specifically tailored to meet the demands of this type of operation, and can be used in association with a regular PBX.

Supplying telephone trunks, lines, and switchboards to "right-of-way" companies – those engaged in such services as the transmission of electric power, the transportation of oil or gas via pipe lines, or the operation of railroads or other transportation facilities – is one of many Bell System services. At first, this might seem to be the standard PBX service offered to many telephone customers. Right-of-way companies operate over large areas and long distances, however, and utilize many different means of communication. To control and coordinate the widely separated activities of such an operation, a dispatcher at the headquarters or other major operating center must have finger-tip access to all the communication channels being used. The new 508A PBX makes this possible.

This new PBX is designed to interconnect with the many different types of communication channels used by such dispatchers. These may include wire lines, carrier systems, and radio-telephone systems. Some of the carrier systems may be on telephone lines while others are on power lines; both may extend to locations that are remote, somewhat inaccessible, or hazardous. Microwave radio is used extensively, particularly in mountainous country. Two-way radio is provided in some areas to communicate with crews in repair trucks.

Most calls involving the 508A PBX are either originated or terminated by the dispatcher, but occasionally he must interconnect certain facilities through his PBX switchboard to provide communication paths for conversations between other stations. Because of the variety of service requirements of right-of-way companies, most installations of this new PBX have been individually engineered by the Operating Telephone Company concerned. An extreme example of the need for such an arrangement was a midwestern power company's dispatcher location where, before a 508A PBX was installed, the communication channels terminated in seventeen different telephone instruments on one desk.

A typical installation at the Portland (Oregon) General Electric Company is shown above. The 508A PBX is essentially a 100-channel key-ended switchboard, with provision for a limited amount of through switching. Physically, it consists of one or more line and trunk panels and a control panel. The panels are small – only eight inches high – so that the dispatcher can monitor system conditions on a map, control panel, or combination of the two, which often cover a wall. Housings for the panels are provided by the customer according to his physical needs and esthetic taste. Spring-loaded cord reels are used instead of the conventional cords and cord weights, to provide a compact equipment assembly. All relay equipment is mounted on standard relay-rack bays in another room.

Each line and trunk panel consists of a row of lamps, a row of ten keys, another row of lamps below the keys, and two rows of jacks at the bottom. Each key is operated up to connect the dispatcher to one line or trunk, and down to connect him to another line or trunk. The lamps above and below each key are associated with the corresponding lines and trunks. All circuits also appear in jacks for through switching. Jacks in the upper row correspond with the upward throw of the keys and those in the lower row correspond to the downward throw.

Combination lamp and designation strips are provided, with two lamps mounted side by side for each line or trunk. One lamp is a combination line, busy, and hold signal. It flashes on an incoming call, lights steadily when the circuit is busy, and "winks" when the circuit is being held while the dispatcher is busy with another call or other business. When a lamp is winking, it is lighted most of the time and only winks out for a very short interval, about once each second. Where the second lamp is used, it indicates a transfer or cut-off condition, whichever of these features is included in its associated circuit.

At large installations of the 508A there is generally another PBX, such as the manual 605A, for company administrative purposes. In this case, it is associated with the 508A and equipped to handle certain of the dispatcher's traffic. Some of the communication channels appear only at the 508A, a few may appear only at the regular PBX, and some may appear at both switchboards under control of transfer or cut-off keys in the 508A. Traffic arranged for transfer is normally between a communication-channel terminal and the dispatcher. When he is too busy or is leaving the switchboard, he may transfer this traffic to the regular PBX by operating the appropriate trunk key and the common transfer key. When he wishes to reseize the transferred trunk, he may monitor the circuit before restoring it to normal, to avoid interrupting a conversation.

Certain stations may be on a party line; the dispatcher, or the attendant at the regular PBX, can select the desired station on the line by dialing. Each station can select another station or either PBX by dialing, but the dispatcher has preferential service. He can monitor calls to the regular PBX and can gain exclusive use of a circuit by cutting off the regular PBX, but he cannot be monitored or cut off. Tie trunks between the 508A and the regular PBX are automatic. Calls on lines or trunks at the regular PBX may be switched to the 508A by means of these trunks, just as calls may be switched in the opposite direction.

Fig. 1 — In the Bonneville installation, panels are "double decked" to provide a small working area.

Except for the individual line and trunk keys and jacks, all functions of the 508A are incorporated in the control panel. This panel contains all "common" keys for such functions as ringing, holding, transfer or cut-off, transfer or cut-off release, buzzer cut-off, battery cut-off, and connecting the hand generator in place of the regular ringing supply. A dial is available for the dispatcher. In installations where the panel is mounted vertically the four pairs of cord circuits are often mounted in the lower part of the panel, with the plugs projecting horizontally. Where a sloping panel is used, or it is not desired to mount the cord circuits in the panel, they can be mounted in the more conventional fashion in the desk surface, Figure 1. The resulting space in the panel may be used for mounting a clock or for other purposes.

The common keys are used in conjunction with the line and trunk keys to perform the various functions. For example, to transfer or cut off a trunk, the dispatcher operates the trunk key and then the non-locking transfer or cut-off key; he then restores the trunk key to normal, permitting it to be operated in the opposite direction for a call on the other line or trunk associated with that key. The transfer or cut-off condition is indicated by one of the two lamps for the particular trunk. To restore the trunk to normal, he again operates the trunk key, which now permits him to monitor the circuit, operates the common non-locking release key, and restores the trunk key to normal. If the dispatcher wishes to hold a call, he operates the common non-locking hold key and then restores the trunk key; the trunk key will already be operated because he has been talking over the trunk. The lamp now winks to indicate the "hold" condition. To reseize the trunk, he operates only the trunk key, which restores the talking path.

Terminal equipment for the various communication channels is arranged for either two-way ringdown signaling, or incoming ringdown and outgoing dial. That is, signaling toward the 508A from the terminal is ringdown but signaling from the 508A is either ringdown or dial as required. Where dial signaling is required, an additional pair of wires is used between the 508A and the terminal equipment for supervisory purposes.

Some of the communication channels appearing at the 508A switchboard may require a transmission pad in each circuit to provide the proper voice levels. When a call on such a channel is answered by operating a line or trunk key, a pad is switched in by relay contacts. When the call is answered with a cord, battery or ground derived from a simplex circuit on the talking path switches the pad out. In the associated regular PBX, each line or trunk terminates in two jacks. One jack, for local traffic, includes the pad in the circuit. The other does not include the pad and is used for through traffic or for both through traffic and outward dialing, depending on the type of trunk.

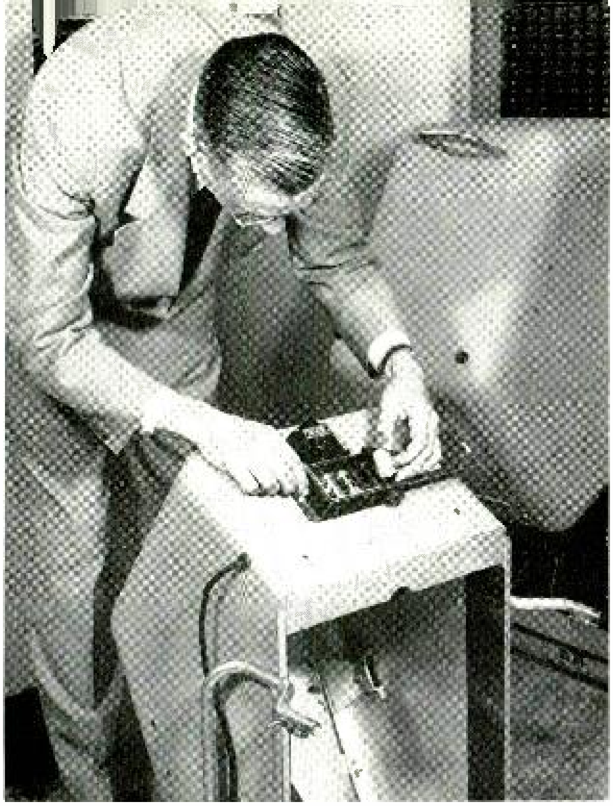
The first installations of the 508A were put into service in 1953 in territory served by the Pacific Telephone and Telegraph Company. The customer was the Bonneville Power Administration whose operations are spread over the states of Washington, Oregon, Idaho, and Montana. Bonneville's load-dispatching communications are presently being handled by 26 panels of the new 508A PBX's and 8 regular PBX's, with installations varying from 20 to 100 channels.

THE AUTHOR

Charles J. Schulz joined the New England Telephone and Telegraph Company in 1947, after receiving the degree of B.S. in E.E. from Purdue University, and engaged in central-office manual and toll equipment engineering. He transferred to the Laboratories on temporary assignment in 1950 and has subsequently become a permanent member. He has engaged in circuit design of step-by-step equipment, particularly community dial offices, and in special systems development where he has been involved with PBX circuit design and with concentrator-identifier equipment as applied to secretarial answering services. During the war, Mr. Schulz was a communications and electronics officer in the submarine service.

W. H. Brattain Elected to Academy of Arts and Sciences

Walter H. Brattain of the Laboratories Physical Research Department was recently elected a Fellow of the American Academy of Arts and Sciences in Boston. The membership of this Academy, limited to 1350 Fellows, is divided among four classes. Mr. Brattain's election was for the Class 1 – Mathematical and Physical Sciences. The Academy of Arts and Sciences, established in Boston in 1779, is dedicated, in part, to "promote and encourage medical discoveries, mathematical disquisitions, philosophical inquiries and experiments, and to cultivate every art and science."



Manual collection of traffic usage data is cumbersome, requires considerable clerical effort to translate the data into proper form, and is subject to human errors. Recently, the Laboratories developed the traffic usage recorder as the first step in automatizing the collection of traffic data. The latest step in this direction is the Traffic Register Camera, to provide permanent photographic records of traffic data — accurately, economically, and automatically.

D. H. BARNES *Traffic Studies*

W. J. RUTTER *Component Development*

Automatic Recording of Traffic Data

In some respects, a dial telephone switching system may be likened to a human being. Both can receive and remember information, make decisions based on instructions, and take suitable action. Both have considerable adaptability to meet changing conditions. Both man and machine perform most efficiently when capabilities most nearly match demands. To realize the most from either requires not only the proper assignment of work, but also regular checkups for a continuing healthy system. In switching systems, automatic measurement of traffic greatly facilitates performance checkups by allowing the accurate and economical recording of all significant traffic data.

One of the first items in a Laboratories program for the automatic measurement of traffic was the traffic usage recorder.* Data can be automatically accumulated by the machine day after day and week after week in accordance with a simple setting of keys or dials. The results, however, are presented on traffic registers and the manual transcription of hundreds of readings at prescribed intervals, and comparisons with earlier readings, is rather burdensome.

In fact, one drawback to the manual recording of traffic register readings is the necessity for prescribing and scheduling as much as a year in advance the times at which readings will be made. We could do a much better job at no greater effort if we had a device that automatically recorded traffic register readings, so easily, accurately, and economically that all likely data would be available for selection as required.

This is accomplished by the traffic register camera, the next logical item in the program of automatic recording. It consists of an aluminum hood into which are assembled projection lamps, a timer, a clock, a mirror, and a 35-mm camera unit. The hood prevents extraneous light from affecting the exposure and prevents the flash of the projection lamps from affecting over-all light conditions in the room. Components are assembled and wired to a chassis that is easily removable for maintenance. The mirror forms a part of the optical system and permits a considerable reduction in the depth of the hood. The camera shutter and film-wind are both automatic.

