Nationwide dialing by telephone customers is the ultimate realization of many of the Laboratories current planning and development activities. A most fascinating aspect of this program is that its eventual achievement literally places a multi-billion-dollar continent-wide mechanism of extraordinary complexity and versatility at the fingertips of customers.

Switching at Its Boldest

J. MESZAR *Switching Systems Development II*

Like other digital systems, a telephone switching system is an information processing machine. It receives and stores information, and manipulates this information toward a useful end in accordance with the rules of logic built into it.

In spite of a relatively recent start in the outside world, the capabilities and ramifications of such machines have already acquired impressive proportions. Well-known examples are the large-scale digital computing machines that furnish answers to mathematical problems previously beyond the resources of human calculators. Also in operation are railroad and airline seat-reservation systems and other similar automatic inventory systems that keep accurate track of thousands of items and furnish instantaneous answers to complicated inventory questions. Public demonstrations have been given of automatic printed-page typesetting systems, and power-tools controlled by instructions recorded on paper. Studies are being made of automatic air traffic control systems, and there are visions of fully automatic factories, of machines for weather predicting, for library searching, for language translating.

Striking as are the outside examples of digital systems, a modern common-control dial central office is as yet unsurpassed in scope of concept, in amount of mechanized intelligence, and in versatility of actions. This machine is an exquisitely organized system of component units, accepting and executing orders of thousands of its customers for telephone connections. Each end-product of this machine's labor – an established telephone connection – appears like a simple accomplishment, but those who have looked "under the hood" appreciate the fact that this end-product is the result of a series of split-second internal actions of a high order of mechanized intelligence.

Even an over-simplified non-technical account of these actions for establishing a straightforward intra-office connection will evoke respect for the accomplishments of this machine. In an instant, when one of its thousands of customers lifts his telephone handset, component units of the dial central office locate and identify his line, attach themselves to it, give him the signal to proceed with his order, count the dial pulses and spins, store the identity of the requested telephone, determine how and where to get access to it, locate and test the numerous transmission paths leading to it, select and link up the most appropriate combination of these paths, and then ring the called telephone, if it is not in use. It usually takes less than a second to establish the requested connection after the identity of the desired telephone has been dialed. Also, while the series of actions just described is taking place to establish one telephone connection, additional groups of component units in perfect teamwork promptly execute similar orders received at random from others among the thousands of customers. Further, while certain groups of component units set up connections, different ones in precise coordination record on paper who calls whom, and when each conversation starts or ends, so that customers can be properly billed for services rendered. Even more: as part of their work, all these control units also check the validity of their own actions, and in case of trouble they record the circumstances and will then start afresh to put the call through.

One could enthusiastically elaborate further on the intricate dynamics of a modern common-control dial central office. However, such a central office is not the theme of this article. It does not merit the title: "Switching at Its Boldest." This title signifies an objective of switching technology which is far more astonishing in scope and in implementation than is a central office. The machine earning this title is the over-all telephone switching mechanism which is now being fashioned for nationwide dialing by customers.

There are many important, though prosaic, facets of customer nationwide dialing; some, for instance, think of it in terms of seconds saved per average long distance connection; others look at it in terms of dollars of annual operating economy. Still others stress the aspect of greater customer convenience, increased service reliability, and so on. However, at least philosophically, these are not the imaginative views of customer nationwide dialing. For some of us the most exciting aspect of customer nationwide dialing is that it literally places at the fingertips of the telephone customer an automatic mechanism whose magnitude, complexity, and built-in intelligence are unique on a grand scale.

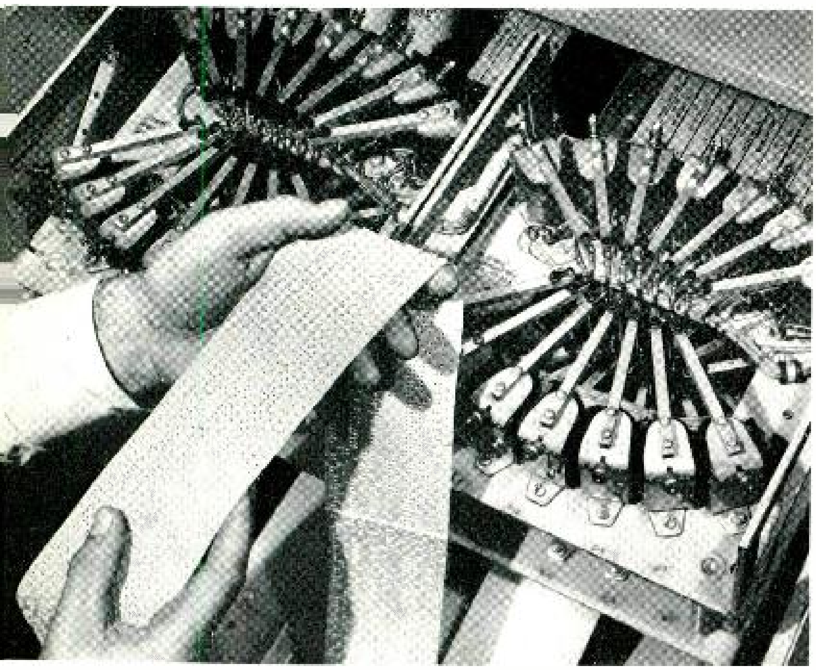


Fig. 1 — As one of their functions, telephone switching machines record data to compute charges for their services.

The typical customer doesn't have any idea of this mechanism whose sole reason for existence is to do his bidding. He has a little instrument, the telephone set with its dial, with which he gives his orders to the machine. However, the contrast between this little instrument and the mechanical giant it sets into motion in the hidden world inside telephone buildings is sharp in the extreme.

In fact, even we switching development people who have been sculpturing this mechanism over the years, are hard put to visualize it in its full dimensions. Most of us are so engrossed daily in chipping away at individual stone blocks that we do not lift our eyes to behold the cathedral. Most of the time our attention is focused on the internal workings of building blocks such as a register, or a translator, or a connector, or some other unit. When a situation so requires, our mental grasp can, and does, of course, expand to cover the whole central office mechanism — but not much more. One reason for this boundary is, of course, the limitation of our technical comprehension. A central office represents probably the largest switching entity within which our mind — with intense concentration — can still visualize the direct interplay of component trunks, link controllers, senders, markers, etc. However, there is another reason for this limitation and that is rooted in the history of telephone switching. Until relatively recently, our central office machines had only the ability to set up connections within their respective local areas, and customers needed the services of operators if they wanted connections much beyond such areas. These trained, intelligent human beings acted as the higher echelon switching systems linking the central office machines of the country into a coordinated whole. Then came the Englewood, N. J., trial, and by now approximately a dozen commercial extensions of this experiment. Like a stone hitting a window, these experiments shatter our provincial switching outlook. The realization suddenly dawns on us that the central office machine is a totally inadequate concept for the mechanism that is already at the fingertips of some of our customers. This concept of a switching mechanism larger than a dial central office was, of course, valid and necessary even prior to customer nationwide dialing. However, with customer nationwide dialing the valid and necessary concept suddenly expands to extraordinary proportions — it becomes that of a multi-billion-dollar mechanism, physically dispersed over the whole continent, but unified and integrated to function as a single automatic entity.

Trying to form a full mental picture of this continental mechanism in action would indeed tax our powers of imagination. However, we can attempt to visualize it in terms of the artist's sketch which portrays a recognizable face with a few strokes of the crayon.

The physical components of this continental mechanism are, of course, the galaxy of dial central those that receive and obey instructions one small step at a time; there are those that can memorize and execute complete orders. There are component machines that have the flexibility and vigor of youth, and there are those that follow the grooves of age. There are machines that receive orders in only one "language," and there are those that can

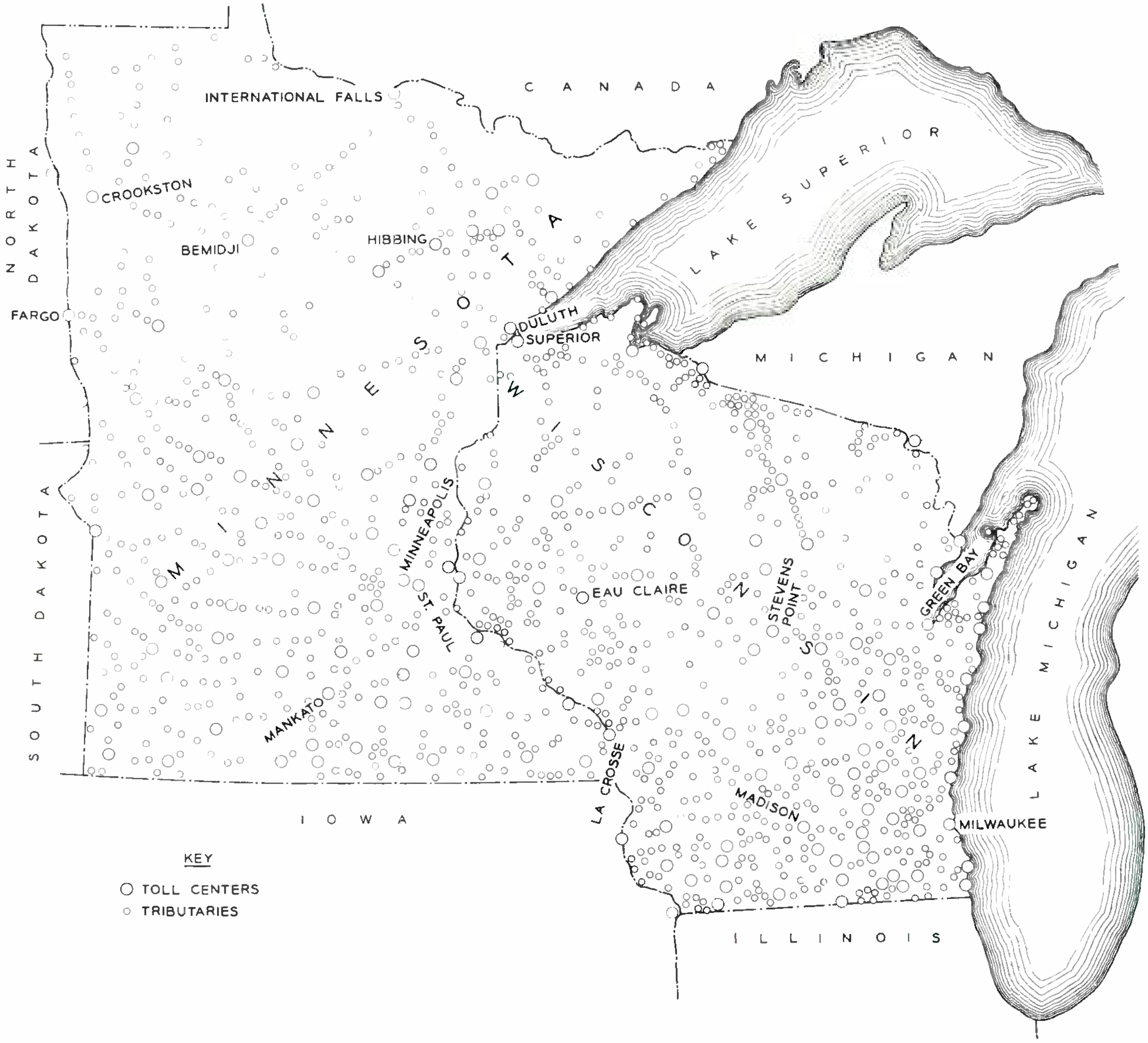


Fig. 2 — In a typical section of the country, the small circles represent tributary telephone offices at any one of which long distance calls originate and terminate. The large circles are long distance operating centers located throughout the section.

office machines installed in cities and towns throughout the length and breadth of the continent. One of these typical component machines includes hundreds of tons of intricate switching equipment, and the continental mechanism will eventually comprise thousands of such component machines. These component machines are of great variety. There are readily respond to commands in several "languages." There are machines that communicate directly with the customers, and there are those that deal primarily with other machines with higher echelon responsibilities. These component machines of the continental mechanism are knitted together by a superb network of wires, coaxial cables, and radio

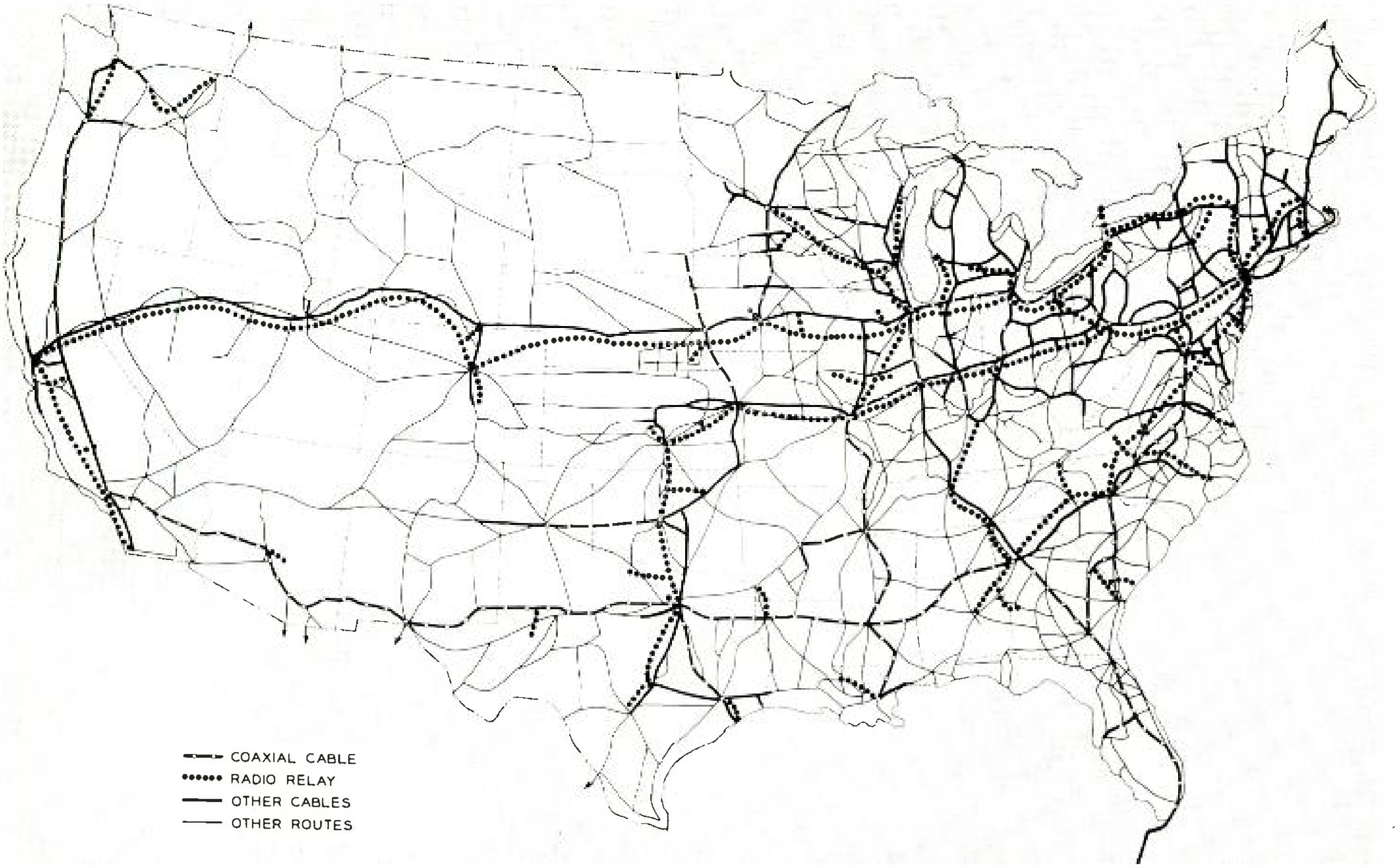


Fig. 3 — In the intricate network of telephone highways and byways, there are many alternate patterns of linkages between the points of origin and destination.

links. The full structure of this continental mechanism is some years away; its vigorous integration has just started, but already a mother in Englewood, for instance, spins her little dial and immediately hundreds of relays go into a huddle in the Englewood No. 5-type central office, crossbar switches snap in the Pittsburgh A4A-type toll office, signal tubes throb in the Oakland No. 4-type toll office, a marker hustles in the San Francisco tandem office, brushes slide over terminals in a panel-type central office, and about the time this sentence is finished, the telephone is ringing in her daughter's home close by the Golden Gate. A slightly different spinning of her dial would bring into play, within seconds, component branches of the continental mechanism in New York, Chicago, Milwaukee – or in Pittsburgh, Cleveland, Detroit and their suburbs.

Imposing as is the physical size of this continental mechanism coming into being, it doesn't serve as a true measure of switching at its boldest. A far more fascinating and significant aspect is the great resources of mechanized intelligence and versatility that are being embodied in this mechanism. Telephone customers by the tens of millions are spread over the vastness of this continent – in the modest homes of little villages, and in the soaring steel hives of the big cities; in the lonely farm houses of the Mid-west and in the humming seaports of the Coasts; in factories, mountain camps, gasoline stations, and so on. The telephone identity of any of these customers will be given to the continental mechanism as a simple number of 10 digits or less. The task of the mechanism is to accept any one of these numbers, dialed by the customer, then search for the destination it represents, and link together swiftly and with precision appropriate sections of telephone highways and byways to form a continuous private voice-path from the point of origin to the point of destination, wherever on the continent these may be.

The audacity of this continental mechanism's task stands out even more when one is reminded that in the network of telephone highways and byways there are a great many traffic lanes and a great many alternate patterns of linkages between the points of origin and destination. The number of available traffic lanes and the patterns of linkages are forever changing. The continental mechanism has to have, therefore, up-to-the-minute knowledge of this complex and changing network within its collective memory to utilize its rich routing possibilities; it must be able to take instantaneous bearing of the available links leading progressively toward each call's destination; it must have enough built-in intelligence to choose and connect the most preferred combination of these links. And the mechanism will, of course, have to perform this intricate task without the benefit of any human assistance. In fact, one of the truly intriguing aspects of this continental switching mechanism will be that it will connect in a few seconds two telephones thousands of miles apart without any human being knowing what the geography of the connection is. The customer requesting the connection won't know, the people who maintain the mechanism won't know, and even the engineers who designed the mechanism won't know what route a specific call took, and what cities it went through to get to its destination. The planning and designing engineers and the maintenance craftsmen will, of course, know what rules the mechanism follows in reaching its decisions while working on a customer's request. But the application of these rules to the well-nigh infinite variety of instantaneous telephone traffic conditions of the country is the machine's own function and responsibility.

One's respect for the versatility and knowledge of this continental machine is further enhanced by the realization that, to establish a connection, its branches communicate with each other in one of several machine languages; that they may have to substitute for, delete, or add to the information they themselves receive in order to reach the call's destination; that they have to self-program all their actions; that they are called upon to record in a permanent form, adequate data for customer billing; that they have to handle irregular situations resulting from telephone traffic congestions, customer errors, internal failures, and so on.

Above everything else, however, the facet of this continental machine that kindles the imagination most vividly is its dynamic aspect. This machine will have tens of millions of customers, all of whom will give their orders when and as they please. Some of the orders will be simple – they merely want to talk to their nearby neighbors. Others, in contrast, will require searching far and wide, and some will necessitate spanning the continent to bring the desired voices. All the orders pouring into the mechanism from these millions of customers in the East, in the West, North and South, and in between, have to be executed promptly, without confusion. It is a refreshing mental exercise to close one's eyes and make an attempt to visualize this mechanism as it performs; a giant robot with limbs stretching over the continent, serving the whole nation with its brawn and brain, weaving a constantly changing pattern of nearby and far-flung telephone connections.

It is not out of order for us telephone people to express a little pride in this robot. Men, as creators and builders, are proud of the many obvious triumphs that they have fashioned out of metal for use by society: the great ships that carry commerce.

THE AUTHOR

John Meszar, Director of Switching Systems Development II, joined the Laboratories in 1922 as a technical assistant in toll switching circuits. Five years later he became a circuit design engineer for toll switching systems, and in 1936 became supervisor of his group. During the war he was supervising instructor in the Laboratories' School for War Training, later returning to circuit design supervision, with particular attention to the automatic message accounting system. Mr. Meszar received his B.S. degree in E.E. from Cooper Union in 1927. A member of the A.I.E.E., he is Secretary of the Institute's Communication Division Committee.

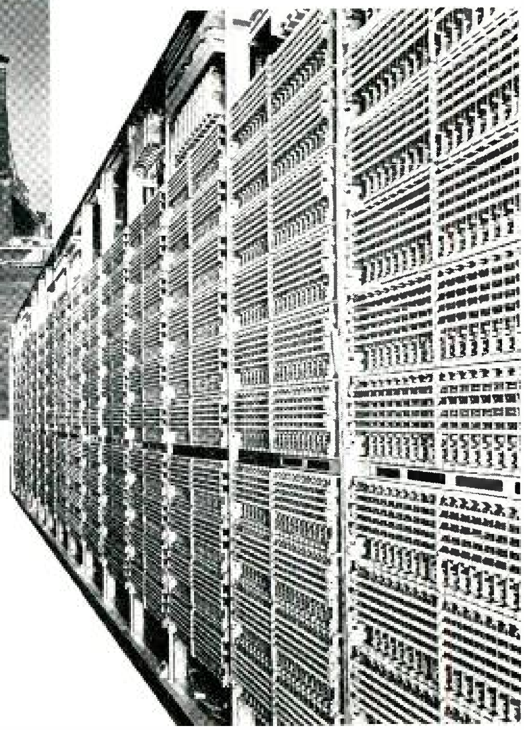
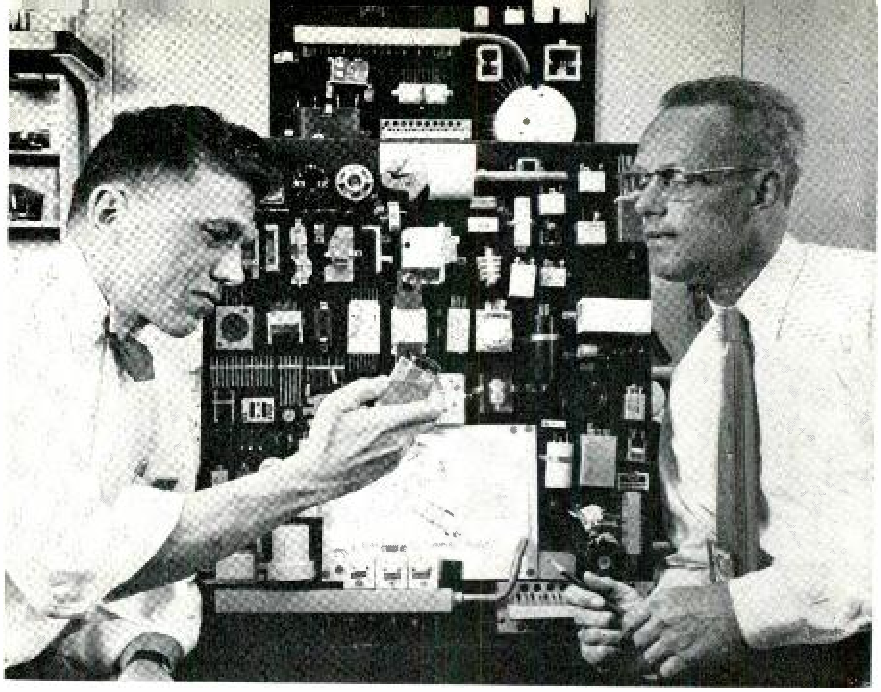


Fig. 4 — (Above) Triumphs of metal that industry has fashioned for use by society . . . (Right) Triumph of metal created by telephone people for serving the public.

plowing through the ocean waves; the towering skyscrapers that shelter busy working people; the strong bridges that link opposite shores for motor traffic. Great accomplishments as these are, the continental machine for nationwide dialing that we telephone people are fashioning out of metal, tops them all in scope, concept, and in service to society. Our machine will bring 160 million people within a few spins of the little dial; it will knit the villages, towns, and cities of a whole continent into a neighborhood. It will bring, within seconds, from a thousand miles away, the greeting of a friend, the laughter of a youngster, the voice of the business partner. It will obey the clerk, and it will be at the service of the "top brass"; it will work for the farmer and it will execute the instructions of the banker. It will usher in a new era in communication, add a new dimension to the telephone as a social force. It will advance to new heights the ideal of "serving the public."



Casting and Potting Resins: Some Chemical Aspects

W. J. CLARKE *Chemical Research*

The familiar circuit schematics tell only part of the story of the complex electronic equipment designed at Bell Telephone Laboratories, for many of the components must be supported or encased to withstand rugged usage. This is especially true of much Bell System and military equipment that must operate efficiently under extreme conditions of temperature, moisture, and physical shock. Laboratories' chemists and engineers have found the new liquid thermosetting plastic resins to be the answer to many of these difficult casting and potting problems. By a simple pouring and curing process, components can be safely and permanently encased.

There seems to be no end to the stream of resins and plastics issuing from the chemical industry's reactors or to the number of ingenious ways in which these products may be employed. In recent years, the industry has made some interesting additions to the group of plastic materials known as casting resins. Unlike the earlier casting plastics, these improved types are easy to handle. This has opened up all sorts of possibilities to apparatus designers and manufacturers in various fields. The new resins have appealed particularly to engineers in the electrical industry as an entirely different approach to the assembly of their apparatus.

These resins are furthermore playing an important part both in the protective encasement and in the miniaturization of electronic equipment. They are being used, for example, in the encasement of certain types of transistors, amplifier circuits, and transformers; as L3 carrier component supports, as special rural pole line insulators,* as terminal strips,† and as a means of unitizing a group of parts in various other Bell System equipment. They are also widely employed in the assembly and protection of electrical components in military equipment.

The older hot-melt insulating materials were hardened around electrical components simply by a cooling process. The new casting materials are different in that they are capable of being polymerized — that is, hardened by chemical action. Starting usu-

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* Record, *April*, 1954, *page* 121. † Record, *May*, 1954, *page* 179. *Also see page* 468 *of this issue.*

ally from a low molecular weight, pourable liquid form, they are changed by means of a catalyst and heat into a dense, solid, infusible form with outstanding insulating properties. As a result, within the electrical industry a very promising new field has been growing up in the resinous potting and encasement not only of individual components but of entire circuit assemblies and associated parts.

Waxes, asphalts, oils, and varnishes have served well for the simple impregnation and potting of coils and other parts, and they will continue to be used for a long time wherever service conditions permit. However, such materials may crack when cold, melt when hot, or sometimes leak from containers, and they give satisfactory results only over a relatively narrow temperature range. Present-day requirements for the protection of electrical apparatus in the telephone plant, and for equipment designed for the military, are becoming more and more severe.

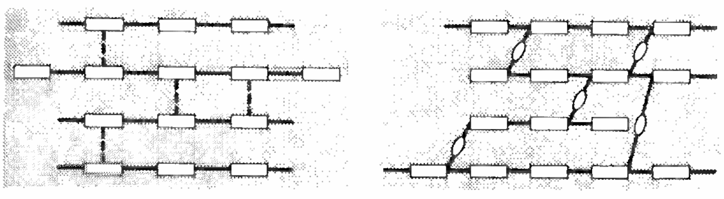


Fig. 1 — (a) Weak cross-linkage of the thermoplastics, which melt under high temperatures; (b) strong cross-linking molecules of non-softening thermoset plastics.

Intermittent or continuous service conditions from minus 40 to plus 200 degrees F are not uncommon, and sometimes these temperatures may be greatly extended. This places a very severe demand on organic materials. Such materials also must often withstand unusual thermal and mechanical shock. To satisfy these demands, Laboratories' chemical engineers and chemists examine and modify new resins and polymers as they are commercially developed, constantly seeking those with the most suitable combinations of properties.

The principal casting and potting plastics that have appeared in recent years are (1) the styrene-polyesters and (2) the epoxide resins. Both of these classes of materials are of the thermosetting rather than the thermoplastic variety, which is to say that they polymerize into a tough, non-softening, cross-linked molecular structure.