Accuracy of register totals is guaranteed by a photographic record of all readings, taken simultaneously at preset times that may be automatically

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* Record, *September,* 1954, *page* 326.

regulated for a week at a time. Economy results from the use of inexpensive 35-mm film. With the data thus conveniently available, particular hours or particular days may be selected or rejected for detailed analysis. Included in each picture are readings of the hour, date, and office name for easy identification.

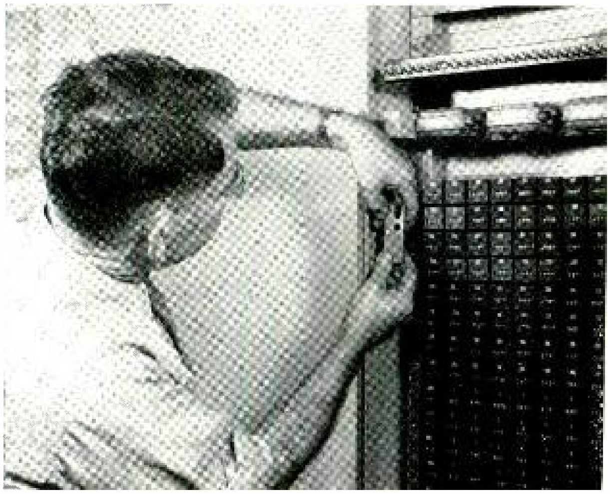
With this film file at hand, the next step is to make the data conveniently usable. In nearly all cases, the first step is comparison of one set of readings with an earlier set. This will be made easy by a "double printing" of enlargements of the two sets of data being compared, so spaced that subtractions may be made and recorded directly on the print. A commercial office photocopy process is employed that gives fast, convenient, low-cost processing.

To mount the camera on a register rack, special brackets, Figure 1, are attached at the ends of the register mounting plates. A handle at each side of the camera provides support during mounting, Figure 3, and extensions of the handles fit into the special mounting brackets to lock the camera in place. Two types of handles are available to permit using the camera with either of the two standard widths of mounting plates. Two cameras may be placed on a single register rack by turning the bottom camera upside down, so that 300 registers may be photographed on one register rack. The camera, weighing about 25 pounds, may be dismounted by simply lifting it out of the mounting brackets. A ground-pulse control lead from a camera-control circuit or a traffic usage recorder is permanently installed at each traffic register rack. The pulse from a control circuit may be common to all cameras in a building so that all readings involved are taken simultaneously.

Illumination of the registers during an exposure is provided by six 100-watt projection lamps that flash on for 0.5 second for each exposure. An on-off switch in each camera can render it inoperative independently of the control circuit. A pilot light near the switch indicates when the camera is activated and ready for exposures at the desired times. A push-button start switch provides manual control when desired.

Ordinarily, reflections of the lamps from the face of a register would cause high-lights and obscure parts of the photograph. Reflections are eliminated by placing polarizing filters in front of the projection lamps and another filter in front of the camera lens with the axes of polarization at right angles. The filters also permit a more convenient and efficient location of the projection lamps, and those in front of the lamps also diffuse the light for even illumination.

Fig. 1 — W. J. Rutter attaches one of the special mounting brackets.



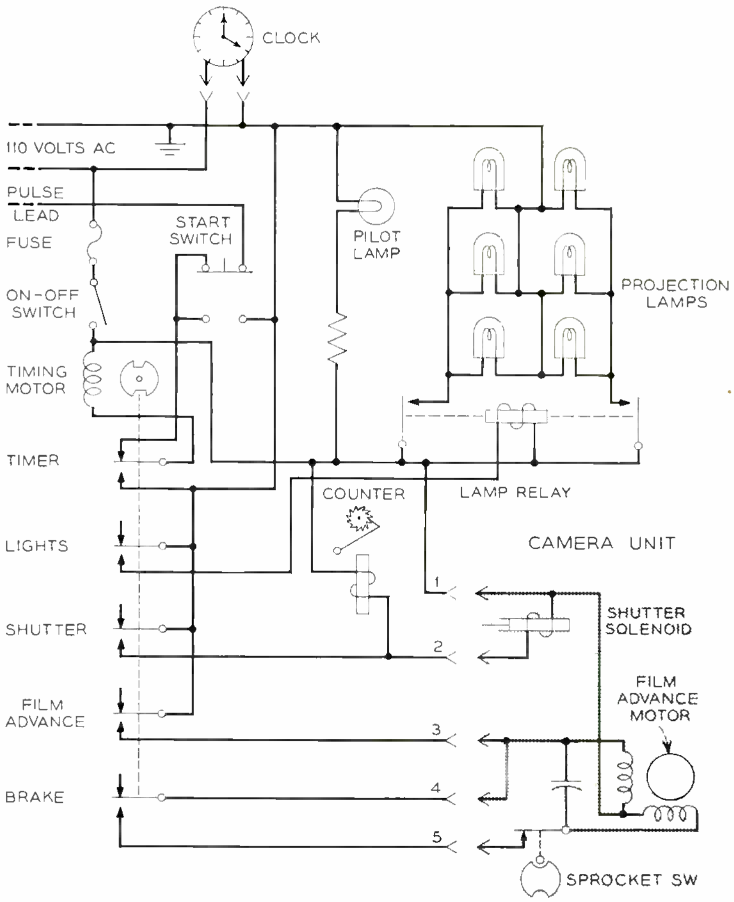


Fig. 2 — Schematic diagram of the complete camera.

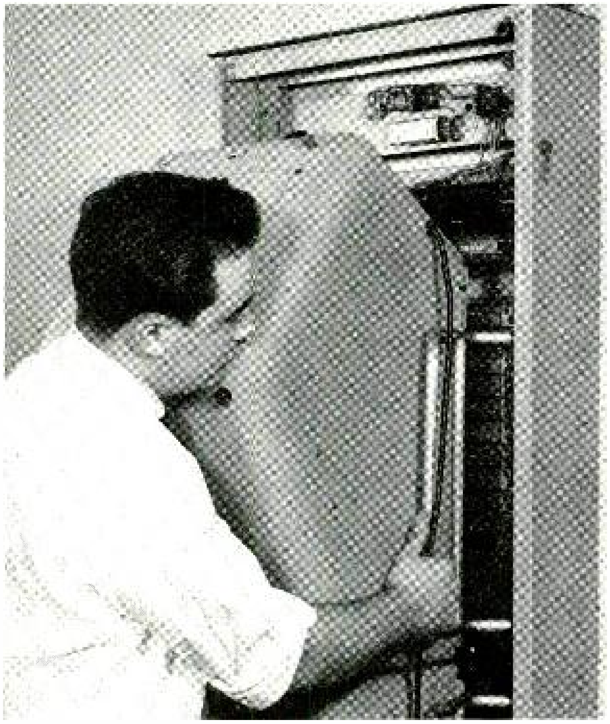


Fig. 3 — B. J. Scotti mounts a second camera on the register rack.

The automatic 35-mm camera unit may be seen in the headpiece illustration which shows the author loading a camera before it is hung in position. The camera unit plugs into the chassis and is held in place by only two screws, permitting easy removal for maintenance. It utilizes commercially-available 20- and 36-exposure rolls of 35-mm film; for this purpose, however, 33 exposures can be made on the short roll and 60 exposures on the long roll. Film advance is accomplished by a special dynamic-braking ac capacitor motor driving the take-up spool. The film is pulled over a sprocket that measures off the proper length of film and operates a micro-switch. This in turn connects a short circuit across the motor capacitor to provide the dynamic braking. The motor then stops promptly. Figure 2 shows the wiring schematic for the complete traffic register camera.

After the first six exposures have been made on a new roll of film, the build-up of film on the take-up spool actuates a locking device to prevent the back cover being opened. The back then cannot be opened until the film has been rewound into its original light-tight film holder. A lever releases the motor drive from the spool while the film is being rewound. A two-wheel counter is wired in parallel with the shutter solenoid to record the number of exposures made. The counter is manually reset to zero after each new roll of film has been loaded into the camera.

The six 100-watt lamps, polaroid filters, switches, pilot light, and counter are assembled and wired to the chassis, which is held in the hood by four screws. During normal operation, no hood ventilation is necessary but a 1.25-ampere fuse with a thermal-cutout element is included in the circuit to prevent critical temperatures from developing. The fuse will operate if more than 10 manual cycles are made in a short period of time, or if the lamps remain lighted for more than 15 seconds.

An exposure is made by connecting ground to the pulse lead for about three seconds. This ground can be a pulse from the control circuit or can result from the operator pressing the manual exposure button (start switch). The timing motor is set in motion and, in about one-half second, locks operated for a period of five seconds, or one complete exposure cycle. All functions are controlled by cams on the timing motor shaft. Figure 4 shows the sequence of events. The lamps are on for only 0.5 second and the shutter and counter operate during this period. Next, the film-advance motor starts and the sprocket switch opens. The brake switch closes but the motor continues to run until the sprocket micro-switch closes. After the film stops, power is disconnected from the film-advance motor and then the braking is removed.

One-half second later, the timing motor stops and the camera is ready for another exposure. A clock with a 12-hour day and a 12-hour night dial is included in the photographed area to record the time each negative was taken. This clock continues to keep time regardless of the setting of the on-off switch, Figure 2.

It is expected that the film will be processed by local photofinishers. Commercial equipment is available, however, that will automatically develop, fix, wash, and dry the rolls of 35-mm film. Single rolls

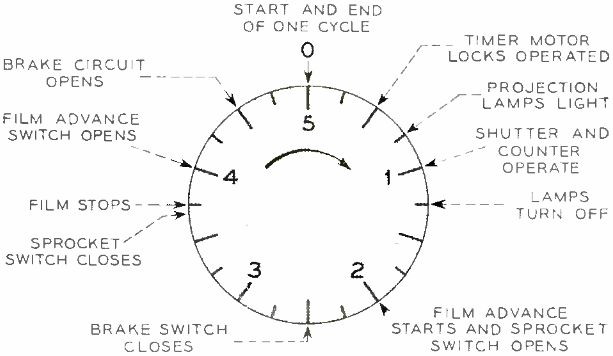


Fig. 4 — Sequence of events in an exposure cycle.

may be processed in a simple daylight-loading tank using ordinary developing procedures.

Complex problems were encountered in making acceptable prints because each print consists of the information contained on two negatives as well as a space for recording the differences in pencil. Since the registers have black wheels with white characters, a photographic print would have two black stripes with white characters and a white stripe for tabulation. This type of print was considered to be hard to read. A satisfactory print, white with black characters, was obtained through the use of a commercial office copying machine that produces a nearly dry print in 45 seconds without requiring a dark room.

A special semi-automatic enlarger will be used to project the film onto a negative-printing paper held in the carriage of a printing easel. A slotted mask covers the paper and allows only one-third of it to be exposed at one time. In the first position of the paper, a flash exposure is used to provide a white area for pencilling-in the difference between readings; the next two positions then print the old and new readings. Associated settings of the enlarger and easel are protected by an interlocking switching circuit that prevents exposures being made when the settings are not correct.

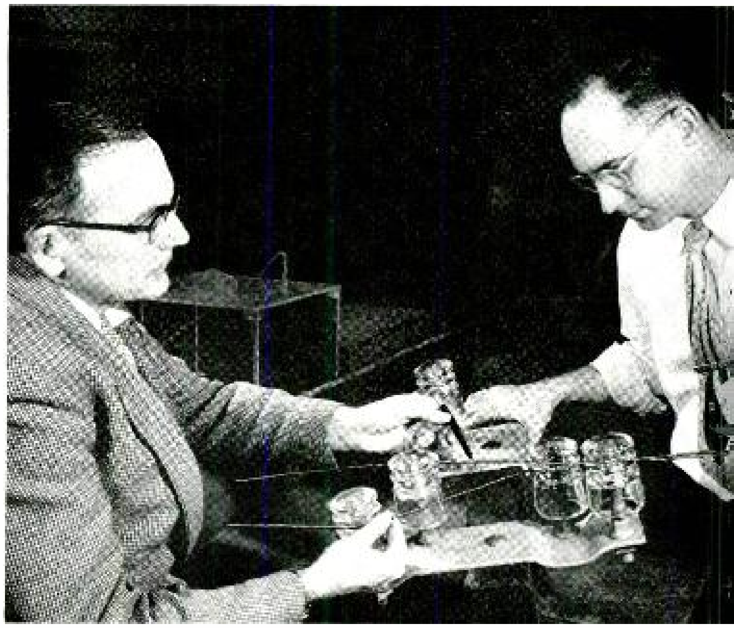
A Laboratories model used in field studies functioned perfectly, producing data with a speed, accuracy, and economy previously unobtainable.

THE AUTHORS

D. H. BARNES joined the Staff of Bell Telephone Laboratories in 1951 following ten years service with the Ohio Bell Telephone Company in its Traffic Engineering Department. He graduated from Lehigh University in 1938 with a B.S. in Industrial Engineering. Since joining the Laboratories Switching Engineering Department, Mr. Barnes has been chiefly concerned with traffic engineering and traffic measurement, establishing development requirements for the traffic usage recorder and the traffic register camera. He is currently engaged in studies on a fully automatic recording and processing system for handling traffic data.

W. J. RUTTER joined the Bell Telephone Company of Pennsylvania in 1922. He was loaned to the Laboratories in 1942 where he worked on sonar devices until 1945. Mr. Rutter subsequently designed lecture kits for the Publication Department, was involved in the design of the 3CL switchboard, and helped redesign the AMA tape-reeling equipment and the original AMA installation in Philadelphia. He became a permanent member of the Laboratories in 1949 and has since been engaged in the design of central-office maintenance tools. He was responsible for the mechanical design of the traffic register camera.

New Hardware for Type-O Carrier



P. G. Clark (left) and H. E. Randall inspecting line-wire arrangements of transposition bracket. "Pinch" bracket is seen on rear of crossarm section.

Type-O carrier was developed as an economical way of simultaneously transmitting up to sixteen telephone conversations over relatively short distances on a single pair of open-wire lines. This system was designed in such a way that it can be applied to existing plant without installing completely new facilities and with the least possible line rearrangement. Since Type-O carrier greatly increases the message carrying capacity of open-wire lines, it is widely used in the field.

In general, wires of pairs on existing short-haul lines are spaced twelve inches apart. The Type-O carrier transposition system, however, requires an average spacing of eight inches. To respace the wires from twelve to eight inches when Type-O carrier is applied would be a costly operation. To avoid this, a less expensive technique has been developed that retains the twelve-inch spacing at nontransposition points, which occur at every other pole in the Type-O carrier system, and reduces the spacing to four inches at transposition points.

To make this scheme practical, it was necessary to develop new hardware and methods. The hardware consists of two new types of crossarm-mounted brackets – one for making a transposition and the other for pinching in the wires of a pair to four inches when no transposition is required. These brackets are shown in Figures 1(a) and 1(b), respectively. The transposition bracket is a "point" type bracket. The transposition of one wire over the other to reduce inductive interference is here seen to take place virtually at a "point" rather than over a span between poles.

The use of these two brackets can be seen in

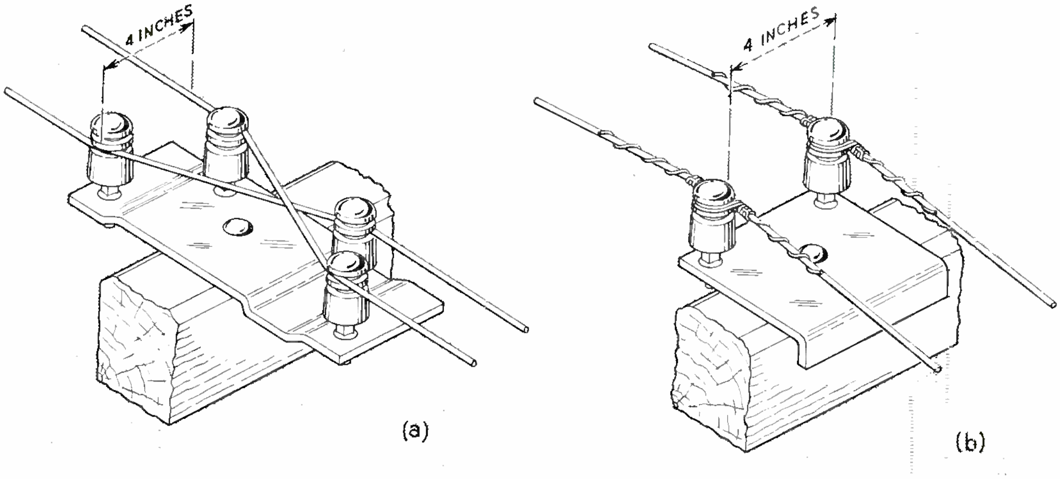


Fig. 1 — (a) The new point-transposition bracket for Type-O open-wire lines: (b) the new "Pinch" bracket.

Figure 2. Basically, the method is to alternate between the existing twelve-inch spacing and the new 4-inch spacing, so that the over-all average will be the desired 8-inch average spacing. From the left in the drawing, wires spaced 12 inches apart "pinch" down to 4 inches and then diverge back to 12 inches. They next converge to 4 inches again and are transposed on the point-type bracket, thereafter to continue through similar cycles along the open-wire route. In this manner, half the poles on an existing route require no change when Type-O carrier is introduced.

The new 4-inch point-transposition bracket and the pinch bracket are made of high-strength alloy steel and are hot-dip galvanized to resist corrosion. They are designed to withstand all conditions of storm loading, including the torsional effects encountered when they are mounted on corner poles. Both are assembled on crossarms with a single carriage bolt, which is placed in an existing insulator-pin hole, thus avoiding the expense of boring new holes. In addition, the new transposition bracket costs about one-third as much as the conventional 8-inch point type bracket which is required for a uniformly spaced 8-inch pair. Altogether, substantial savings are to be expected from the use of this technique when transposing open-wire lines.

P. G. Clark,
Outside Plant Development

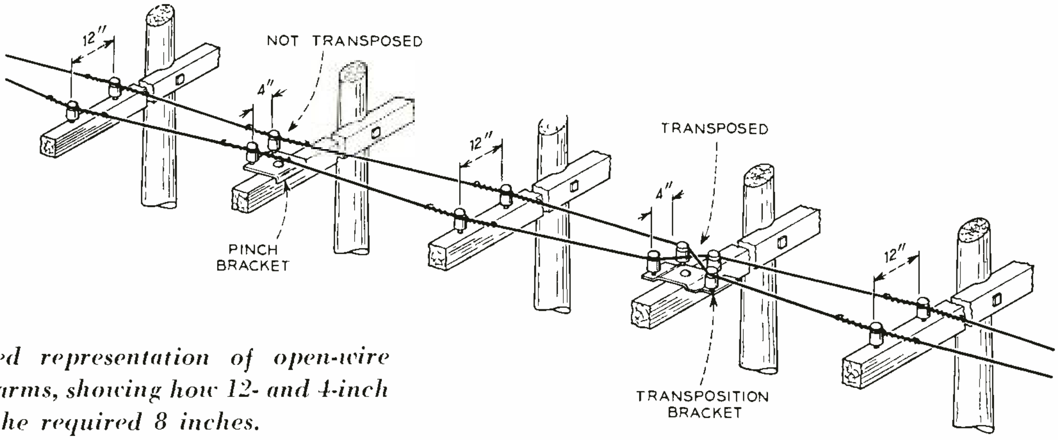


Fig. 2 — Simplified representation of open-wire lines on pole crossarms, showing how 12- and 4-inch spacings average the required 8 inches.

Members of the Laboratories Awarded Honorary Degrees

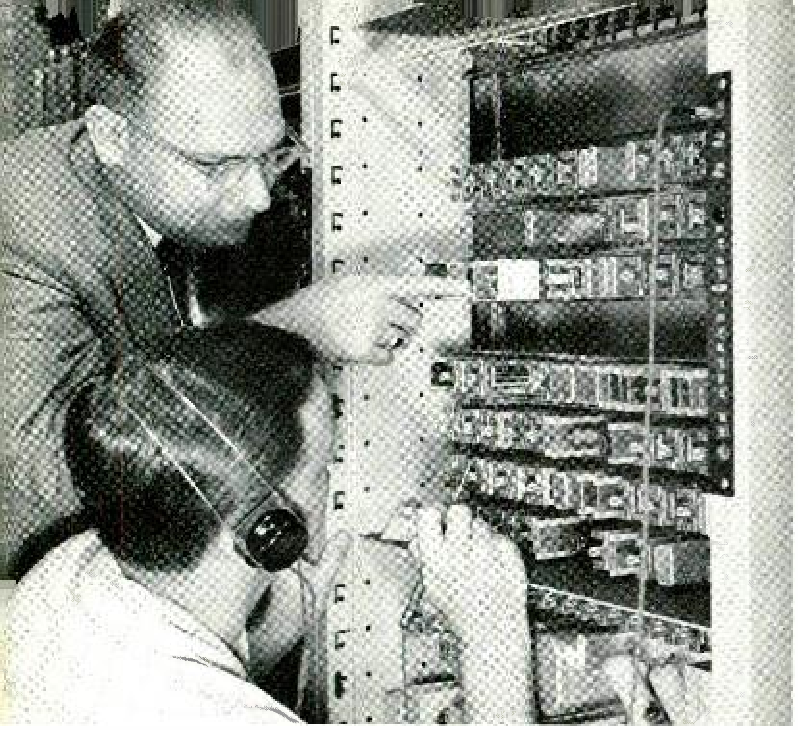
Dr. J. B. Fisk, Executive Vice President, E. I. Green, Vice President, D. M. Chapin, G. L. Pearson and E. E. Schumacher were among Laboratories Members to receive honorary degrees at recent commencement exercises.

Dr. Fisk was awarded an honorary degree of Doctor of Science by the Carnegie Institute of Technology who honored him for "knowledge and leadership through which key discoveries have been made and put to use for the welfare of our country and its people."

Mr. Green was awarded an honorary degree of Doctor of Science by Westminster College. He was cited for "his personal contributions to the art of communication and his direction of the planning and development of complex communication systems which have furthered the advance of civilization and promoted understanding among people."

D. M. Chapin and G. L. Pearson, two members of the three-man team that developed the Bell Solar Battery, were awarded honorary Doctor of Science degrees by Willamette University. Mr. Chapin was cited as an "eminent scientist, contributor to the well being of his fellow man through important research activities, and devoted associate of one of America's great research staff in the Bell Telephone Laboratories." Mr. Pearson was cited as a "distinguished physicist, able writer on scientific subjects, servant of church and state, and scholarly associate of Bell Telephone Laboratories."