In a thermoplastic potting material, such as a microcrystalline paraffin wax, Figure 1(a), the forces holding the chain-like molecules together are

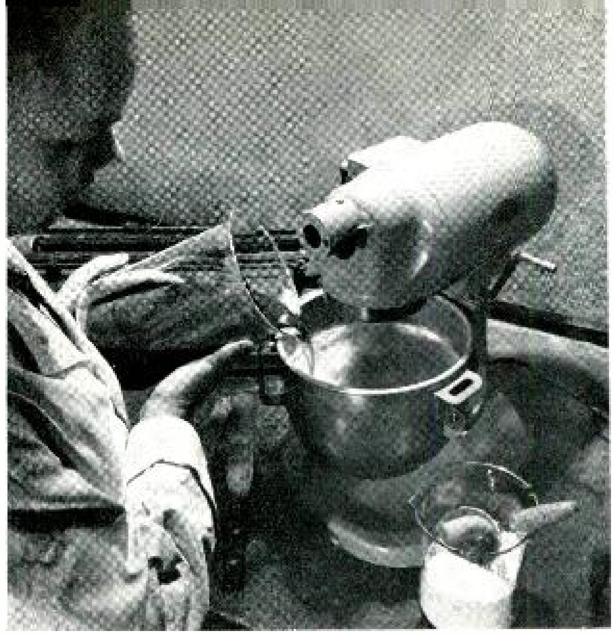


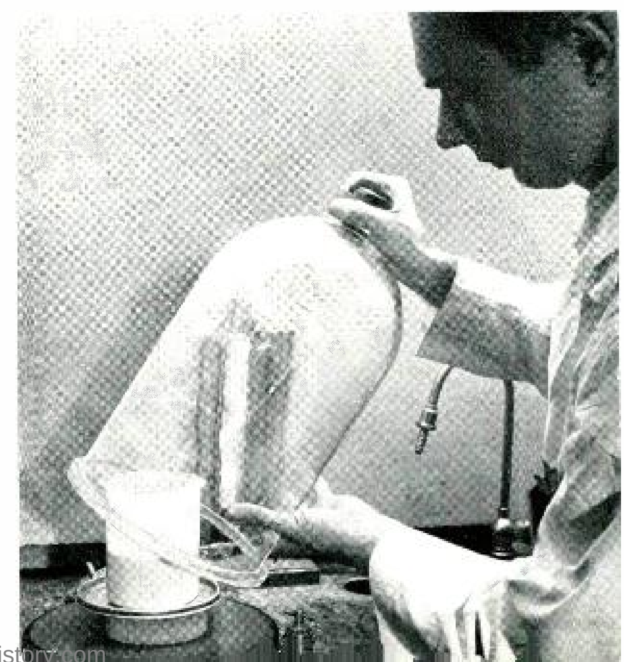
Fig. 2 — F. H. Doleiden mixing base resin and filler.

weak crystalline or other weak intermolecular forces. However, in the more recent thermoset plastics, such as a cured styrene-polyester or epoxide resin, Figure 1(b), the originally liquid polymer chain-molecules have been further chemically cross-linked at various points, thus converting the material into a solid that will not melt even at high temperatures. Both representations must be thought of in a three-dimensional way as dense, net-like structures.

Such materials are thus useful over a far broader temperature range than any of the older polymerizable thermoplastic materials. Furthermore, no objectionable by-products are given off during their polymerization, and corrosive catalysts — undesirable in electrical applications — are not required.

Both the styrene-polyesters and the epoxide resins — especially the hard, tough varieties — have

Fig. 3 — J. T. Ryan preparing to remove air from a batch of thermoset plastic compound.



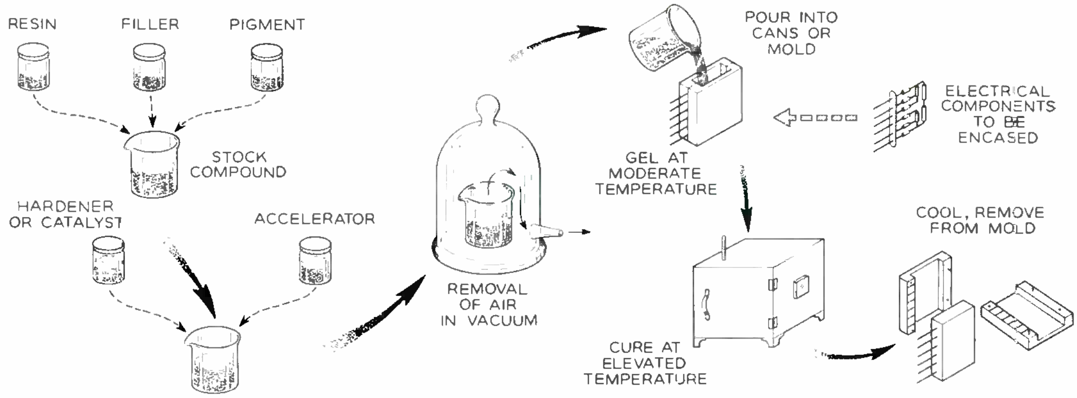
excellent electrical insulating properties. The styrene-polyester compositions are particularly good in electrical surface resistivity under prolonged humid conditions. The adhesion of the styrene-polyesters to metals, however, is low, and their shrinkage is relatively high. Shrinkage is desirable in encasement or assembly work where the finished rigid plastic casting is to be removed from the mold. The epoxide resins, on the other hand, exhibit a high order of adhesion to a wide variety of materials, and their shrinkage during polymerization is so much lower than the polyesters that they are most promising where electrical apparatus is to be potted.

Of course, with the proper selection of a mold material and mold-release agents, either of these new classes of materials may be used for both potting or casting. Epoxide resins, for example, have been successfully cast in non-sticking plastic molds or in polished and well lubricated metal molds. Cable terminals, in large scale manufacture at the Point Breeze Works after extensive development at the Hawthorne Works of the Western Electric Company, employ a styrene-polyester base material strictly as a potting composition. It is poured into a modified styrene-plastic injection-molded housing, the latter becoming an integral part of the assembly. The adhesion of the two styrene-containing plastics to one another makes this a unique case of potting, and incidentally saves a great deal of metal mold expense.

For the first of the two basic types of thermoset resins – the styrene-polyesters – there are five constituents making up a typical commercial casting composition. These are (1) the polyester base resin, (2) styrene, (3) an inhibitor, (4) fillers and coloring agents, and (5) a catalyst (plus sometimes an accelerator). The use of these constituents is illustrated diagramatically in Figure 4.

The molecular structure of the polyester base resin may itself be exceedingly complex, but for the purpose of polymerization its most important feature is that it has in its molecular structure a form of reactivity known to chemists as unsaturation. It is represented by a double line or bond between carbon atoms, as in Figure 5(a). This is merely an empirical way of indicating a particular point of activity in an organic molecule at which one of the two bonds can be said to "break" and "attach" to reactive spots in other molecules. Electronically, the double bond involves the sharing of two electron pairs by the two carbon atoms. The initial reactants are chosen by the resin manufacturer so that they are capable of joining one another in a hand-to-hand fashion, but only at the ends of each molecule. Thus thread-like, long-chain polyester molecules are formed with potentially reactive unsaturated spots along the chains. The resin at this stage is often a viscous liquid that is difficult to handle. Hence, a low-viscosity substance, usually styrene, which also contains the characteristically reactive unsaturated carbon-carbon group, is added to the extent of 20 to 50 per cent to reduce the mass to a pourable consistency. The relative proportions of the chemical components of the casting resin affect its ultimate physical properties, which may vary from hard and brittle to soft and rubbery.

Fig. 4 — Representation of encasement of electrical components with a styrene-polyester thermoset plastic.



The base resins obtained from various commercial manufacturers contain a trace of a soluble "inhibitor." This inhibitor prevents the resin from hardening prematurely and is a very important and well guarded secret of the resin supplier. It influences the handling of the resin to a considerable degree.

Carefully selected fillers and coloring agents comprise the fourth of the five constituents. These are often added to the commercially supplied base resins by the ultimate user to suit the particular application. For a few parts where appearance is a factor, the clear styrene-polyester resins may be used as received, but for most practical encasements, and especially in the formation of structural parts for complicated electrical assemblies, it has been

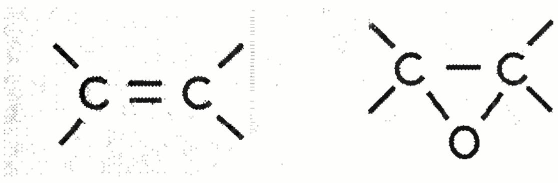


Fig. 5 — The important chemical groups responsible for the polymerization of (a) the styrene-polyester and (b) the epoxide casting and potting resins.

found that the incorporation of pulverized inorganic fillers is extremely helpful. These may be such materials as talc, mica, milled glass fiber, calcium carbonate, or silica, added to the extent of 5 to 60 per cent. These fillers not only improve the strength of castings but, by enhancing heat conductivity, they minimize the local overheating which comes from the highly exothermic (that is, heat-producing) polymerization reaction. Without reinforcing fillers, polymerization is very likely to result in gas bubbles and stress cracks. Fillers also help to decrease the cost of a compound. From the standpoint of pourability, the amount that may be added is limited and is somewhat lower than the amounts possible with compression-molded plastics. Pigments are added to the material for opacity and for identification purposes.

When ready to make a casting, the operator weighs out a sufficient charge of the filled pigmented liquid resin and stirs in thoroughly a predetermined percentage (about 0.3 to 2.0 per cent) of a specified organic peroxide catalyst. Sometimes a small amount of a chemical accelerator, for example a soluble cobalt compound, is finally added, or this may have been originally incorporated in the polyester resin by the manufacturer. From this point on, the catalyzed resin must be handled rapidly. At ordinary temperatures the operator has about one-half hour to an hour before gelation sets in. During this period the air is removed from the mixture in a vacuum chamber, and the catalyzed compound must be poured as soon as possible and not disturbed during gelation. Generally a moderately elevated temperature of about 50 degrees C is used for gelation, followed by a higher temperature of 90 to 120 degrees C for one to two hours for the final cure.

The accelerator aids the decomposition of the catalyst into free radicals, which are active fragments having an electron deficiency. A free radical is able to capture an electron from a carbon in an unsaturated molecular pair. The odd electron left on the adjacent carbon atom creates a new deficiency which reacts with another unsaturated molecule. Thus a chain-like reaction continues, building up large branched and cross-linked molecules. A lot of energy in the form of heat is released during this polymerization process. The heat may be evolved rather suddenly, giving a "high peak exotherm," or it may be released gradually over a long period of time.

If time is plotted against temperature for a given shape and size of casting, a curve is obtained which is characteristic of that particular composition and its curing environment. Several of these curves are shown in Figure 6. There is first an induction period, during which the residual inhibitor is slowly nullified by the catalyst. The curve then rises to a peak, and subsides. The maximum temperature reached in the case of a polyester is a function primarily of the amount of unsaturation in the material.

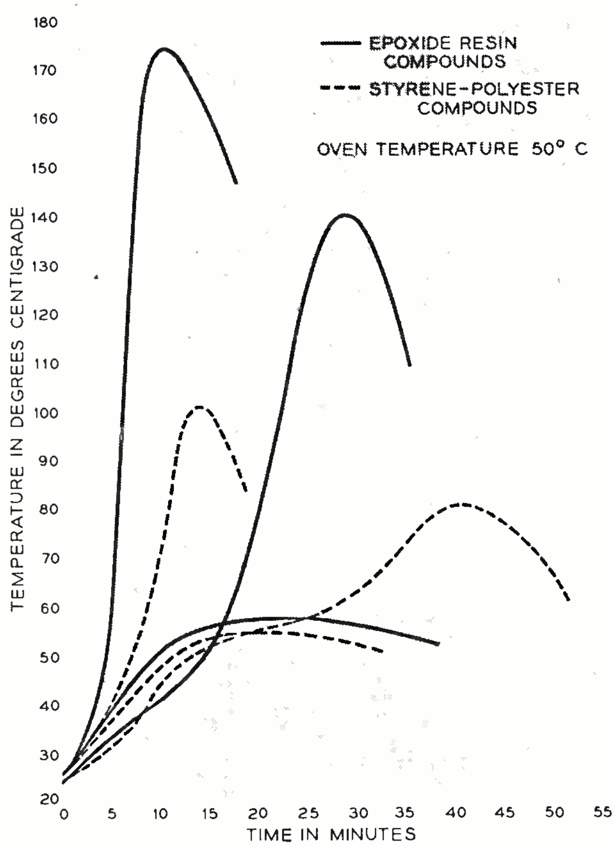


Fig. 6 — Typical exotherm curves.

Much information on the completeness of cure has also been obtained by measuring hardness, flexural strength, and other physical properties of castings. The best electrical properties are attained only at full cure.

Fig. 7 — J. F. Nachazel encasing miniaturized transformers in Murray Hill development shop.

The second of the two basic thermoset resins — the epoxide resins — are cross-linked by an entirely different mechanism. There is no unsaturation in the molecular structure, and catalysts of the sort used for the styrene-polyesters have no beneficial curing effect. A typical epoxide-base resin is composed of complex molecules of varying lengths, but the chief reactive chemical group has the characteristic epoxide carbon-oxygen-carbon ring configuration represented in 5(b).

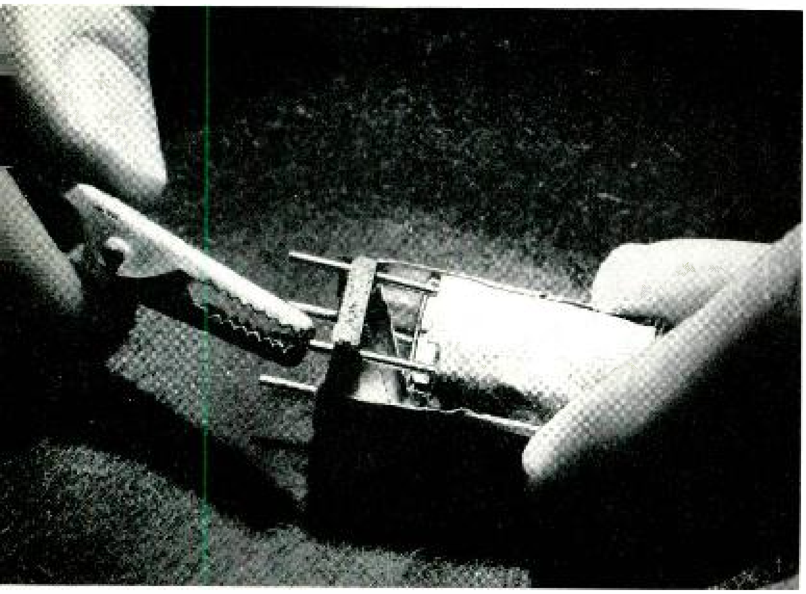
The liquid grades of epoxide resin have been found to be most useful for casting and potting. Both dibasic organic acids and organic amines are commonly used in the polymerization of these resins. A substantial amount, about 5 to 40 per cent, of thoroughly blended-in hardening agent is needed to bring about a satisfactory cure. The rates of reaction and the working or shop-handling times vary widely. The alkaline materials are particularly effective in opening up an epoxide ring structure, with resultant cross-linking of the complex molecules. The chemical reaction in an epoxide resin often gives a peak exotherm considerably higher than that shown by an unsaturated polyester. In some cases, certain amine agents cause hardening to occur at normal room temperatures, but for good electrical and mechanical properties, an oven bake of at least two hours at 85 degrees Centigrade is advisable.