Mr. Schumacher was awarded an honorary degree of Doctor of Engineering by the South Dakota School of Mines and Technology. He was cited for his "outstanding contributions to the development of metallurgical science, both as an administrator and investigator; for his brilliant pioneering in the promotion of industrial research, and organization of researches in metallurgy."



Balanced Revertive-Pulsing Circuits

E. G. SPACK *Special Systems Exploratory Development*

Revertive pulsing is the signaling method used to control motor-driven switches at a terminating office in the panel type of automatic switching system. When crossbar systems were designed, they included revertive pulsing for compatibility with existing offices, using relays to simulate the action of the mechanical switches. No. 5 crossbar has grown rapidly in suburban areas, and it has been found that ac interference in these areas can adversely affect the revertive-pulsing circuits. To prevent this, the Laboratories has designed new balanced arrangements for both panel and crossbar incoming circuits.

When the "panel" type of dial switching was introduced in the 1920's, a signaling method called revertive pulsing was used to control the motor-driven selector switches in terminating offices. In this method, an originating office controls the setting of switches in a terminating office by counting pulses that "revert" back over the trunk from the terminating end. The originating office initiates only "start" and "stop" signals.

The selector switches are activated when the originating office closes the trunk loop as a start signal. A clutch arrangement, controlled by a relay, Figure 1, forces a vertical elevator rod against a driving roller to raise the selector and cause its commutator brushes to pass over a series of commutator segments. As each segment is passed, the selector signals its position by sending or "reverting" a ground pulse generated by its commutator back to the originating office. Equipment at the originating end of the trunk counts these pulses and stops the selector switch by opening the loop when the desired segment has been reached.

When the crossbar systems were designed, it was necessary for compatibility to provide circuits to work with existing panel offices. Consequently, a relay circuit was developed for terminating revertive-pulse calls by simulating the action of a panel selector. The circuit consists of a terminating relay which responds to the start and stop signals just as in the panel circuit, but the pulses are generated (and also counted) by relays rather than by mechanical selector switches.

As the use of No. 5 crossbar has expanded in suburban areas, it has been found that the effects of ac interference can adversely affect revertive-pulsing circuits. Nearby power facilities can cause unwanted induced currents to flow in the signaling path and in the pulsing relays. If the current magnitudes reach certain values, errors may occur in the revertive selections because of erratic performance of the relays and wrong numbers could result. To prevent such troubles, the Laboratories has developed balanced pulsing arrangements for both the panel and crossbar terminating circuits.

These balanced arrangements make the circuits practically impervious to ac interference and also offer other improvements.

Interference may be produced in the original unbalanced panel terminating circuit as shown in Figure 1. Only the basic control elements of a typical panel selector and originating sender are shown in this simplified schematic. The induced currents caused by ac interference flow to ground through both sides of the terminating circuit. Since the impedance of the two paths is different, I_1 will be smaller than I_2 and an unbalance or difference current will flow through the sensitive stepping relay STP in the originating sender. The performance of relay L may be affected by I_1, while relay STP may be affected by the unbalance current.

Although in the new panel circuit, Figure 2, ac interference will still cause induced currents to flow, it is so arranged that the various relays are not affected. Relay L now has two identical windings in the signaling path, so connected that for the dc operating current their magnetic fields add. For the induced ac currents, however, their fields cancel and there can be no effect on the operation of the relay. At the same time, since the impedances to ground through the relay windings are identical, I_1 and I_2 are equal and there is no unbalance current to affect relay STP.

In addition to equal windings on relay L, the balanced method of operation requires a change in the manner of transmitting the revertive pulses. In the original circuit, Figure 1, pulses are sent by simply grounding the loop at relay L; the new arrangement, Figure 2, transmits pulses by shorting the two sides of the loop together. In both cases, the pulses hold relay L operated while removing current from relay STP at the originating sender, causing it to release to indicate that a pulse has been received. To eliminate the need for modification of the panel switches, a pulse-repeating relay PLS is used in the new circuit. Ground through the commutator segments and brushes operates relay PLS, which then shunts the loop. A high-speed glass-sealed dry-reed relay[*] is used to minimize pulse distortion and phase shift.

For best pulsing performance, relay STP in the originating office should be given an inductive "kick" to speed its reoperation after each pulse. Therefore, an N-type relay, which has a laminated core and consequently a relatively high inductance, is used for relay L. On the other hand, when the originating sender closes the loop as a start signal, the current should build up rapidly; this requires a low inductance in relay L.

To meet these conflicting requirements, a compromise was reached in the original circuit by shunting the relay with a non-inductive resistor. Relay L of the balanced circuit, however, uses a third winding to control its inductance. Since this winding is shorted through a contact on relay L while the relay is released, the inductance of the relay is low when the loop is first closed. Once the relay

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[*] RECORD, *September*, 1955, *page* 355.

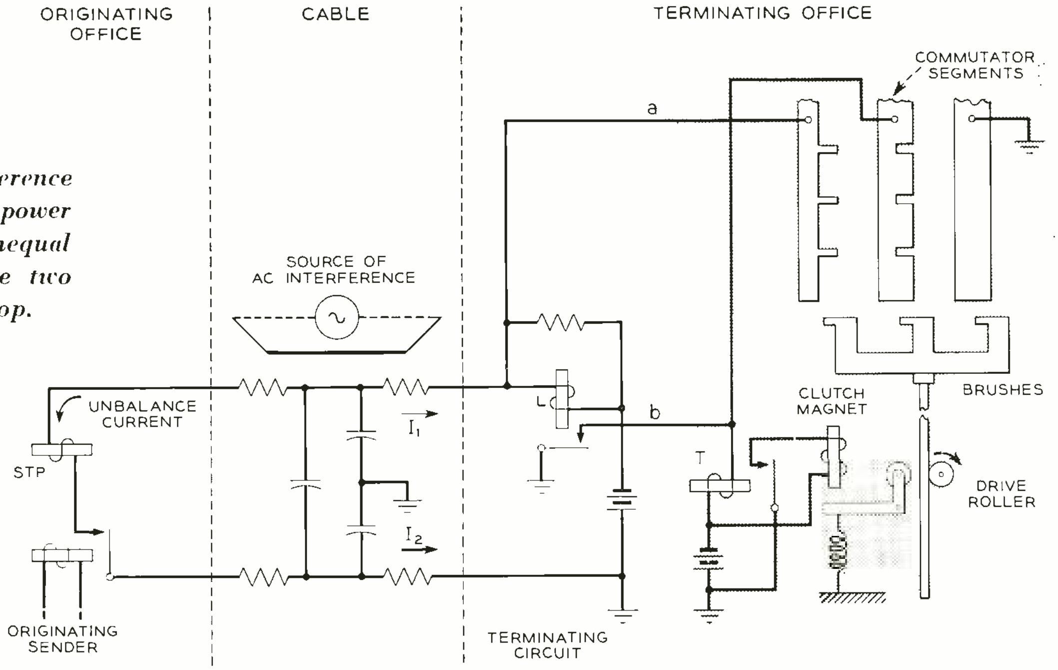

Fig. 1 — Interference from nearby power lines induces unequal currents in the two sides of the loop.

is operated, the short circuit is removed, making the relay inductance high for pulsing. The balanced relay L, therefore, meets both requirements fully and has better pulsing characteristics.

At the end of a selection, relay L must release quickly to stop the up-drive of the elevator and avoid moving the brushes past the desired position. The release of relay L is retarded by the surge current that flows to charge the cable capacitance following the shunt pulse. Since, in the unbalanced arrangement, the cable capacitance is discharged to ground during a pulse, the magnitude of the surge current limits the amount of cable that may be used on long cable loops.

In the balanced circuit, a charge with respect to ground of half the full value is maintained on the cable during a pulse. The surge at the end of a selection is appreciably less in magnitude, permitting relay L to release sooner. Because of this improvement in release time, the new circuit can be used with longer cables than before. A further advantage of the improved release time is that E-type negative-impedance repeaters,* which are finding increasing use in exchange area trunk design, are subject to fewer restrictions. These repeaters tend to increase the release time of relay L, and this is offset by the characteristics of the new circuit.

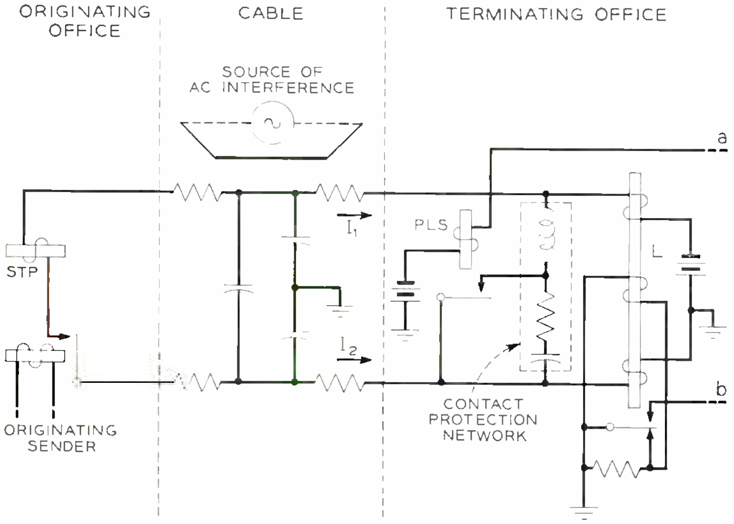

Fig. 2 — The balanced circuit that replaces that of Figure 1.

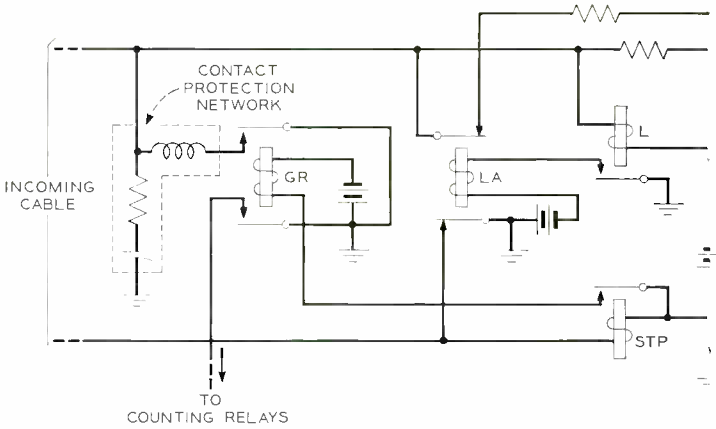

Fig. 3 — The original unbalanced crossbar circuit.

One maintenance problem in panel offices is that of keeping the resistance between the brushes and commutator segments of the selector switches as low as possible. In the earlier circuit, this commutator resistance appears in the shunting path that provides the pulses, permitting a certain amount of "leakage" current to flow through relay STP during a pulse. The value of this leakage current is determined partly by the resistance of relay L and partly by the amount of commutator resistance. In the balanced circuit, relay contacts with negligible resistance shunt the loop to form pulses, permitting a greater choice in the selection of the impedance of relay L and reducing the maintenance necessary on the commutators. Moderate amounts of commutator resistance are permissible since they are in series with the coil of relay PLS and do not affect its operation.