Epoxide resins may or may not require fillers and pigments, depending on the initial reactivity of the base resin. Generally, powdered inorganic fillers help, as in the case of the polyesters, by diluting the chemical reaction and by strengthening the material so that it is useful over a broad service temperature range.

Although the chemical reactions that go on in any of these casting resin systems require continued study, there is no question about the practical value of the materials. Occasionally a minor redesign of certain components may be necessary, such as adding a rubbery outer dip-coat. Usually, however, by the simple pouring of a properly selected casting compound over a nest of lightly joined, often fragile electrical components, followed by oven curing, a single rugged assembly is obtained which will withstand extreme conditions of service.

THE AUTHOR

W. J. Clarke received the B.Chem. degree from Cornell University in 1924. He was first employed at the Devoe and Raynolds Paint Company in Newark, N. J. He joined the Laboratories in 1930, working on protective organic finish formulation problems and has since been associated with various phases of plastics testing in the Chemical Department. In connection with the Laboratories' part-time graduate study program, he obtained an M.A. degree at Columbia University in 1932. He became supervisor of a group doing chemical development work on adhesives, compression molded and extruded plastics and, later, enameled wire coating materials. This group carried out the early investigations for the Laboratories of polyethylene plastic which pointed toward its wide use today in the Bell System as a cable insulation. Following this he became interested in thermosetting casting and potting plastics for both national defense and Bell System uses. Very recently the area of his work has been extended to include again the general study of the properties of all molded plastics.



Miniaturized Transmission Transformers

A. C. EKVALL *Transmission Apparatus Development*

For some years, a major trend in the design of communication equipment has been a steady reduction in the size of apparatus components, with savings not only in space but in cost as well. A number of factors have enabled these economies — new materials, improved manufacturing methods, novel design features. Transmission transformers, widely used in the Bell System, are an excellent example of the miniaturization of apparatus. This trend is receiving added impetus from the increasing use of transistors.

Of the apparatus components used in telephone equipment, the transmission transformer is an outstanding example that, over the years, has undergone a steady reduction in size. Developments of improved magnetic materials have been most effective in this reduction, because of the higher initial permeabilities that have made possible smaller core dimensions.

Continued reduction in size, however, has been accomplished in several other ways. One of these is by the use of finer gauges of wire for the windings. Improvements in manufacturing methods have made it possible to wind wire as fine as No. 46 American wire gauge (0.0016 inch in diameter) economically and without degradation of normal standards of Bell System life. Even smaller sizes of wire, up to No. 50 gauge (0.001 inch in diameter), are being used experimentally.

Improved methods of sealing the transformer assembly have also contributed to miniaturization. Newer techniques of "potting" have resulted in a greater degree of exclusion of moisture from the windings, thereby inhibiting electrolytic corrosion sufficiently to insure adequate service life even for the extremely fine gauges of wire. Through the use of the improved potting procedure, in which this operation is divided into several steps and the temperature and time of the steps are controlled, crevices in the terminal lead insulation are more completely filled, thus inhibiting the usual tendency of moisture to follow the insulation into the windings. This makes it possible to use either flexible leads or rigid terminals that extend through the transformer enclosure directly to the windings, eliminating the need for terminals mounted on the outside of the enclosure.

Above — Small transformer used in signaling circuits, portable test sets, and monitoring head sets.

Arrangement of parts to use space in the most economical way and novel design features, such as the use of one part to perform two or more functions, also contribute to reduced size. Particular attention, too, has been given to making the circuit requirements on transformers as lenient as is compatible with satisfactory circuit performance. Cooperative effort by circuit designers and transformer designers has produced a better appreciation of the objectives of each and has aided in attaining the miniaturization objective.

One example of a miniaturized transformer which embodies several of these modifications, is the 656A input transformer designed for use in the V3 repeater.* Actually, this apparatus combines an input transformer and an output transformer, electrically and magnetically isolated from each other, occupying a common container. It is arbitrarily given an input transformer code classification for identification. Figure 1 illustrates the internal construction of this transformer. Although input and output transformers are usually encased in separate containers to permit flexibility of usage in different circuits, in the design of the V3 repeater equipment, stringent space limitations dictated a total volume of input and output transformers less than that which would be required by two separate transformers. The two units were therefore mounted in a single container and separated internally by a magnetic shield.

The input transformer unit has a magnetic core composed of conventional "E" and "I" shaped laminations of 4-79 molybdenum permalloy (4 per cent molybdenum and 79 per cent nickel), singly interleaved as shown in an exploded view of a partial assembly in Figure 3. This type of core configuration lends itself to applications where there is no superimposed direct current through the windings, since the interleaving of the laminations provides a low reluctance magnetic path and consequently produces a high effective permeability of the core.

* RECORD, *February*, 1949, *page* 45.

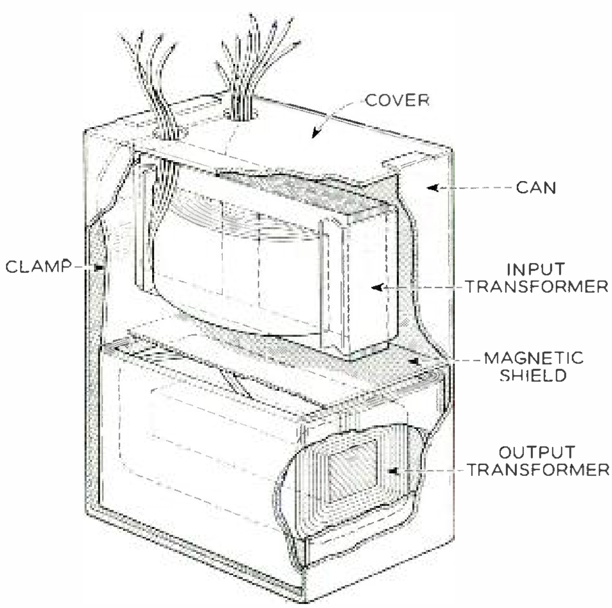


Fig. 1 — Internal construction of the 656A input transformer. Actually, the assembly combines both an input and output transformer.

Fig. 2 — R. J. Morris (left) and the author compare the 656A input transformer with its counterparts, the 626A input transformer and the 500A output transformer.

A ring shaped core of the same magnetic material would provide an even lower reluctance path with its high effective permeability, but a winding suitable for an input transformer would be expensive to wind on this type of core structure.

For the output transformer unit, a "wrap-around" type of core, using 4-79 molybdenum permalloy is used. This core consists of a $^{13}/_{16}$ inch wide magnetic tape folded into an open-ended box form about 1½ inches by 1 inch. The coil is mounted on a stack of "I" shaped laminations, and this assembly is placed within the box-shaped structure. The completed core and assembly are shown in the lower part of Figure 1.

This transformer core was designed with a view of using it where direct current passes through the windings. The small air gaps that exist between the "I" laminations and the inner surface of the enclosing box structure stabilizes the effective permeability when plate current flows through the windings. The shape of the core also makes efficient use of space. Flexible leads are used instead of rigid terminals.

Figure 2 shows the 656A input transformer in comparison with its counterpart, the two transformers used in the V1 repeater, the predecessor of the V3 repeater.

Comparative transmission characteristics are given in Figure 4(a) and 4(b). As can be seen

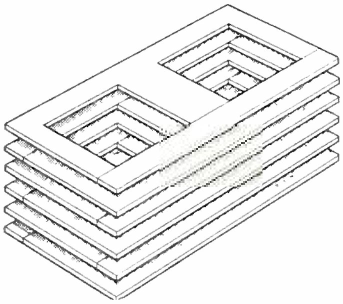


Fig. 3 — Exploded view of input transformer laminations, showing interleaving arrangement.

from Figure 4(a), the output transformer unit has greater mid-band loss than the earlier transformer, and the input transformer unit has lower mid-band gain than its predecessor. A circuit design philosophy permitting higher mid-band losses is not only compatible with, but a necessity for, the reduction of size of transformers operating in the lower frequency bands. This is due to the fact that the result of using smaller size apparatus structures, along with the smaller sizes of wire and large number of turns, is greater mid-band loss.

An improvement in suppression of input noise was realized as a result of characteristics inherent in the small size transformers. The physically smaller dimensions of the 656A input transformer result in capacitance-to-ground unbalances sufficiently small to preclude the need for additional circuit arrangements to compensate for them.

The input and output unit structures of the 656A input transformer are used separately in the six

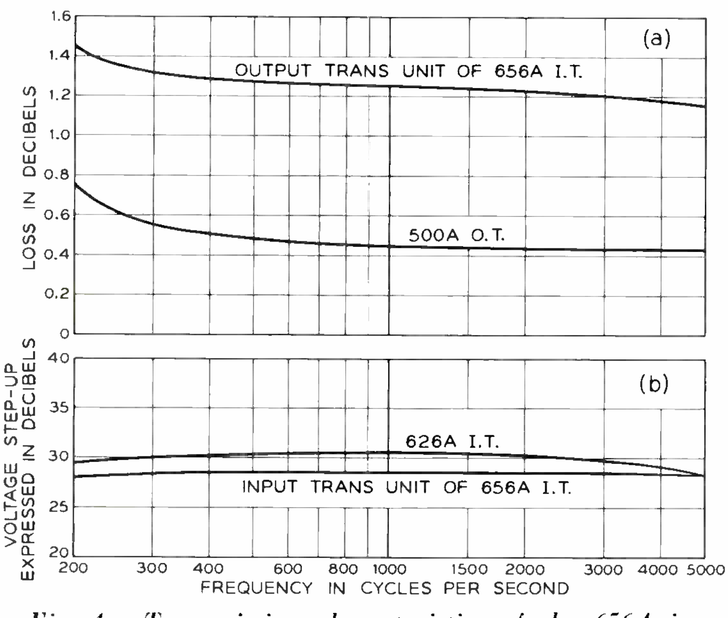


Fig. 4 — Transmission characteristics of the 656A input transformer in comparison with those of the 626A input and the 500A output transformers.

audio, and in one of the signaling transformer designs for the N1 and O carrier telephone systems. The same core units are employed, the "E" and "I" shaped lamination assembly being used for input transformer applications or those in which there is little or no superimposed direct current. The "wrap-around" unit is employed for output transformer applications. Both units have the same container and other common parts. Figure 6 shows an exploded view of the two structures. Either the interleaved or "wrap-around" unit with its corresponding winding assembly is used with the set of common parts shown in the illustration.

Carrier frequency transformers employed in the type N carrier telephone system embody all of the measures responsible for apparatus miniaturization described. Some idea of the result of this is given by a comparison with transformers used in similar applications in earlier carrier systems, 2 versus 15 cubic inches at about one-fifth of the cost. The single structure used for all ten carrier frequency

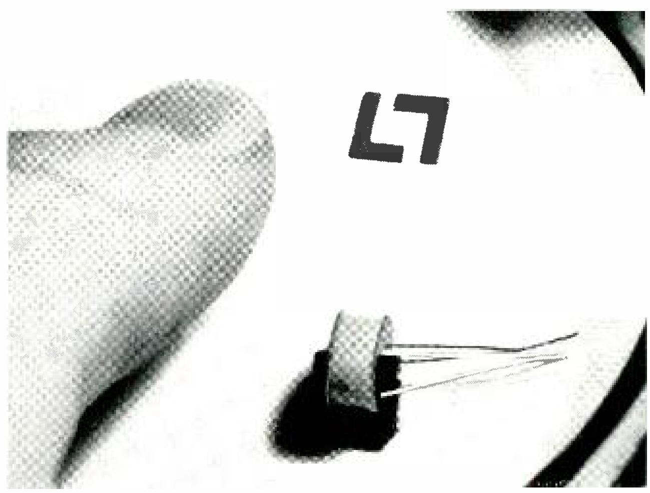


Fig. 5 — Experimental model of sub-miniature audio transformer.

designs in this carrier system consists of four simple inexpensive parts; an aluminum can, a molded terminal plate assembly provided with wire terminals, an 0.8-inch outside diameter compressed molybdenum permalloy powder core ring, and a cellulose acetate filled winding assembly. The winding is assembled on the core by splitting the core, slipping the winding assembly over the end of one of the core sections, and then reassembling the sections with an adhesive to bind the two sections together. The can and the other three parts assembled are shown in

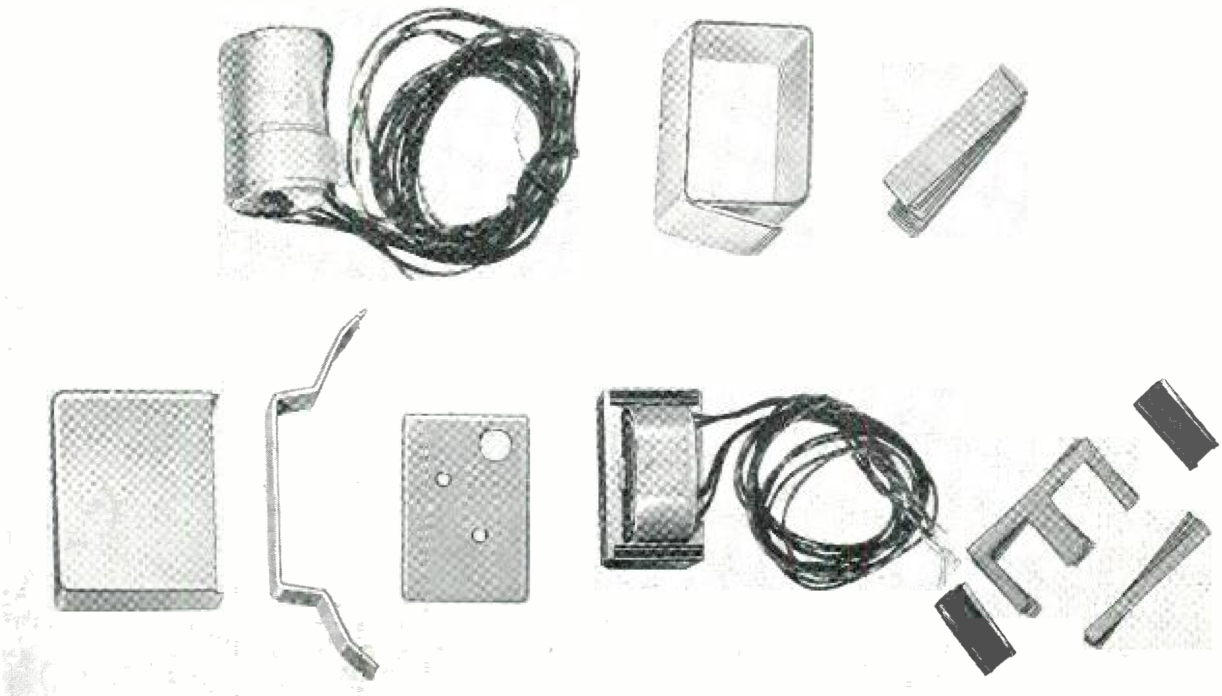


Fig. 6 — Exploded view of the input and output structures of the 656A input transformer.