Basically, the operation of the circuit that terminates revertive-pulsing trunks in a crossbar office is the same as that of the panel terminating circuit. The chief difference is that relays instead of power-driven switches provide the pulses. In the original crossbar type of circuit, Figure 3, relays STP and GR generate the pulses. Relay STP in the terminating circuit "follows" the pulses in a manner similar to that of the stepping relay in the originating sender. Relays L and STP of the unbalanced crossbar circuit may both be affected by induced currents caused by ac interference. Therefore, in the new version of the circuit, each of these relays has been balanced, Figure 4. Polar relays have been used for L and STP because this structure is best adaptable to the pulsing requirements. By using biasing windings on these relays in addition to the balanced loop windings, it is possible to obtain more precise adjustments in terms of loop current and consequently obtain better margins for various circuit conditions. A pulse-help circuit is associated with the biasing winding of relay STP to provide more consistent pulses.

In changing from the unbalanced to the balanced circuit, an additional relay SS has been introduced in the pulse-generating circuit of relays STP and GR to prevent the false operation of relay STP by the current surge at the end of a selection (the same

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* RECORD, *February*, 1952, *page* 56.

surge that tends to retard the release of the panel selector L relay). With windings of STP in both sides of the loop, the full cable-charging current would flow through the relay, tending to operate it and give a false pulse. To prevent this, contacts on relay SS short-circuit the coils of relay STP until the cable is charged.

In addition, the lower inductance of the polar relay coils permits the initial loop current to build up rapidly when the start signal is received so that shunting resistors are not needed for this relay.

In neither the original nor the new crossbar circuits is the release time of relay L a limiting factor because there is no mechanical elevator mechanism to control, so the introduction of an E-type repeater does not affect the circuit. Also, the compensating action of the terminating STP relay makes the effect of these repeaters on the pulse cycle times negligible. The surge bypassing action of relay SS also makes the pulse cycle times more nearly ideal by further improving the compensating action of the stepping relay.

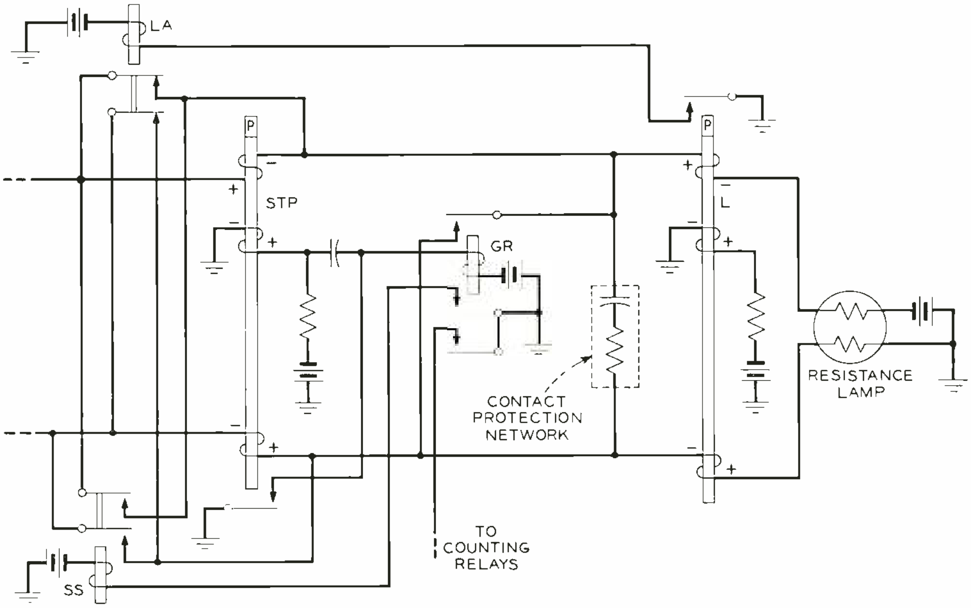


Fig. 4—The balanced circuit designed to replace that shown in Figure 3.

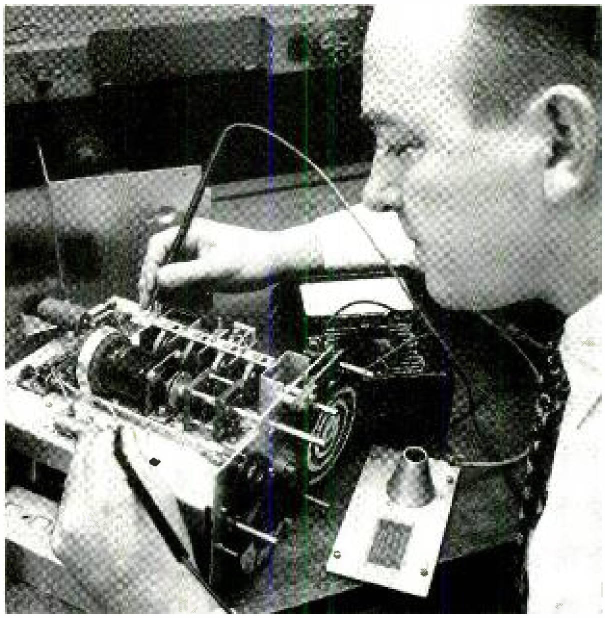
Lower inductance is permissible in crossbar circuits because the intervals between pulses are not dependent upon a mechanical device as in a panel selector and can be regulated to meet the requirements of the originating sender. To protect the low-resistance windings of relay L and to limit the current through the shunting contacts on relay GR, a resistance lamp is included in the new circuit.

Both the panel and crossbar balanced circuits have been designed so that present unbalanced circuits can be readily modified in the field where the existing circuits are subjected to ac interference. Balanced arrangements have been made available for battery cut-off panel selectors (the most widely used type of selector) and for the No. 1, No. 5, and tandem crossbar revertive-pulsing circuits.

THE AUTHOR

E. G. SPACK spent a summer with the Laboratories while attending Rensselaer Polytechnic Institute, working on mercury relay problems associated with single-frequency signaling. After receiving the degree of B.E.E. in 1950, he joined the Communications Development Training program, with rotational assignments in switching research, telegraph transmission, and switching apparatus. He has since worked on pulsing and ringing problems, and engaged in the development of a mercury-relay pulse generator, a ring-up circuit for the telephone answering set, and balanced arrangements for revertive-pulsing circuits. Mr. Spack is presently engaged in the range-extension program for exchange-area signaling circuits.

The Laboratories has recently made a major contribution to better military communications with the development of a compact and portable multi-channel telephone system. For the radio portions of a military network, the "exciter" with its associated frequency-control circuit enables the radio transmitter to operate on any one of a large number of stabilized frequencies.



G. RODWIN and **N. LUND**
Military Communications

Radio Set AN/TRC-24: Exciter and Frequency Control

The transmitter* of Radio Set AN/TRC-24, along with its associated receiver and antennas, forms a military radio-relay that can transmit up to twelve voice-frequency message channels. The radio-relay sections will normally function conjointly with four- or twelve-channel cable carrier equipment to form communication networks up to 1,000 miles long.

The problem of producing frequency modulation with very low distortion has been solved in numerous applications at fixed radio frequencies. The present equipment, however, has the additional requirement of accomplishing the modulation at any one of a large number of radio frequencies and holding the degree of modulation relatively constant over the range without adjustment.

The basic frequency modulated carrier in the AN/TRC-24 transmitter is produced by a group of circuits termed the "exciter" unit. The oscillator frequency generated in this unit is checked against, and is stabilized by, an accurately determined reference frequency generated by an automatic frequency-control assembly. These two sub-assemblies of the transmitter are represented in block form in Figure 1. Both the exciter and the automatic frequency control circuit are plug-in subassemblies of the AN/TRC-24 transmitter.

The oscillator covers the range of 50 to 112.5 mc. This is about the highest range that permits the convenient use of conventional tubes and circuits in a frequency modulated oscillator. It was kept as high as possible in order to minimize the number of frequency multiplications required to provide the higher final output frequencies. A grounded grid type of oscillator circuit is used in preference to the more usual grounded cathode circuit, so that the modulator may be connected across the entire oscillator tuned circuit. The particular circuit arrangement used provides good modulation sensitivity with low distortion and tends to maintain the output of the oscillator at a relatively constant level despite minor variations in tube performance.

The exciter unit employs a four-section variable inductor as the tuning element for the various circuits. The first section tunes the modulator. A second section controls the base radio frequency oscillator, and the other two sections are used for the two buffer amplifiers, which isolate or electrically separate the oscillator from the final power ampli-

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* RECORD, *November*, 1955, *page* 428.

fier. The frequency of the oscillator is corrected by a motor-driven variable capacitor, whose excitation is derived from the frequency control circuits, which will be described later.

The oscillator is frequency modulated by a push-pull modulator, which has an advantage over an unbalanced modulator in that the modulation sensitivity is doubled and the mean oscillator frequency is much less dependent upon supply voltage variations. Modulation is accomplished by means of a variable reactance. In this method of modulation, as represented in the upper left of Figure 1, a voltage is taken from the oscillator, shifted 90° in phase, and applied to the grid of the modulator. The audio frequency signal is also applied to the grid of the modulator. Such an arrangement causes the modulator to present to the oscillator a reactance that is varying at the audio frequency rate, and this varying reactance produces the desired frequency modulation. The first section of a spiral tuner tunes the modulator tube input circuit and provides very nearly the 90° phase shift necessary for proper operation of the reactance modulator.

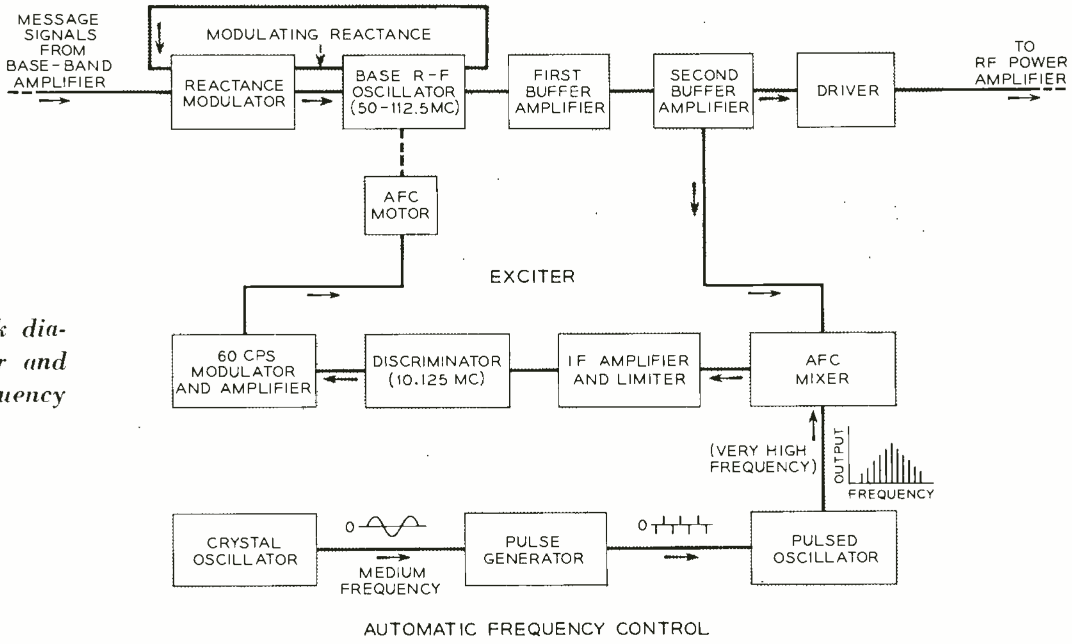


Fig. 1 — Block diagram of exciter and automatic frequency control circuits.