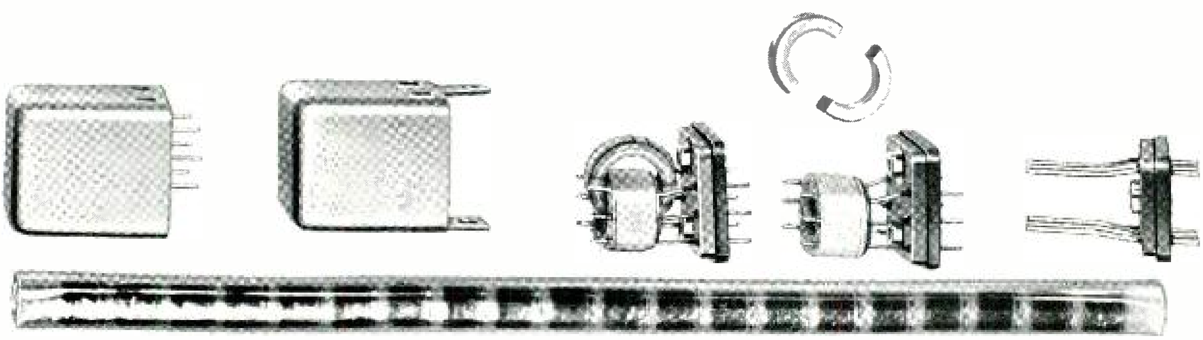


Fig. 7 — Component parts of carrier-frequency transformers.

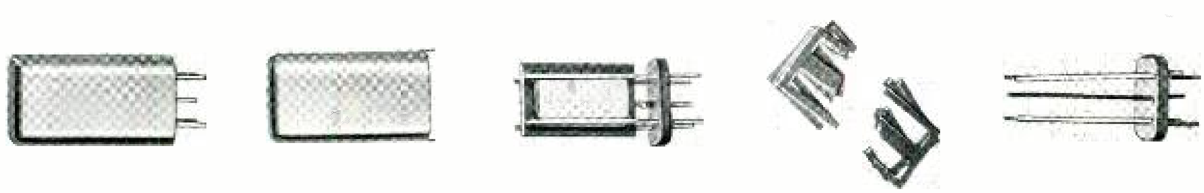


Fig. 8 — Exploded view of transformer shown on page 452.

Figure 7 together with a "stick" of multiple-wound coil assemblies. The "stick," which may contain as many as 20 coils wound simultaneously, is cut into the individual coils which are then assembled as part of the individual transformers. This method of winding provides economical coils and a high degree of uniformity in them. The design thus provides for the utmost in economical manufacture while maintaining high standards of performance.

For other carrier frequency designs in the O carrier system, a core of manganese zinc ferrite is used which, by virtue of having a permeability about 10 times that of the compressed molybdenum powder, provides the necessary wider bandwidth. This core consists of two U-shaped parts butted together to form a rectangular outline. The other parts used with the core, however, are the same size as that are used for the permalloy powder core of the ring.

The need for extremely small size components for use in portable test sets and monitoring head sets has resulted in transformer designs of the size that has been used in hearing aids. These have also been found useful in the signaling circuits of N and O carrier systems. A transformer of this type is shown on the first page of this article and an exploded view in Figure 8.

Exploratory development work directed toward further miniaturization continues in efforts to utilize and discover new materials applicable to this field. A recent experimental model of a so-called subminiature audio transformer is shown in Figure 5. The extremely high initial permeability (minimum 50,000) of supermalloy presages a greater use for this core material in small-size communication transformers in which there is no superimposed direct current.

The lower power and impedance levels at which transformers working with transistors can be operated is making possible apparatus sizes of the same order of magnitude as the transistor itself. These and other measures are being explored and exploited in the never-ending search for the improved methods and materials, and more favorable circuit conditions, which are expected to yield still smaller and more inexpensive transformers in the future.

THE AUTHOR

A. C. Ekvall received the E.E. degree from Cornell University in 1937 and the M.S. degree from Stevens Institute of Technology in 1946. He joined the Laboratories in 1937 and worked first on induction coils and repeating coils. Two years later he was engaged in development work on carrier and radio frequency transformers. During World War II he concentrated on development of apparatus components for the armed forces, including deflection coils, focus and centering coils, audio-frequency transformers, oscillator coils and special networks. After the war he worked extensively on audio frequency transformers and also on induction coils. In 1949, he was put in charge of a group whose responsibility was the development of audio-frequency transformers. In 1953, he was transferred to the Military Branch of the Laboratories at Winston-Salem, N. C. Mr. Ekvall is now Transmission Apparatus Engineer, in which capacity he serves as a liaison between the Laboratories' Apparatus Department and the North Carolina Works of the Western Electric Company, where transmission apparatus for military projects is manufactured.

Microwave Testing with Millimicrosecond Pulses

A. C. BECK *Radio Research*

Very small imperfections in waveguides can be detected by methods similar in principle to the detection of targets by radar systems. The shorter the waveguide, however, and the more closely the imperfections are spaced along the waveguide, the shorter the test pulses must be. Equipment that produces pulses about six billionths of a second long at a carrier frequency of 9000 megacycles is being used for this purpose at the Holmdel Laboratory.

Pulses of radio energy can be caused to "bounce" off solid objects, and therefore can be very useful for radar and communication testing purposes. The principles involved are illustrated by the familiar sound echo. If we shout and later hear an echo, the presence of the echo is evidence of a reflecting object, and the time lapse between the shout and the hearing of the echo is a measure of the object's distance from us.

Reflecting objects can be detected in this manner, however, only if our detection device has sufficiently high resolution. If the object were close to us, and if the sound were reflected back to our ears even before we stopped shouting, then we would have great difficulty determining its time of travel. Therefore to get high resolution, or great ability to discriminate between closely spaced objects, radar systems normally use very short pulses of radio energy, sometimes as short as a tenth of a microsecond, or one ten-millionth of a second.

Because discontinuities of any kind in any transmission medium usually cause reflections, pulses can be used for their location and analysis. Such discontinuities may be faults – such as poor joints in transmission lines – or necessary transitions in shape or impedance in the system. In these cases, best transmission results are obtained when reflections are minimized. Pulses are often used for measuring such effects, and it is obvious that the shorter the pulse-time duration, the better the resolution that is obtained.

Equipment has been built at Holmdel to generate and display short microwave pulses having a length of about 6 millimicroseconds. A millimicrosecond is one billionth of a second. In the length of time energy is transmitted in this pulse, it travels less than 10 feet, even at the very high velocity of light and radio waves. Operating at a carrier frequency in the 9,000-mc range, the pulse used with this equipment contains less than 100 cycles of radio frequency energy. For such a short pulse, a very wide bandwidth is necessary, and in this equipment the pulse occupies a radio frequency band about 500 mc wide.

To get amplification over such a large bandwidth at microwave frequencies, traveling-wave tubes* are necessary. Such tubes were built through the cooperation of the Electronics Research Department. The 9,000-mc amplifiers developed for this

* RECORD, *November*, 1952, *page* 413; *August*, 1953, *page* 281; *April*, 1954, *page* 135.

Above — A. H. Methot checking waveguide connections to experimental antenna at Holmdel.

purpose have a bandwidth of nearly 1,000 mc and a gain of about 30 db. There are five of these amplifiers in this equipment. One of them is used as the basis of a new approach to the problem of generating these pulses, for which the basic principles were suggested by C. C. Cutler of Bell Telephone Laboratories.

Figure 1 is a simplified block diagram of the pulse-generating system. Two traveling-wave tubes are used in this system, both marked "TW" in Figure 1. The heart of this pulse-generating circuit is the loop, drawn with a heavy line. It comprises a feedback type of oscillator in which the traveling-wave tube, delay line, and crystal expander produce short pulses. The crystal expander causes a large power loss for a weak signal and a lower power loss for a stronger signal. If it were not in the loop, the gain could be adjusted to produce continuous-wave oscillations. When it is in the loop, however, the gain is adjusted to permit oscillations only for a strong signal, so that short pulses can be produced. The delay line, consisting of about 60 feet of rectangular waveguide, causes the signal to take 78⅛ millimicroseconds to travel around the entire loop. This time-delay is related to a synchronizing voltage, described below. Thus the output of the oscillator to the second traveling-wave tube in the upper right of Figure 1 consists of a series of pulses that are spaced 78⅛ millimicroseconds apart.

The operation of a system of this nature can be understood in terms of sending just one pulse, and observing the echoes that come back from it. However, to get a continuous oscilloscope picture of

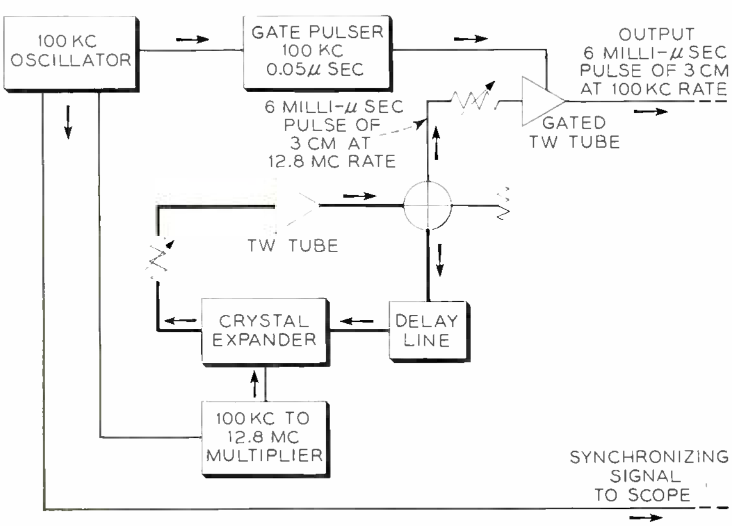


Fig. 1 — Diagram of circuit used to generate millimicrosecond pulses for testing waveguides.

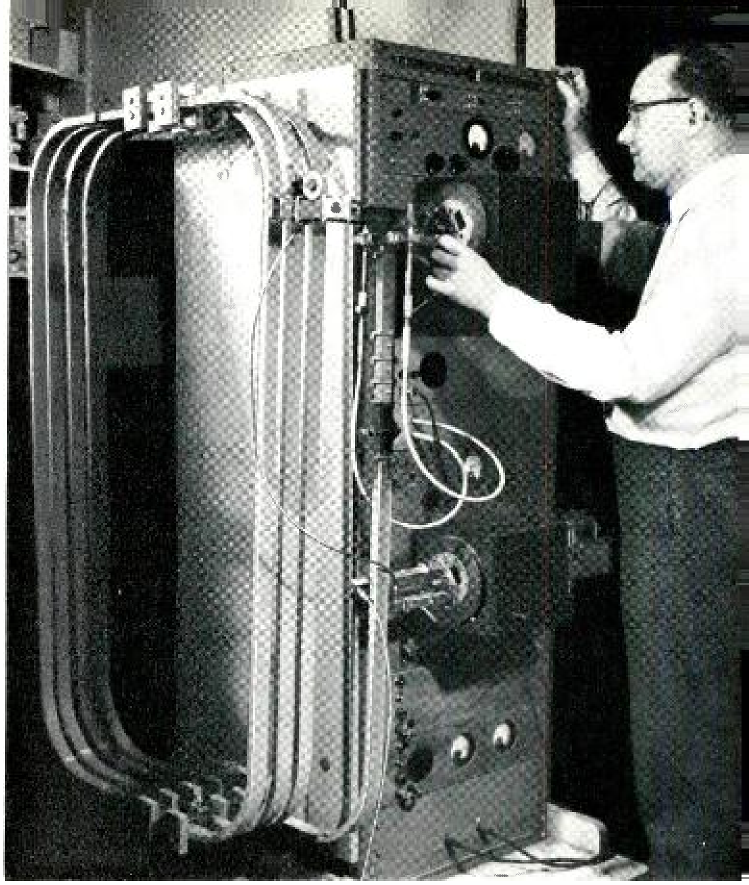


Fig. 2 — The author adjusting attenuator in circuit of millimicrosecond pulse-generating equipment. Delay line at left.

sufficient brilliance to be useful, many pulses per second are sent, and the total effect is added up by superimposing the pulses in the indicator system. To make successive pulses superimpose on the receiving indicator oscilloscope, a synchronizing system must be used so that the pulse-repetition rate is precisely related to the sweep repetition rate of the receiver oscilloscope.

The 100-kc oscillator in the box at the upper left of Figure 1 is the basis of this system. One output is used to synchronize the pulse-generating loop. This is accomplished by doubling the synchronizing frequency seven times so that a 12.8-mc voltage is obtained for connection to the crystal expander. This sets the pulse-repetition rate very accurately at 12.8 mc, corresponding to the delay time of 78⅛ millimicroseconds around the feedback loop. Another output of the 100-kc oscillator is used as a synchronizing signal on the receiving oscilloscope.

The repetition rate of the pulses obtained from the loop is too high to use for most testing purposes, since to prevent confusion, the time between pulses must be longer than the time taken for the signal to return from the farthest reflection point. The repetition rate is therefore reduced by means of the traveling-wave tube shown on the right-hand side of the diagram. This amplifier acts as a "gating" circuit to block off most of the pulses and to pick out only those appearing at the desired time intervals. The tube is identical to the one in the loop. It is kept in a cutoff condition for 127 pulses and then gated to give normal amplification for the 128th pulse, by using another output from the synchronizing oscillator. By this method, the output of the complete pulse-generator consists of the millimicrosecond pulses at a repetition rate of 100 kc, so that they come every 10 microseconds. This gives enough time to receive the desired echoes before the next pulse appears.

Figure 2 shows the pulse-generating equipment. The traveling-wave tubes can be identified by the black solenoids with cooling fins that cover them. The 60 feet of waveguide delay line can be seen coiled up at the left side of the equipment.

The simplified block diagram, Figure 3, shows the layout for the receiver and indicator equipment. The receiver consists of three traveling-wave tube amplifiers connected in cascade. A detector and a wide-band video amplifier are used, and the output signal envelope is connected to the vertical plates of an oscilloscope. The horizontal sweep circuits for this oscilloscope have been built especially for this purpose; they produce a sweep speed in the order of 6 feet per microsecond. These parts of the system are controlled by the 100-kc synchronizing input from the pulse generator standard frequency oscillator, as mentioned in reference to Figure 1.

To measure the time at which return echoes are seen, a precision phase-shifter is used in the synchronizing signal path. Its function is similar to that of a range unit in a radar system. By turning this phase-shifter, it is possible to look at the entire ten-microsecond interval of time between pulses on the oscilloscope. At any one time, however, only a very small part of this is displayed on the five-inch width of the screen. This phase-shifter moves the position of a pulse appearing on the scope by changing the starting time of the horizontal sweep. Accurate measurement of pulse delay-time is possible from the phase-shifter dial, which is calibrated in millimicroseconds.

An outgoing pulse is shown on Figure 3. The peak power output of the pulse-generating system is about one watt, before compression in the gated amplifier causes much pulse broadening. The receiver noise figure is rather poor, and its bandwidth is wide, so that noise becomes the limiting factor on the indicator at full gain. With the present equipment, however, echo pulses can be seen that are about 70 db below the transmitted pulse. While this is a smaller measuring range than radar systems have, it is enough to be very useful in our work at the Laboratories.

Figure 4 shows a waveguide arrangement placed between the pulse generator and the receiver to show the resolution that can be obtained with this equipment. It demonstrates the very short length of the pulses being used. The two side connections are so constructed that if they were terminated by a device that would absorb all the energy passing into the branches, no energy would be transmitted to the receiver at the right. However, a short circuit (closure at the end of a branch) placed on either side branch will send energy through the system to the receiver by reflection from the short circuit. These short circuits were so placed that the one on branch 4 was four feet farther away from the junction than the one on branch 2. The pulse on the left side of the photograph is produced by a signal traveling from the pulser to the short circuit on branch 2, and then through to the receiver. This path is drawn with short dashes in Figure 4. The second pulse is produced by a signal that travels from the pulser through branch 4 to the short cir-

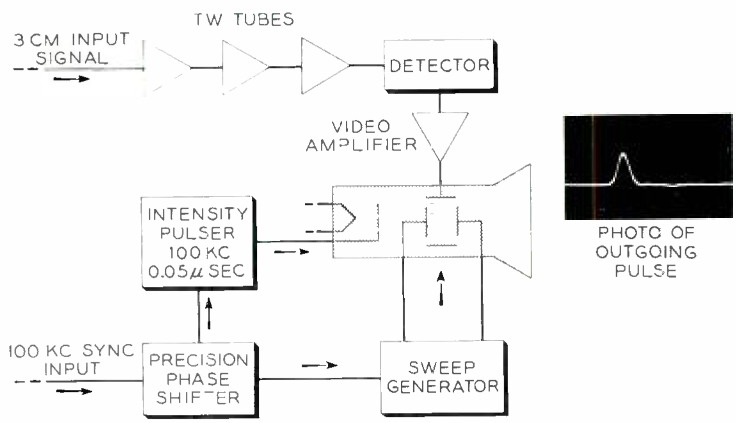


Fig. 3 — Diagram of receiver and indicator equipment.

cuit, and then back to the receiver. This is shown by the path drawn with long dashes. The second pulse has traveled only eight feet further in the waveguide than the first pulse, but it is seen to be well resolved. This would be almost equivalent to seeing two separate radar echoes from targets about 4 feet apart. In fact, pulses separated by a shorter distance could still be resolved by this equipment. Ordinarily, this is only true when the pulses are nearly of the same amplitude. If the first pulse is very much stronger than the other, the resolution is not so good as this, because of recovery time from the overloaded strong pulse. However, resolu-

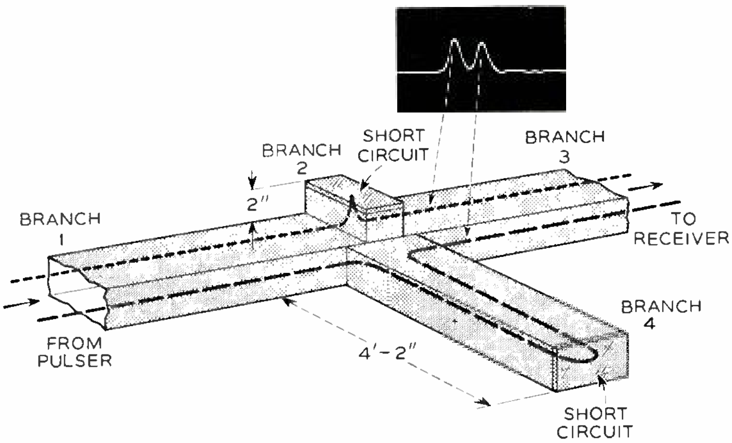


Fig. 4 — Waveguide apparatus used to demonstrate high resolution produced by pulse-generating equipment.

tion is not decreased very much by overload in this equipment, and measurements can be made of a weak pulse not very far away from a strong one.

One of the applications of this equipment is in the testing of waveguide runs such as those used between antennas and the equipment in microwave repeater systems. Figure 5 shows the effect of a defective joint in a 3-inch diameter copper waveguide 150 feet long. The pulses are sent in, as shown by the lower arrow, through a directional coupler at the left side of the figure. This coupler consists of two parallel, rectangular waveguides having coupling holes in their common wall. Some of the energy returning from the round waveguide appears in the upper branch of the directional coupler and comes out where an arrow is shown pointing upward to the left in the figure. The receiver is connected at this point. This particular round waveguide had very good soldered joints, and was thought to be electrically very smooth. The oscilloscope photograph above the drawing, however, shows three pulse indications. At the left is an indication of the input signal as it comes from the coupler, and at the right is the pulse reflected from the short-circuited end of the waveguide. The signal

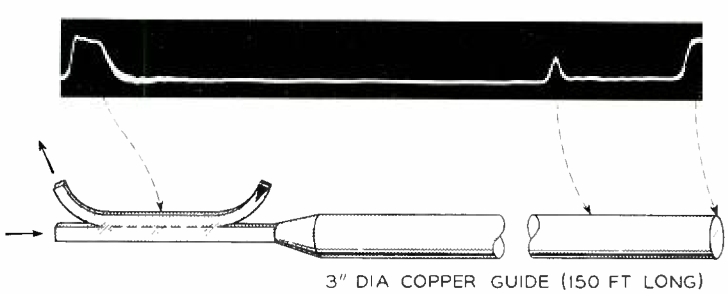


Fig. 5 — Waveguide with oscilloscope photo showing presence of location of defective joint.

between these two is produced by an imperfect joint in the round waveguide. The exact location of the defect causing this echo was found by using the phase shifter. The particular joint that was at fault was then cut out of the line for inspection. Figure 6 is a photograph of this joint after the pipe had been cut in half through the middle. This waveguide is quite smooth on the inside, despite the discolored appearance of the solder, but on the left side the open crack is seen where the solder did not run into the joint properly. This open joint caused the reflection shown on the trace.

Figure 7 illustrates the use of this equipment in the testing of waveguide and antenna installations, such as those used for microwave radio-repeater systems. This work was done in cooperation with the antenna research group at the Holmdel Laboratory, who designed the antenna and the waveguide-to-horn transition section. A directional coupler was

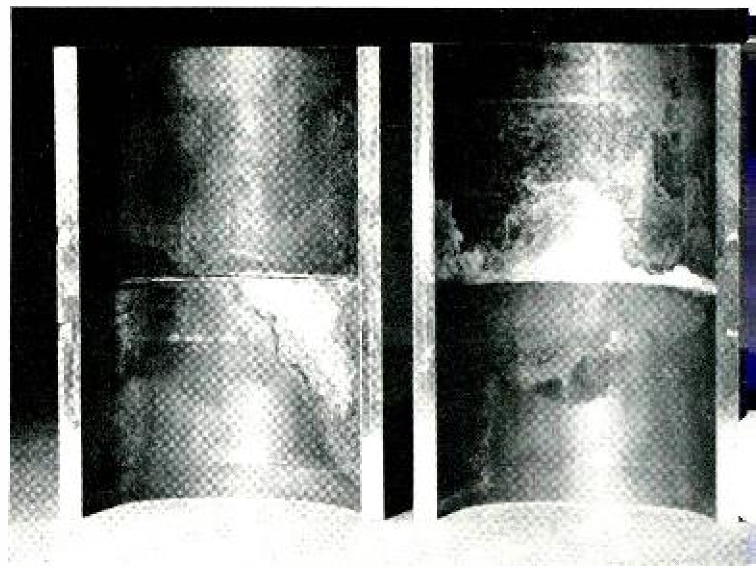


Fig. 6 — Defective joint caused by imperfect soldering detected by millimicrosecond pulses.

also used here to send energy to the transducer and waveguide, and then to the antenna. In this case two different kinds of waveguide joints were being tested. The waveguide sections are about 10 feet long. However, the main purpose of this test was to measure the reflection from the transition section between the round waveguide and the square horn throat. A clamped joint in the waveguide gave the reflection following the initial overloaded pulse. A well made threaded coupling in which the ends of the pipe butted squarely is seen to have a very much lower reflection, scarcely observable on this trace. Since there is always reflection from the aperture and upper reflector parts of this kind of an antenna, it is not possible to measure the performance of a throat transition piece in the antenna by ordinary methods. Here, however, the short pulses completely separated the transition-piece reflection from the other reflections, and made a measurement of its performance possible. In this particular antenna, the reflection from the transition is almost 60 db down from the incident signal, which represents very good design. As can be seen, the returned energy from the reflector and aperture is also quite low, which shows that this is a good antenna in this respect.

Figure 7 also shows the effect of placing a Fiberglas weatherproof cover over the open mouth of the horn. This cover normally would produce a troublesome reflection. In this antenna, however, it is a continuation of one of the side walls of the horn. Consequently, outgoing signals strike it at an oblique angle. The reflections that come from it are not returned directly and are not focused by the reflector back at the waveguide. Therefore, the overall reflected energy was found to be rather low. As measured with this equipment, however, a reflection appeared to originate at a point sixteen feet in front of the mouth of the horn, as is shown on the second oscilloscope-trace photograph on the figure. This is accounted for by the fact that energy reflected from this cover, because of its oblique position, bounces back and forth inside the horn before getting back into the waveguide, thus traveling the extra distance that makes the measurements seem to show that it comes from 16 feet out in front of the antenna.

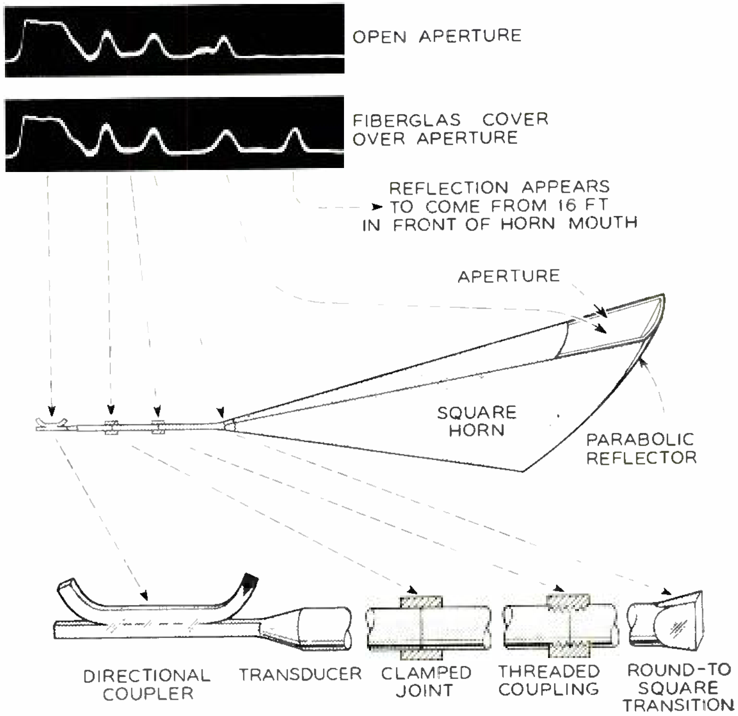


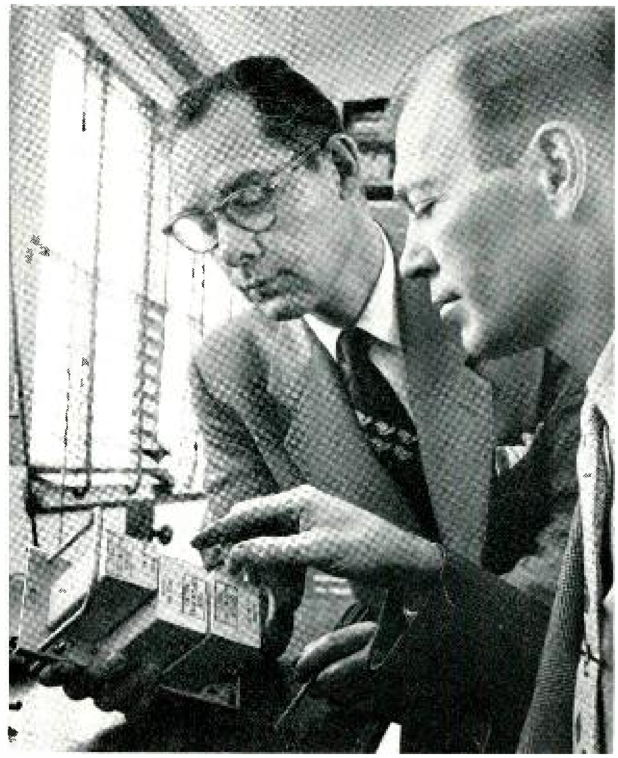
Fig. 7 — Waveguide and antenna with photo showing reflections from joints, transition piece, and cover.

This short-pulse equipment is being used for many other purposes in waveguide research. These examples, however, indicate its possibilities in design and development testing procedures.

THE AUTHOR

A. C. Beck received the E.E. degree from Rensselaer Polytechnic Institute in 1927. After two summers in the test department of the New York Edison Company and a year as instructor in mathematics at Rensselaer, he joined the Technical Staff of these Laboratories in 1928. In the Radio Research Department he was engaged in the development and design of short-wave and microwave antennas and related equipment. During the war he was chiefly concerned with radar antennas and the associated waveguide structures and components. For several years after the war he worked on development of microwave radio repeater systems. Later he worked on microwave transmission developments for broadband communication. Recently, he has concentrated on further developments in the field of broadband communication using waveguides.

A Long-Lived Packaged Amplifier for Aircraft



J. G. MATTHEWS
Military Equipment Development

Packaged amplifiers with a long life expectancy, designed to operate under the adverse conditions that go with use in aircraft, are expected to aid materially in solving many U.S.A.F. maintenance problems. The successful design of such units at the Whippany Laboratories can be said to have been based on the admonition, "For a long life — keep cool!" By applying this principle to the various components in a package, especially electron tubes, highly reliable amplifiers have been developed.