Distortion requirements on the complete equipment for radio relay use are very rigid compared to conventional radio equipment used to transmit on a single message circuit between two station locations. Good shielding is used, radio frequency filters are furnished on the power leads, and the feedback and phase-shift circuits are carefully designed and controlled. As a result, the base oscillator can be frequency modulated with excellent linearity with frequency swings of at least 100 kc. on either side of the average carrier frequency.

The modulated oscillator output is fed into two buffer stages in tandem, and these, besides their isolating action, also reduce any extraneous amplitude modulation that may have been introduced. The exciter unit also includes a higher powered stage or driver, which serves as a doubler when translation to a higher frequency range is required. With an air-cooled tetrode (4X-150A) in this stage, powers of 5 to 20 watts in the 50- to 225-mc range are available at the output of the exciter unit.

As mentioned earlier, the output frequency is accurately held at the desired value by the automatic frequency-control (AFC) unit. For many transmitters, such control is a relatively simple matter — the desired frequency is merely fixed by a quartz crystal oscillator. The AN/TRC-24, however, must be capable of operation on any one of a large number of usable radio frequency channels, and each frequency must be accurately controlled to prevent overlapping between nearby channels. By the conventional method of frequency control, about 250 crystals would have to be supplied with each transmitter for this purpose.

Instead, the AN/TRC-24 uses a novel system employing only three crystals to derive 250 basic frequencies, and, with the use of frequency multiplication, this method provides a total of 425 radio frequency channels in the range of 100 to 400 megacycles. One of the crystals (see Figure 2) is used in a circuit that generates a rather large spectrum of harmonic frequencies. The operator tunes the transmitter to the correct harmonic in the AFC circuit and later matches the base oscillator to this frequency. The AFC motor and variable capacitor then keep the base oscillator on frequency despite varying environmental conditions.

As seen in the lower part of Figure 1, the crystal oscillator generates a medium-frequency sine-wave signal that operates a pulse generator. The pulses from this circuit are fed to a pulsed oscillator, whose output is the spectrum of harmonics. Following the pulsed oscillator, the next three circuits are essentially the same as those used in an ordinary FM receiver. The AFC "mixer" combines the pulsed oscillator frequencies with the frequency-modulated carrier from the second of the two buffer amplifiers, and the resultant beat frequencies are amplified by the intermediate-frequency amplifier. This IF amplifier also reduces or limits any amplitude modulation that may be present. The discriminator or FM detector has a center frequency of 10.125 mc, and this frequency may be accurately adjusted by use of the second of the three crystals. The output of the discriminator is a dc voltage whose magnitude and polarity reflect the amount and direction of error in the base oscillator frequency. The dc voltage is converted to ac by the 60 cycles-per-second modulator, and this alternating current controls the AFC motor in the exciter unit.

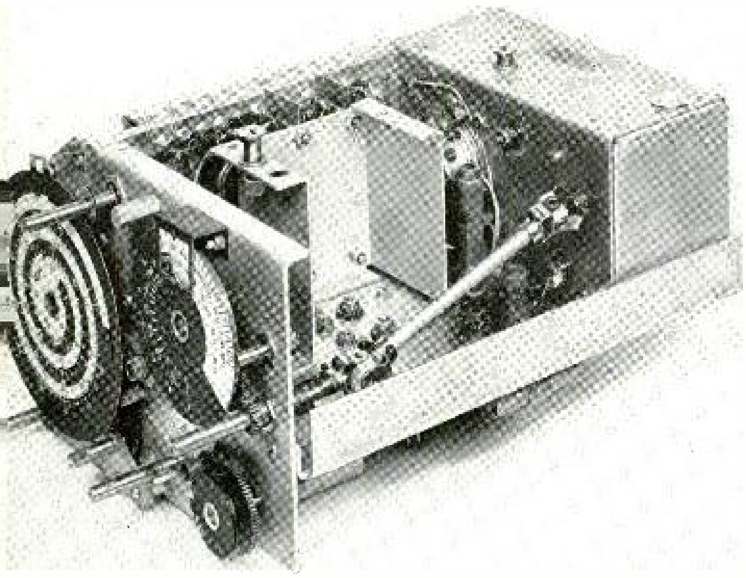


Fig. 4 — The complete exciter unit.

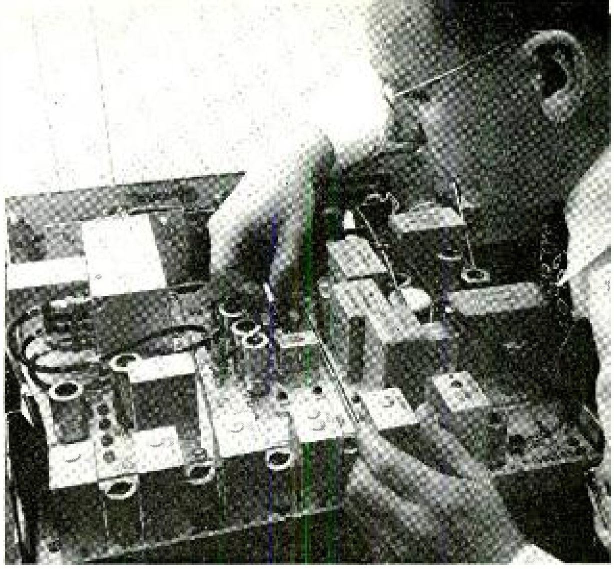
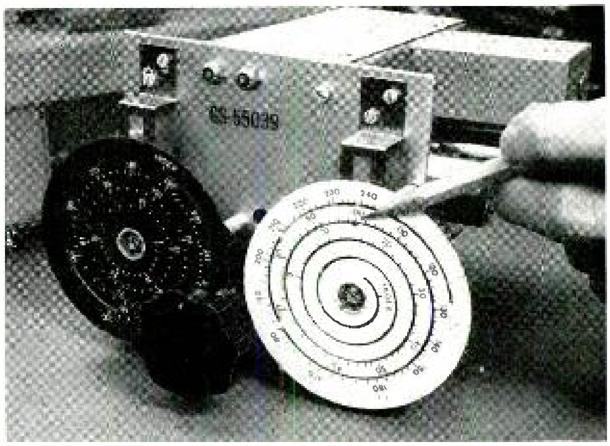


Fig. 2 — N. Lund inserting unit-channel crystal into oscillator and pulse generator assembly.

It will be noticed that in the mixer stage, the base oscillator frequency will beat with each harmonic of the AFC spectrum, and each of these beat frequencies will be modulated with any signal present in the reactance modulator. Thus, a large number of side-band components are present which, without special precautions, would tend to obscure discrimination between the desired frequencies. There is consequently a limit to the closeness of spacing between components of the reference spectrum. A spacing of 0.5 mc is used, but since the actual radio frequency channels are spaced as closely as 0.25 mc apart, some method of filling in the additional channels had to be found. Actually, each "picket" or harmonic of the AFC spectrum is used to provide two stabilized frequencies of the base oscillator, either above or below the reference frequency. Two calibrated dials (Figure 3) are provided to

Fig. 3 — The twin spiral dials of the pulsed oscillator unit. Pencil points to channel 100 on even-numbered dial; odd-numbered dial at left.



tune the pulsed oscillator. One is calibrated for even-numbered channels where the pulsed oscillator frequency is higher than the base oscillator frequency, and the other is calibrated for odd-numbered channels where the pulsed frequency is lower than the base frequency. These two dials are geared to the same tuning shaft, which turns a spiral inductor similar to that used in the exciter unit.

The next step in the tuning procedure is to match the base oscillator frequency with the AFC reference. The base oscillator tuning dial, however, cannot be calibrated with sufficient accuracy to identify channels spaced only 0.25 mc apart. This problem is solved by using the third crystal to create initially a reference spectrum in which the components are spaced 2.5 mc apart – five times the 0.5 mc spacing used in the later steps. The operator therefore tunes to the nearest ten-channel mark, at which time he can effectively eliminate the dial calibration error by resetting the adjustable dial index. He then switches over to the other crystal and tunes to the desired channel. Peak reading of the tuning indicator meter may be observed in making the final adjustment in order to provide still another check that the oscillator has been tuned to the desired frequency.

In the AN/TRC-24 transmitter AFC scheme, three factors determine the over-all frequency accuracy. These are the accuracy of the crystal from which the harmonic frequencies are generated, the accuracy of the crystal fixing the discriminator center frequency at 10.125 mc, and the "dead zone" of the motor control circuit. In the dead zone, the motor is practically stationary and the operating current is very low. The sum of these factors gives a maximum frequency error of about plus or minus 0.02 per cent.

The automatic frequency-control circuits are divided into four small plug-in assemblies (Figures 2 and 3), and the exciter is mounted in a single unit (Figure 4). These components, like all of those incorporated in a complete AN/TRC-24 Radio Set, have been mechanically designed both to give good service under adverse field conditions and to permit rapid and convenient maintenance.

THE AUTHORS

GEORGE RODWIN received the B.S. degree in Electrical Engineering from Columbia University in 1925 and joined the staff of Bell Telephone Laboratories in 1930. His early work was in overseas radio on the LC, LD, and LE single-sideband radio systems and on the Musa system. During World War II Mr. Rodwin was engaged in the design of radar equipment and in the design of microwave radio-relay equipment. Since 1945, his work has been in connection with a number of new designs of single-sideband radio equipment for the Bell System and for the Armed Services and of communication equipment for the Signal Corps.

NEAN LUND received a B.S. degree in E.E. from the University of Wisconsin in 1935. After a year of post-graduate study at the University and a period as a radio consultant, he joined the staff of Bell Telephone Laboratories. He first worked on the development and testing of single-sideband radio receivers, and during World War II was concerned with military development of loran, radar, and microwave radio-relay. Mr. Lund subsequently engaged in circuit development of single-sideband radio transmitters and the measurement of distortion in this type of equipment. Recently he has been engaged in circuit development of the AN/TRC-24 radio transmitter. Mr. Lund is a member of the A.I.E.E., the I.R.E. and Eta Kappa Nu.

D. A. Quarles, M. J. Kelly in Stevens Commencement Ceremonies

Secretary of the Air Force Donald A. Quarles, a former Vice President of Bell Telephone Laboratories, was awarded an honorary Doctor of Science degree by Stevens Institute of Technology in Hoboken recently. Secretary Quarles was also commencement speaker. He was introduced to the commencement convocation by Dr. M. J. Kelly who is a member of the Institute's Board of Trustees.

As "a researcher who became a director of researchers," Secretary Quarles was cited as one who has "by his penetrating analysis of scientific problems, especially in the fields of electronics and atomic energy, and by his talent for inspiring solutions to those problems, made science serve his country in peace and war and in the prevention of war."

Left to right, J. H. Davis, President of Stevens, Donald A. Quarles, and M. J. Kelly following commencement exercises at Stevens Institute of Technology.

Mr. Quarles was named Secretary of the Air Force last August after serving two years as Assistant Secretary of Defense for Research and Development. He joined Bell Laboratories shortly after serving in World War I. While at the Laboratories he directed the development of a number of significant advances in electronics, including coaxial systems for multi-channel telephony and television as well as important military devices. Mr. Quarles was elected a Vice President of Bell Laboratories in 1947, became President of Sandia Corporation and Vice President of Western Electric Company in 1952, and joined the Defense Department in 1953.