During the past ten years, the use of electronic equipment to control and operate aircraft has increased rapidly, and the problem of maintaining the equipment has consequently become increasingly difficult. The adverse conditions to which the apparatus is subjected in high altitude aircraft use, and the relatively rapid rotation of airforce maintenance personnel make highly reliable and easily replaceable circuit units almost a necessity. One step toward providing such units was taken recently by Bell Telephone Laboratories at Whippany where highly reliable packaged amplifiers of a plug-in type were developed for use in aircraft equipment.

Plug-in networks have been used extensively in aircraft equipment, but few attempts have been made to encase complete amplifiers including electron tubes. Also, the conception of such a plug-in amplifier with a high probability for a long life is completely new. Previously existing aircraft packaged amplifiers were designed for use in expendable rockets and guided missiles where a long trouble-free life is not required. The long life expectancy of these new packaged amplifiers materially reduces the amount of maintenance work required by decreasing the frequency of circuit failures. Moreover, these units have been designed in such a way that the same type unit can be used in a number of different places. This reduces the number of spare parts that must be carried and further simplifies maintenance. Since electron tubes, resistors, and capacitors are permanently grouped into a limited series of multiple use assemblies, the individual components cannot be replaced; if any of the components fail, the whole package is discarded.

The expressed aim of the amplifier development program was to provide packaged units that have a high probability of survival at 2,000 hours. Many factors were involved in attempting to achieve this aim, but a basic principle was felt to be "controlled environment;" that is, protection of the circuit from humidity, dirt, vibration, and tampering. Moreover, some provision had to be included for adequate heat dissipation. The protective requirements seemed to dictate the use of some form of hermetic sealing, and after experimenting with various methods, it was concluded that embedding the entire circuit in a plastic was the best solution to the problem. This process also provided the most efficient means for dissipating the heat that is generated by the circuit.

To provide packaged amplifiers with long trouble-free life, each of the components in the encased circuit must be highly reliable. It was thought that the limiting factor would be the life expectancy of the electron tubes, since tube failures usually head the list of troubles in ordinary amplifiers. It was found, however, that this reputation for vulnerability is largely undeserved; many cases of tube failure are due to operation under excessive thermal and electrical conditions, improper circuit applications, poor power source regulation, or changes in the characteristics of associated circuit components. The average life of an electron tube can be greatly extended by giving due consideration in the amplifier design to three conditions: the tubes must be of high quality, and designed for long-life operation; the circuit design must be such that the tubes and associated passive components are operated well below their rated capacities; and the tubes must be kept cool.

The first of these conditions can be satisfied by using special "premium" tubes that have a life expectancy in excess of 5,000 hours when they are operated under specified conservative conditions. Life of this order, far beyond the expectancy for normal JAN-specification tubes, is attained by more rugged construction, 100 per-cent "burn-in,"* and rigid screening tests by the tube manufacturers. They can supply curves of life performance up to 5,000 hours from which survival probabilities of individual tubes for shorter periods can be determined. In a packaged amplifier containing four tubes of the same type, for example, the survival probability at 2,000 hours might be 0.97 for each tube. Disregarding possible failure of other components, the package then has a survival probability of 0.97^4 or about 0.89; nine out of ten packages would last 2,000 hours.

* "Burn-in" is the term given to a 50-hour continuous application of full operating voltages to weed out tubes that would otherwise be early failures.

To minimize the probability of amplifier failures through parts other than electron tubes, only the highest quality passive components are used and they are operated well below their rated capacities to give wide wattage or voltage margins at the maximum temperatures expected in the proposed applications. Deposited carbon resistors are used to avoid drift with age and temperature, and capacitors are restricted to types capable of operating at 125°C, since package temperatures of 100°C are encountered.

No matter how high the quality of the tubes used, and how carefully the circuit is designed, packaged amplifiers will not have a reliably long life if the tube envelopes get too hot. Bulb temperatures above a certain point, usually considered to be 160°C, materially shorten tube life by promoting the release of occluded gases from the envelope and other tube parts. It was therefore necessary to devise some means whereby heat generated in the tubes could be drained off rapidly and efficiently.

To accomplish this, the tubes are almost completely buried in wells in an aluminum casting that

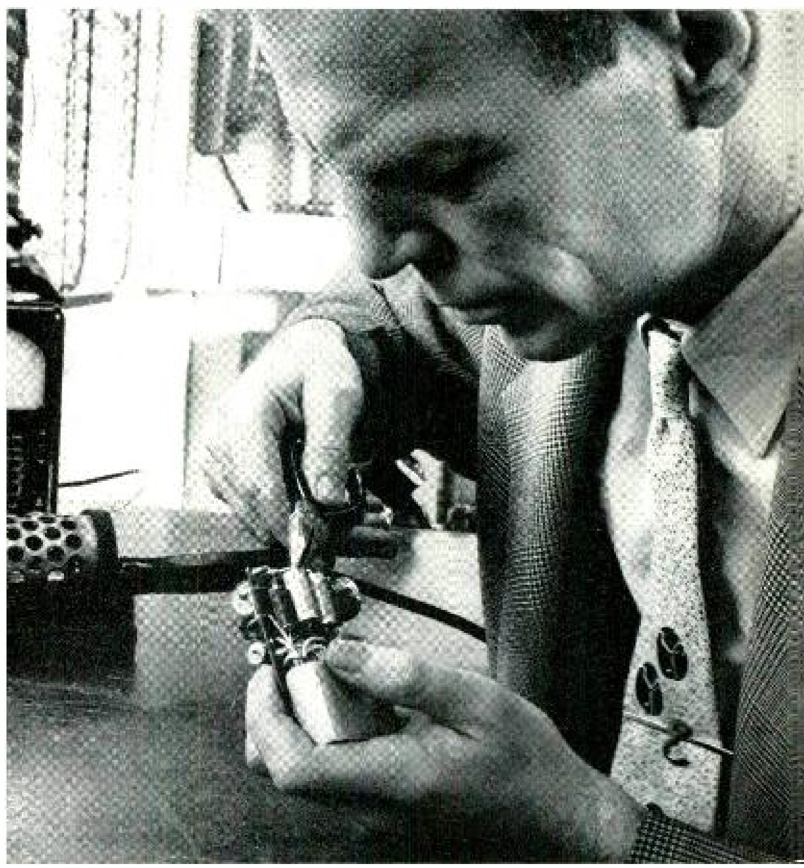


Fig. 1 — F. E. Ladd wiring the components in a packaged amplifier before it is embedded in plastic.

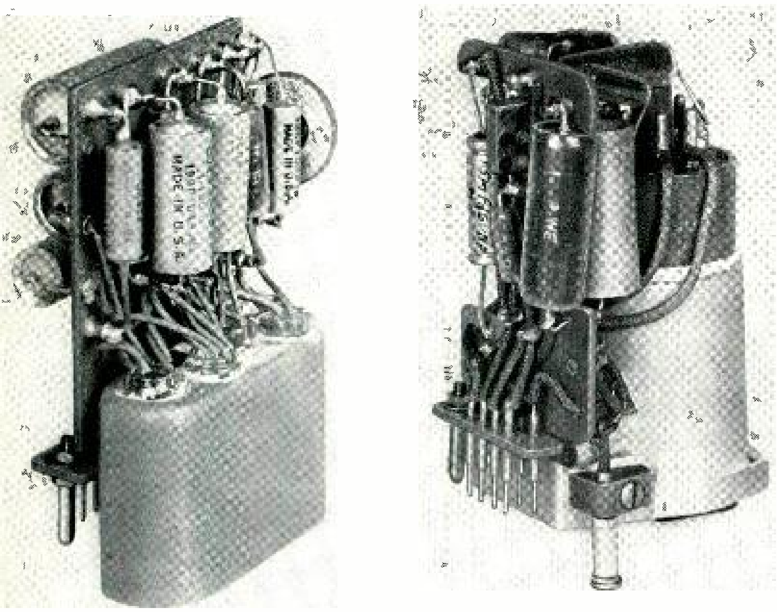
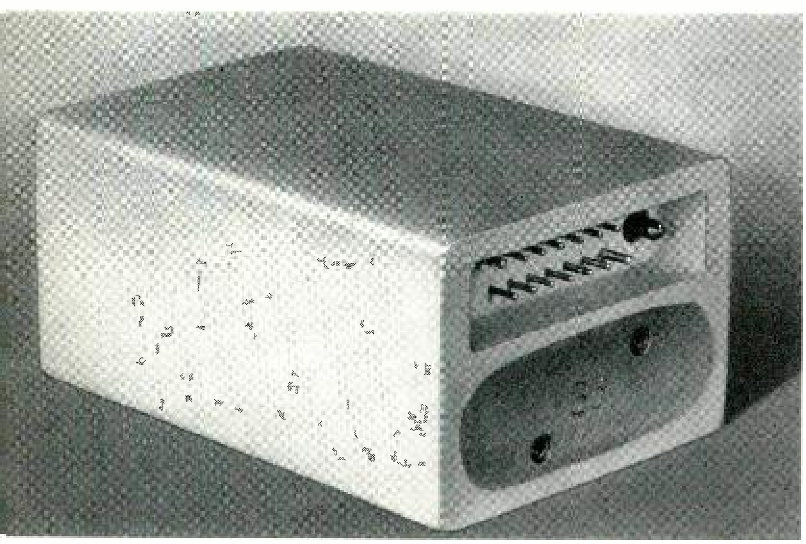


Fig. 2 — Packaged amplifiers: (left) elements including subminiature tubes before over-all plastic covering is applied; (right) method of mounting standard size tube in a casting; and (below) a typical complete packaged amplifier.



forms the base of the unit. The small spaces between the envelopes and the aluminum are then filled with silicone rubber to provide for an efficient transfer of heat from the glass to the base casting. The rubber is put into the wells in the form of a paste, and the tubes are then pressed into place. This forces the paste up around the tube to fill the space completely. A jig is used to hold the tubes of the amplifiers in the proper orientation and depth during the following short oven curing process which turns the paste into a moderately dense rubber.

Other materials such as aluminum dust and foil were tried in place of silicone rubber but they did not have the desired retaining and sealing features, and were not so effective in heat transfer. The success of silicone rubber in this regard, in spite of its relatively low thermal conductivity, seems to be due to the liquid-like uniform contact it provides between the glass and metal surfaces. The heat generated in the tubes is conducted from the glass envelope through a low impedance path consisting of the rubber film and aluminum casting directly to the chassis, and this results in remarkably low bulb temperatures.

Units shown at the top of Figure 2 illustrate the elements in several types of packaged amplifiers before they have been embedded in an over-all sealing plastic. The aluminum casting in the foreground at the left of Figure 2 contains four subminiature tubes embedded in silicone rubber. In actual practice, a rubber coating is also applied over the exposed tube end to prevent cracking the glass while the plastic encasement is being polymerized. This coating has been omitted in the figure to better show the amplifier parts. The method of mounting a standard size tube in a casting for use with amplifiers of a different type is shown at the upper right in Figure 2. Again the tube base is normally coated with silicone rubber. This unit also includes a subminiature input tube and the high impedance grid of this tube is connected to a separate post on the casting to provide greater oversurface insulation under humid conditions. The bottom surfaces of the aluminum castings for all amplifier units are machined smooth to provide area-contact when they are mounted with machine screws to a chassis.

The passive components for each amplifier are mounted on a phenolic board supported by the aluminum base, and interconnections are made among these parts, the tube pins, and the terminal end of an external-connection plug as shown in Figure 2 (upper right and bottom). After a unit has been completely assembled but before it is embedded in over-all sealing plastic, it is thoroughly tested. The tests include an over-all performance test, a microphonics test, and a rigid mechanical inspection. The amplifier is then on-off cycled for twenty-four operating hours. In this way an occasional defective component that might have produced early failure can be detected and replaced.

When a unit has successfully passed these tests,

TABLE I — HEAT MEASUREMENTS ON TYPICAL PACKAGED AMPLIFIERS

TUBE COMPLEMENT →	*Package A* TWO SUBMINIATURE	*Package B* THREE SUBMINIATURE	*Package C* ONE SUBMINIATURE AND ONE STANDARD
Tube envelope rise	16°C	22°C	40°C*
Chassis rise	15°C	19°C	26°C
Temp. diff. between hot test and coolest points in package	10°C	12°C	19°C
Side of package rise	10°C	14°C	23°C
Top of package rise	6°C	10°C	21°C
Non-dissipative component rise ..	10°C	17°C	24°C
Watts dissipated ..	3.9	5.8	8.7
Dissipative area in sq. in.	28	37.2	39.8
Watts per sq. in. area	0.140	0.156	0.218

Test Conditions: Sea level, still air, 28°C surrounding air temperature, package mounted on 3" x 4" isolated plate, no heat sink.
* The underlined reading is shown in Fig. 3(a) bar graph.

TABLE II — HEAT MEASUREMENTS ON TYPICAL HOUSING CONTAINING PACKAGED AMPLIFIERS

	60,000 feet alt. 30°C amb.		*sea level 55°C amb.*	
	ACTUAL TEMP.	RISE OVER AMB.	ACTUAL TEMP.	RISE OVER AMB.
Thermocouple Location	°C	°C	°C	°C
Package A tube bulb ...... (Submin.)	68	13	69	12
Package B tube bulb ...... (Submin.)	74	19	71	14
Package C tube bulb ...... (Standard)	107	52*	89	32*
Side of package C	103	48	86	29
Top of package C	100	45	17	22
Temp. diff. between hottest and coolest points in package C	—	7	—	10
Chassis 1" from package C ..	99	44	79	22
Power transformer	133	78	93	36
Exhaust air	60	5	60	3
Average housing ambient* ..	55	—	57	—

Test Conditions: 220 watts, 2,000 sq. in. housing, 90 cu. ft. per minute sea level fan. Underlined readings are shown on Fig. 3 bar graph.
* Air temperature measured in region of packages under test.

the assembly is placed in a mold and embedded in a liquid plastic that solidifies when mixed with a catalyst and subjected to the proper heat treatment. Glass-loaded styrene polyester, and epoxy resins have been used for this process; both produce packages that are essentially waterproof, impervious to solvents, capable of withstanding temperature extremes without changing their properties, and pleasing in appearance. A typical complete packaged amplifier is shown at the bottom of Figure 2. The plug is recessed to protect the pins, to permit stacked storage, and to simplify mounting the mating receptacle on a chassis.

An indication of the thermal advantage gained by using packaged amplifier construction is given in the bar graph in Figure 3. The measurements in this graph were made under various conditions at the envelope of a standard-size tube mounted in a packaged amplifier, and in an identical circuit but with a conventional socket mount. The first set of these measurements — (a) in Figure 3 — was made at sea level in still air in an ambient temperature of 28°C. The bulb temperature rise of the tube mounted in a packaged amplifier is about 35°C less than that of the tube mounted in a conventional socket. The envelope temperatures of subminiature tubes under similar conditions are significantly lower. More detailed data on the temperatures of packaged amplifiers of various types under these conditions are given in Table I.