C. W. Phalen Elected Director of A.T.&T. Co.

C. W. Phalen, Executive Vice President of the A. T. & T. Co., was recently elected to the Board of Directors of that company to fill a post created by the resignation of W. Cameron Forbes.

Mr. Phalen began his Bell System career as a lineman for the New York Telephone Co. in 1928 after graduation from Yale. By 1944, he had advanced to Personnel Vice President. A year later, he became Public Relations Vice President of the New York Co. and in 1948 took charge of public relations for the A. T. & T. Co. In succeeding years, he held other vice presidential posts, and in 1952 was elected President of the Michigan Bell Telephone Co. He assumed his present duties on March 1 of this year.

In accepting Mr. Forbes' resignation, President Cleo F. Craig said, "The members of the Board deeply appreciate his wise counsel and advice over the years. Mr. Forbes' wide experience in administration as Governor General of the Philippines and as Ambassador to Japan, and his active participation in many industrial enterprises gave him a long-range perspective and deep insight which have been of great value in dealing with the problems of the telephone business."

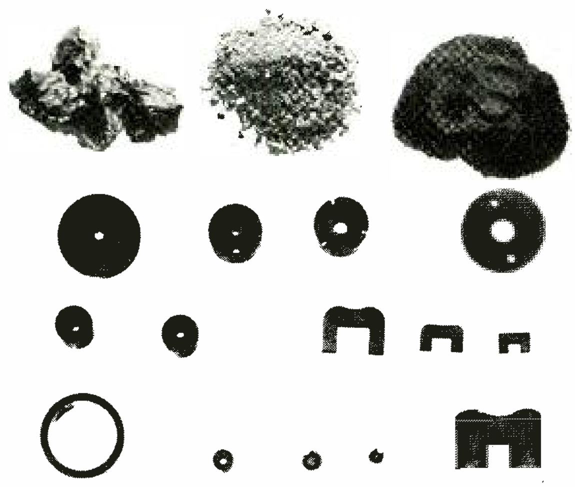
H. V. Schmidt Elected to Laboratories Board of Directors

H. V. Schmidt, Vice President – Chief Engineer of the Western Electric Company was recently elected to the Board of Directors of the Laboratories. He succeeds J. R. Bransford, Vice President, Telephone and Installation Division of Western Electric, who had been a member of the Board since September 1955.

Mr. Schmidt became Vice President – Chief Engineer of Western Electric on May 1. He had served as Engineer of Manufacture since 1952. Mr. Schmidt began his career with Western Electric in 1917 as a manufacturing student in the Hawthorne Works in Chicago.

Ferrite Cores Widely Used in Telephone System

Improved ferrites with high permeabilities have been made available as a result of research programs at the Laboratories. These ferrites have a number of present-day uses in the Bell System, such



Top row, left to right, original ferrite raw material, intermediate coarse-ground material, and fine powder. Below, various molded ferrite cores used in telephone inductors.

as in the cores of coils operating at radio and carrier frequencies, and many new applications are being investigated. Uses of the ferrite cores include induction coils in the Speakerphone, the volume control telephone set, and in short-haul carrier equipment. The coils will also be included in the recently announced transistor "tone ringer."

Laboratories and Western Electric engineers have cooperated closely in developing the manufacturing operations used to mass produce these cores. Raw materials for the ferrites, including iron oxide, zinc oxide, and manganese carbonate are thoroughly mixed, dried, and then broken up into particles that resemble coarsely ground coffee. The granular particles are then fired to an orange heat for several hours and rotated in a cylinder where hundreds of steel balls pound it into a fine powder.

The powder is aged for a period of from ten days to two weeks. At the end of this aging period, the powder is pressed into a variety of shapes. Then the most critical operations are performed – firing and cooling – when ferrite parts acquire their magnetic properties. A machine, 56 feet long, processes parts automatically through these crucial stages. After preliminary processing, the parts are conveyed to the firing furnace where every factor that affects the magnetic properties is precisely controlled. These factors include the nitrogen-oxygen atmosphere, the rate at which the temperature is raised to more than 2,000 degrees Fahrenheit, the length of time the parts are fired, and finally, the speed at which they are cooled to room temperature.

When the ferrite parts emerge from the machine, they are hard ceramic solids possessing the magnetic characteristics necessary for use with wire coils. The cores are then ground to size, usually within limits of from one to three thousandths of an inch. After careful inspection and electrical testing, they are ready to be coupled with wire coils to serve as inductors in telephone circuits.

Patents Issued to Members of Bell Telephone Laboratories During April

Bardsley, J. R. – *Housing for Electrical Apparatus and Method of Manufacture* – 2,743,308.

Beck, A. C. – *Pulse Heterodyne Transmission Testing Systems* – 2,741,740.

Becker, J. A., and Waltz, M. C. – *High Speed Negative Resistance* – 2,740,940.

Belek, E. – *Wire Wrapping Tool for Fine Wires* – 2,741,436.

Crump, E. E. – *Radar Method for Target Acquisition* – 2,743,439.

Felch, E. P., and Merrill, F. G. – *Frequency Multiplier Apparatus* – 2,743,367.

Fuller, C. S. – *Method for Portraying p-n Junctions in Silicon* – 2,740,700.

Graham, R. E. – *Differential Photocell Detector Using Junction Semiconductors* – 2,740,901.

Graham, R. E. – *Television Pick-Up Tube* – 2,740,912.

Hannay, N. B. – *Method of Forming Junctions in Silicon* – 2,743,200.

Holden, W. H. T. – *Resolving and Integrating Arrangement* – 2,740,583.

Hollenberg, A. V. – *Electronic Amplifier* – 2,742,588.

Kirkpatrick, W. E. – *Semiconductor Signal Translating Devices* – 2,740,837.

Kreer, J. G., Jr. – *Magnetically Loaded Electrical Conductors* – 2,740,834.

Leed, D. – *Automatic Frequency Control* – 2,743,362.

Mallery, P. – *Gas Diode Translator* – 2,743,316.

Mason, W. P. – *Electromechanical Transducer and Systems* – 2,742,614.

Merrill, F. G., see Felch, E. P.

Merrill, J. L., Jr. – *Negative Impedance Repeaters* – 2,742,616.

Mills, J. K., and Ross, W. S. – *Ringing and Signaling Current Supply for Telephone System* – 2,740,845.

Pierce, J. R. – *Pulse Transmission System* – 2,740,838.

Pierce, J. R., and Suhl, H. – *Solid State Amplifier* – 2,743,322.

Ross, W. S., see Mills, J. K.

Ruhlig, E. O. – *Method of Operating Cold Cathode Stepping Tubes* – 2,743,394.

Suhl, H., see Pierce, J. R.

Waltz, M. C., see Becker, J. A.

Papers Published by Members of the Laboratories

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

Albrecht, E. G., Dietz, A. E., Christoferson, E. W., and Slothower, J. C., *Co-ordinated Protection for Open-Wire Joint Use – Minneapolis Tests,* Comm. and Elec., **24**, pp. 217-223, May, 1956.

Anderson, P. W., *Note on Ordering and Antiferromagnetism in Ferrites,* Phys. Rev., **102**, pp. 1008-1013, May 15, 1956.

Bennett, W. R., *Techniques for Measuring Noise – Part III.,* Electronics, **29**, pp. 162-165, May, 1956.

Bennett, W. R., *Methods of Solving Noise Problems,* Proc. I.R.E., **44**, pp. 609-638, May, 1956.

Bennett, W. R., *Electrical Noise. Part IV – Design of Low Noise Equipment,* Electronics, **29**, pp. 154-157, June, 1956.

Bonneville, S., see Noyes, J. W.

Boyd, R. C., *Objectives and General Description of the Type-P1 Carrier System,* Comm. and Elec., **24**, pp. 188-191, May, 1956.

Boyet, H., see Weisbaum, S.

Bullard, W. R., and Weppler, H. E., *Co-ordinated Protection for Open-Wire Joint Use – Present Trends,* Comm. and Elec., **24**, pp. 215-216, May, 1956.

Chynoweth, A. G., and McKay, K. G., *Photon Emission From Avalanche Breakdown in Silicon,* Phys. Rev., **102**, pp. 369-376, Apr. 15, 1956.

Chynoweth, A. G., *Surface Space Charge Layers in Barium Titanate,* Phys. Rev., **102**, pp. 705-714, May 1, 1956.

Dietz, A. E., see Albrecht, E. G.

Ditzenberger, J. A., see Fuller, C. S.

Dudley, H. W., *Fundamentals of Speech Synthesis,* J. Audio Engg. Soc., **3**, pp. 170-185, Oct., 1955.

Eberhart, E. K., Hallenbeck, F. J., and Perkins, E. H., *Circuit and Equipment Descriptions of Type-P1 Carrier System,* Comm. and Elec., **24**, pp. 195-204, May, 1956.

Ellis, H. M., Phelps, J. W., Roach, C. L., and Treen, R. E., *Co-ordinated Protection for Open-Wire Joint Use – Ontario Tests,* Comm. and Elec., **24**, pp. 223-236, May, 1956.

Fuller, C. S., and Ditzenberger, J. A., *Diffusion of Donor and Acceptor Elements in Silicon,* J. Appl. Phys., **27**, pp. 544-553, May, 1956.

Gaston, C. M., *Stop Playing Hide-and-Seek with Engineering Drawings,* Iron Age Magazine, **177**, pp. 100-101, May 17, 1956.

Gaudet, G., see Noyes, J. W.

Hallenbeck, F. J., see Eberhart, E. K.

Harrower, G. A., *Auger Electron Emission in the Energy Spectra of Secondary Electrons from Mo and W.,* Phys. Rev., **102**, pp. 340-347, Apr. 15, 1956.

Howard, J. D., Jr., *Application of the Type-P1 Carrier System to Rural Telephone Lines,* Comm. and Elec., **24**, pp. 205-214, May, 1956.

Hutson, A. R., *Effect of Water Vapor on Germanium Surface Potential,* Phys. Rev., **102**, pp. 381-385, Apr. 15, 1956.

Katz, D., *A Magnetic Amplifier Switching Matrix,* Comm. and Elec., **24**, pp. 236-241, May, 1956.

Kowalchik, M., see Trumbore, F. A.

Logan, R. A., see Thurmond, C. D.

Lundberg, J. L., and Zimm, B. H., *Sorption of Vapors by High Polymers,* J. Phys. Chem., **60**, pp. 425-428, Apr. 16, 1956.

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

McLean, D. A., *Tantalum Solid Electrolytic Capacitors,* Proc. Natl. Conf. Aeronautical Electronics, pp. 289-294, May, 1956.

McSkimin, H. J., *Propagation of Longitudinal Waves and Shear Waves in Cylindrical Rods at High Frequencies,* J. Acous. Soc., **28**, pp. 484-494, May, 1956.

O'Brien, J. A., *Cyclic Decimal Codes for Analogue to Digital Converters,* Comm. and Elec., **24**, pp. 120-122, May, 1956.

Owens, C. D., *Stability Characteristics of Molybdenum Permalloy Powder Cores,* Elec. Engg., **75**, pp. 252-256, Mar., 1956.

Pearson, G. L., *Electricity from the Sun,* Proc. World Symp. Appl. Solar Energy, pp. 281-288, Book.

Perkins, E. H., see Eberhart, E. K.

Phelps, J. W., see Ellis, H. M.

Pierce, J. R., *Physical Sources of Noise,* Pro. I.R.E., **44**, pp. 601-608, May, 1956.

Pomeroy, A. F., and Suarez, E. M., *Determining Attenuation of Waveguides from Electrical Measurements on Short Samples,* I.R.E. Trans., **MTT-4**, pp. 122-129, Apr. 1956.

Prince, E., *Neutron Diffraction Observation of Heat Treatment in Cobalt Ferrite,* Phys. Rev., **102**, pp. 674-676, May 1, 1956.

Reiss, H., *p-n Junction Theory by the Method of Functions,* J. Appl. Phys., **27**, pp. 530-537, May, 1956.

Rice, S. O., *A First Look at Random Noise,* Comm. and Elec., **24**, pp. 128-131, May, 1956.

Smith, D. H., *Power Supplies for the Type-P1 Carrier System,* Comm. and Elec., **24**, pp. 191-195, May, 1956.

Suarez, E. M., see Pomeroy, A. F.

Theuerer, H. C., *Purification of Germanium Tetrachloride by Extraction with Hydrochloric Acid and Chlorine,* J. of Metals, **8**, pp. 688-690 May, 1956.

Thurmond, C. D., and Logan, R. A., *The Distribution of Copper Between Germanium and Ternary Melts Saturated with Germanium,* J. Phys. Chem., **60**, pp. 591-594, May, 1956.

Thurmond, C. D., see Trumbore, F. A.

Trumbore, F. A., Thurmond, C. D., and Kowalchik, M., *The Germanium-Oxygen System,* J. Chem. Phys., Letter to the Editor, **24**, p. 1112, May, 1956.

Weisbaum, S., and Boyet, H., *Broadband Non-Reciprocal Phase Shifts – Analysis of Two Ferrite Slabs in Rectangular Guide,* J. Appl. Phys., **27**, pp. 519-524, May, 1956.

Wood, Elizabeth A., *The Question of a Phase Transition in Silicon,* J. Phys. Chem., **60**, pp. 508-509, Apr., 1956.

Weppler, H. E., see Bullard, W. R.

Talks by Members of the Laboratories

During May, a number of Laboratories people gave talks before professional and educational groups. Following is a list of speakers, titles, and places of presentation.

Congrès Tubes Hyperfréquences, Paris, France

Collier, R. J., see Feinstein, J.

Cook, J. S., see Kompfner.

Feinstein, J., and Collier, R. J., *A Magnetron Controlled by a Symmetrically-Coupled* TE_{011} *Mode Cavity.*

Kompfner, R., Cook, J. S., and Yocom, W. H., *Slalom Flow, A New Method of Periodic Electrostatic Focusing of Electron Beams.*

Yocom, W. H., see Kompfner, R.

1956 Electronic Components Symposium, Washington, D. C.

Anderson, J. R., *A New Type of Ferroelectric Shift Register.*

Egan, T. F., see Hermance, H. W.

Embree, M. L., and Williams, D. E., *An Automatic Card Punching Transistor Test Set.*

Feder, H. S., and Haines, A. B., *New Type Miniaturized Power Transformers for High-Temperature Airborne Applications.*

Flaschen, S. S., see Sauer, H. A.

Haines, A. B., see Feder, H. S.

Hermance, H. W., and Egan, T. F., *Examination of Contact and Other Surfaces by a Plastic Replica Technique.*

Legg, V. E., and Packard, G. N., *Magnettor Probe for Traveling Wave Tube Magnetic Field.*

Packard, G. N., see Legg, V. E.

Sauer, H A., and Flaschen, S. S., *Positive Temperature Coefficient of Resistance Thermistor Materials for Electronic Applications.*

Williams, D. E., see Embree, M. L.

Other Talks

Ahearn, A. J., *Mass Spectrographic Studies of Bulk Impurities and Surface Contaminants of Conductors and Insulators,* Conference on Mass Spectroscopy, American Society for Testing Materials, Committee E-14, Cincinnati, Ohio.

Anderson, J. R., *A New Type of Ferroelectric Shift Register,* I.R.E., New York Section, New York City.

Baker, W. O., *Communications in a Technical World* under the general theme "The Chemists Look at Communications," American Institute of Chemists Annual Meeting, Boston, Mass.

Bangert, J. T., *Present Status of Network Synthesis,* I.R.E. Chicago Section, and *Present Status of Advanced Network Synthesis,* I.R.E. Chicago Chapter of the Professional Group on Circuit Theory, Ill.

Beck, A. C., *Waveguides for Long Distance Communication,* A.I.E.E. – I.R.E. Joint Student Branch, Rutgers University, New Brunswick, N. J.

Bittmann, C. A., *Metallurgical Aspects of Semiconductor Device Technology,* American Institute of Mining and Metallurgical Engineers Student Chapter, Polytechnic Institute of Brooklyn, New York City.

Blecher, F. H., *Electrical Properties of Diffused Types of Junction Transistors,* University of Michigan, Ann Arbor.

Bozorth, R. M., Williams, H. J., and Walsh, Miss D. E., *Magnetic Properties of Some Ferrites and Cyanides at Low Temperatures,* Conference on Physics of Magnetic Phenomena, Sverdlovsk, U.S.S.R.

Bradley, W. W., *Metallic Coatings,* U. S. Navy Material Catalog Service, Navy Building, Brooklyn, New York City.

Braunwarth, W. W., *The Organization and Work of Bell Telephone Laboratories,* New Jersey Bell Telephone Company, Newark.

Calbick, C. J., *Industrial Electron Microscopy,* Institute of Microbiology, Rutgers University, New Brunswick, N. J.

Chapin, D. M., *The Conversion of Solar Energy to Electrical Energy,* University of California, and Physics Department Seminar, University of Southern California, Los Angeles; and *The Bell Solar Battery,* Junior High School Science Students, Hanover Township Schools, Whippany, N. J.

Ciccolella, D. F., *The Bell Solar Battery,* Essex County Fuel Oil Dealers Association, Orange, N. J.

Dacey, G. C., *High-Frequency Transistors,* Electrical Engineering Seminar, University of Illinois, Urbana.

Darlington, S., *An Introduction to Time-Variable Networks,* I.R.E. Professional Group on Circuit Theory, Los Angeles Chapter, Calif.

Donahoe, A. H., *Systems Engineering of the Rural Subscriber Carrier System,* University of Illinois, Champaign.

Dudley, H. W., *Speech Synthesis – Theoretical and Applied Aspects,* I.R.E. Monmouth County Subsection, Little Silver, N. J.

Feder, H. S., see Haines, A. B.

Fleckenstein, W. O., *Switching Circuits for Automatic Control,* I.R.E. Professional Group on Communication Systems, Syracuse, N. Y.

Geller, S., *Crystallographic Studies of Perovskite-Like Compounds,* "Point Group" Crystallography Seminar, Polytechnic Institute of Brooklyn, New York City.

Gilleo, M. A., *The Crystal Structure and Ferromagnetism of* $La(Co_{0.2}, Mn_{0.8})O_3$, Symposium on Ceramic Dielectrics, Rutgers University, New Brunswick, N. J.

Goddard, C. T., *Opportunities for Young People in the Field of Science,* Young People's Group, West Parish Church, Andover, Mass.

Green, E. I., *Science and Liberal Education,* Westminster College, Fulton, Mo.

Talks by Members of the Laboratories, continued

Gretter, R. W., *Mechanical Problems in Submarine Cable*, Massachusetts Institute of Technology, Department of Mechanical Engineering Graduate Colloquium, Cambridge.

Haines, A. B., and Feder, H. S., *New Type Miniaturized Power Transformers for High Temperature Airborne Applications*, National Conference on Aeronautical Electronics, Dayton, Ohio.

Hammann, P. L., *NIKE I – A Guided Missile System for AA Defense*, St. Louis University; Southwestern Bell Telephone Company, St. Louis; and Missouri School of Mines, Rolla, Mo.

Hannay, N. B., *The Mass Spectrographic Analysis of Solids*, American Society for Testing Materials, Annual Conference on Mass Spectrometry, Cincinnati, Ohio.

Heidenreich, R. D., *Emission Microscopy and Its Application to Metals*, National Bureau of Standards, Washington, D. C.

Herring, C., *Thermoelectricity and Thermoconduction in Semiconductors*, Physics Colloquium, Columbia University, New York City.

Karlin, J. E., *User Preference Research in Engineering*, Harvard Business School Club, Northern New Jersey, Glen Ridge.

Keyser, C. J., *An Application of Modified Control Limits and a Continuous Sampling Plan*, American Society for Quality Control, Metropolitan Section, Newark, N. J.

King, J. C., *Structure Sensitivity of Quartz*, Frequency Control Symposium, Asbury Park, N. J.

Kock, W. E., *Speech, Music and Hearing*, I.R.E., Schenectady, N. Y.

Langhammer, F. L., *Engineering NIKE I Systems*, American Society of Mechanical Engineers, New York Machine Design Section, New York City.

Matlack, R. C., *Recent Trends in the Communications Aspects of Data Processing Systems*, Petroleum Industry Electrical Association Convention, Dallas, Texas.

McLean, D. A., *Tantalum Solid Electrolytic Capacitors*, National Conference on Aeronautical Electronics, Dayton, Ohio.

Moose, L. F., *Field Trial Technique as a Tool to Improve Reliability and Life in Electron Tubes*, R.E.T.M.A. Symposium, Reliable Application of Electron Tubes, University of Pennsylvania, Philadelphia.

Nielsen, J. W., *Growth of Single Crystals of Ferromagnetic Compounds*, Symposium on Ceramic Dielectrics, Rutgers University, New Brunswick, N. J.

Ohm, E. A., *A Broadband Microwave Circulator*, Electrical Engineering Department Colloquium, University of Wisconsin, Madison.

Paterson, E. G. D., *The Role of the Inspector in Quality Assurance*, Frankford Arsenal, Philadelphia.

Pomeroy, A. F., and Suarez, E. M., *Improved Method for Accurate Determination of Waveguide Attenuation*, I.R.E. Section on Microwave Theory and Techniques, Northern New Jersey, Murray Hill.

Raisbeck, G., *The Bell Solar Battery*, A.I.E.E., Wilmington, Del.

Remeika, J. P., *Growing Single Crystals of Rare Earth Perovskite-Like Compounds*, Physics Colloquium, Polytechnic Institute of Brooklyn, New York City.

Riesz, R. R., *User Preference Research in Engineering*, I.R.E. Houston; A.I.E.E.-I.R.E., Southwestern Research Institute, San Antonio; Southern Methodist University, Dallas, Texas; and Purdue University, Students of Industrial Psychology Group, Lafayette, Ind.

Schawlow, A. L., *The Intermediate State of Superconductors*, Physics Colloquium, Rutgers University, New Brunswick, N. J.

Schmidt, W. C., *Problems in Miniaturization*, American Society of Mechanical Engineers Design Engineering Conference, Philadelphia.

Schroeder, M. R., *Information Theory and Speech*, University of Goettingen, Third Institute of Physics, Germany.

Schumacher, E. E., *The Contract of an Engineer*, South Dakota School of Mines and Technology, Rapid City.

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Slepian, D., *Information Theory*, I.R.E., North New Jersey Section, Murray Hill.

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