The second set of measurements — (b) in Figure 3 — was also made at sea level, but the tubes and packaged amplifiers were mounted in a housing

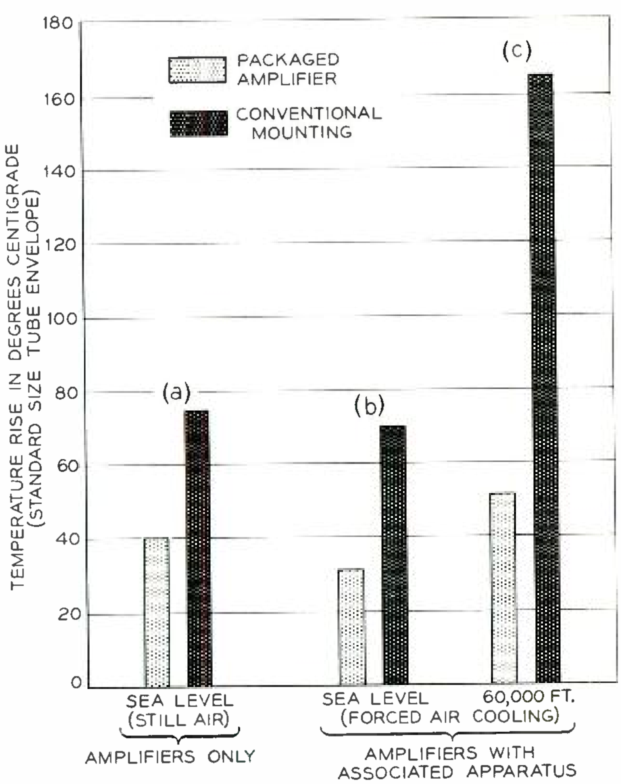


Fig. 3 — Bar graph indicating thermal advantage gained by using packaged amplifier construction.

cooled by forced air. Under these conditions, an assemblage of a number of sub-units of the type shown in the headpiece of this article, consisting of packaged amplifiers with associated transformers, networks, potentiometers, and other normally mounted components, shows considerable thermal advantage over the same equipment identically housed but with conventional socket-mounted amplifier construction. The surface of a packaged amplifier plus that of the surrounding chassis into which much of the heat is conducted provides a large dissipative area as compared to the relatively small area of a tube envelope. This permits a more efficient transfer of heat to the air, and as a result, the whole equipment is uniformly warm but nothing gets excessively hot as does the envelope of a tube mounted in a conventional socket.

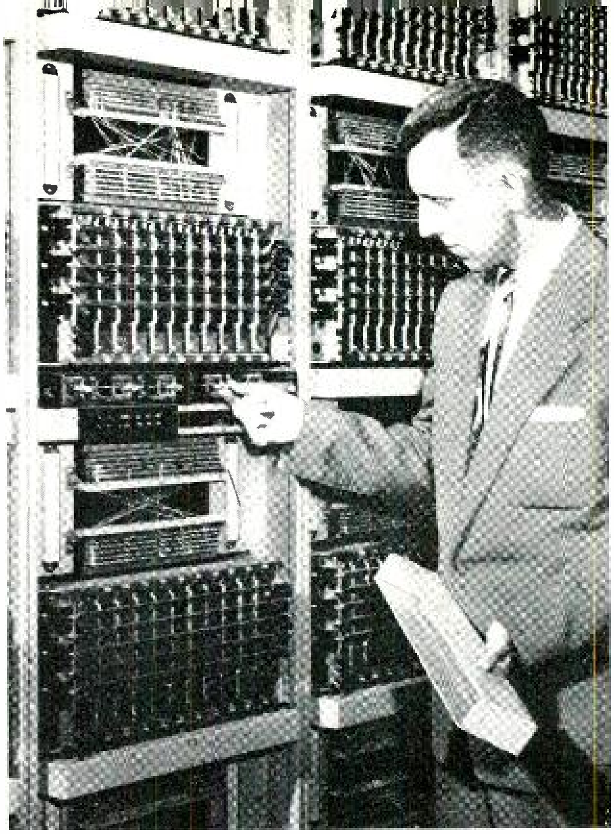
The third set of measurements (c) was made on the same units cooled by forced air under the formidable conditions of a 60,000-foot altitude and a surrounding air temperature of 30°C. Again, packaged amplifier construction is seen to yield a considerable thermal advantage. A detailed list of the temperatures encountered in packaged amplifiers operated with associated equipment in a forced-air-cooled housing is given in Table II, for both sea level and 60,000 feet.

Although the electron tube envelope temperatures in packaged amplifiers are comparatively quite low, the difference in temperature between the hottest point in a package — the tube bulb — and the coolest point — the exterior of the package — is quite small. The temperatures of the passive elements in the package lie somewhere in this narrow range, and hence, they must operate at somewhat higher temperatures than they would in an open air mounting. This is why components used in the packages are limited to those capable of operating at 125° C.

If field usage confirms the encouraging results of laboratory life tests, this type of packaged construction should materially prolong trouble-free operating intervals. In terms of telephone equipment, a reliable 2,000-hour life for active components may seem to be merely surviving infancy. However, under the adverse conditions that go with the operation of aircraft, this would be a laudable extension of the mortality tables.

THE AUTHOR

John G. Matthews started his Bell System career with Electrical Research Products in 1928, spending eight years on the engineering and installation of sound recording and reproducing equipment, and on such specialty products as the watch master for the repair and timing of watches. For the next five years, as recording supervisor at General Service Studios, he was concerned with the design of new equipment used in motion picture studio operations. He has been a member of the Laboratories since 1942, engaged in design and supervision on military electronic equipment. His projects have included the development of aircraft radio, bombing, and navigational apparatus as well as naval weapons control systems. Mr. Matthews received the E.E. degree from Johns Hopkins University in 1928. He is a member of the I.R.E.



Much of the new equipment installed in the Bell System not only switches telephone calls automatically, but also checks itself and, by means of lamps and alarms, tells maintenance men when and where to look for trouble. For the operational maintenance of intertoll trunks, a new automatic outgoing intertoll trunk-test circuit has been developed for such rapid, automatic testing. This circuit, with its testing speed of about 350 trunks per hour, will be a valuable supplement to existing maintenance equipment.

A New Intertoll Trunk-Testing Circuit

R. C. NANCE *Switching Systems Development*

Intertoll trunks or talking and signaling paths used for long distance calls represent a sizable investment in the toll plant, largely due to their great number and length. Concurrently with the rapid growth of the toll system, many new trunks are being installed as additions to existing installations and as component parts of new toll center construction. To keep pace with the ever-increasing demand for extensive and economical telephone service, adequate maintenance is therefore essential.

Intertoll trunks are maintained by test personnel at the various toll offices. They have at their disposal a variety of manually operated special-purpose test sets for use at toll test boards and other testing positions. Malfunctions on intertoll trunks are detected by test board and central office maintenance personnel during periodically scheduled routine or special testing cycles, by trouble indicating and recording devices which have been provided in the automatic toll switching systems, by alarms, and by toll operators as an incidental service while handling toll calls.

The progress of toll switching mechanization has steadily reduced the number of manual operations required in completing toll calls, and has consequently reduced the number of trouble conditions detectable by toll operators. The introduction of the No. 4A toll crossbar switching system further emphasizes this trend toward mechanization, and since operators are less frequently involved, detection of trouble by test board and central office maintenance personnel becomes an increasingly important problem. It can be seen that, as mechanization of toll switching accelerates in the future in conjunction with the nationwide toll operator-dialing and nationwide customer-dialing programs, maintenance devices will also tend to become more mechanical and automatic.

Since adequate preventive maintenance requires frequent routine tests on toll circuits, it is necessary for economic reasons to improve maintenance by building into the toll switching system a special testing device to perform routine tests on intertoll trunks. This device should have two functions: first,

Above — The author inspecting control relays in an automatic outgoing intertoll trunk-test circuit connector frame at New York Long Lines.

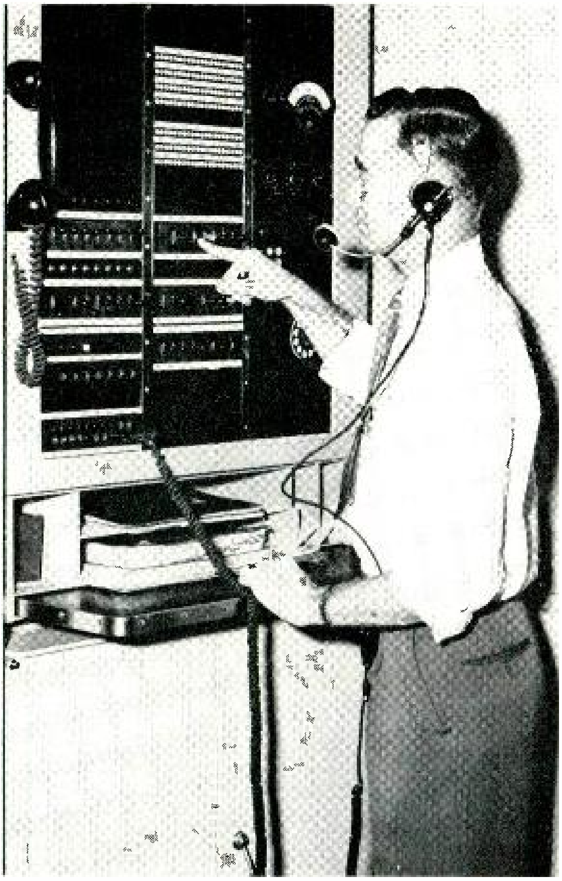


Fig. 1 — W. D. Frietsche, New York Long Lines, starting a test cycle at the automatic outgoing intertoll trunk-test circuit test panel.

to detect failures as soon as possible by performing rapid and convenient automatic tests, and second, to report the detected troubles to the maintenance forces in a manner that will identify the actual circuit that is in trouble and indicate just what the trouble is.

A device of this nature, termed "The Automatic Outgoing Intertoll Trunk-Test Circuit" or AOIT, has recently been designed and put into service. The AOIT will be provided in all No. 4-type toll offices. Figures 1 and 2 show the AOIT installation in the New York Long Lines Building, and its function is represented schematically in Figure 3. The AOIT was designed primarily to test only the outgoing appearances of intertoll trunks.

Suppose in Figure 3 that the test room personnel at the New York No. 4 office decided to test the New York-to-Chicago trunks. The AOIT would be set to start testing on the first trunk in the Chicago group. Then, seizing the trunks one at a time, the AOIT would complete the connection to Chicago, request connection to a "103 test line," and perform an operational test on the circuit. The 103 test line receives test signals from the AOIT and acknowledges receipt of these by returning supervisory signals to the test frame. The AOIT can repeat the test or go on to the next Chicago trunk, depending upon the type of test desired. If trouble is encountered, the operation will stop and lamps will display for the benefit of the test room attendant, telling him what trunk was malfunctioning and why.

The AOIT consists of a test frame like that seen in Figure 1, located for convenience in proximity to the toll test board, and one or more test connector frames (Figure 2) which may be located elsewhere for convenience in cabling and wiring. The test frame contains the test circuit relays, control keys, class and trouble indicating lamps, a telephone set, key set and dial, and local talking trunks for intra-

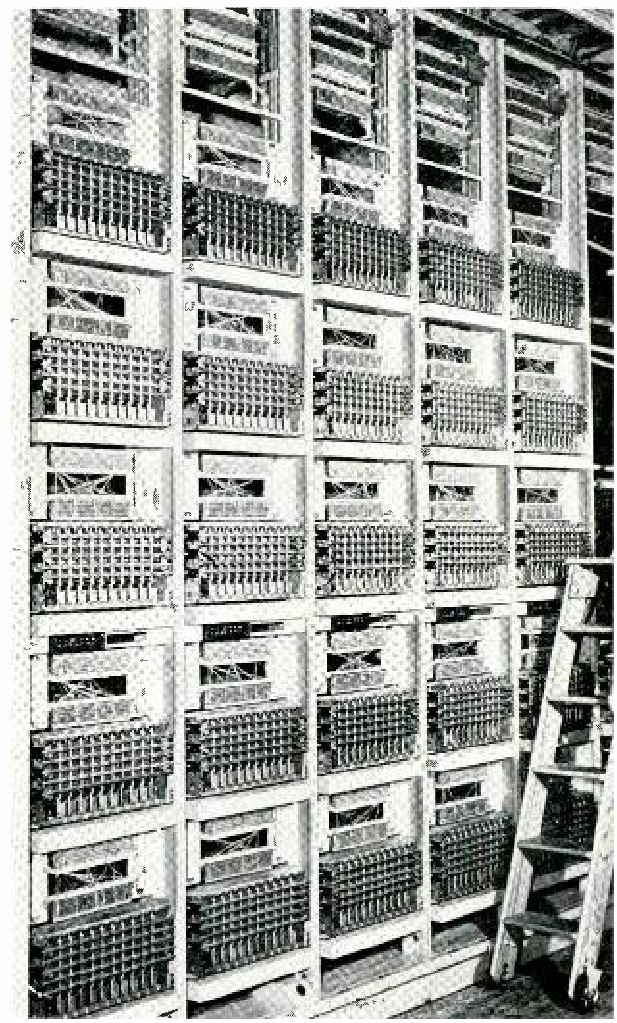


Fig. 2 — One-half of the connector bay frames required in New York Long Lines installation.

office communication. The test connector frames consist of crossbar switches and associated relays to provide access to the control leads of the intertoll trunks for setting up the test connections. Each test connector frame has a capacity of 1,000 trunk appearances.

The AOIT, however, tests more than the trunk equipment between the near and far offices. It acts as an incoming trunk to originate test calls, and thus includes in the tests the connection through the office switches. It also performs the function of an incoming sender to make other tests possible and to pulse out a code necessary to obtain a 103 test line at the distant office.

A few of the technical details of the AOIT will give some idea of its manner of operation. Figure 2 shows five frames of test connectors, containing twenty-five crossbar switches, each of which represents connection to two hundred trunks. The AOIT proceeds to test the two hundred trunks on one of the crossbar switches, goes on to the next two hundred on a second switch, and so on until all trunks are tested. As each trunk is tested, a four-digit lamp display on the test panel (Figure 1) identifies the test connector appearance of the trunk, and this information can easily be translated into the actual office circuit-number of the trunk.

A preliminary connection by the test connector switches starts the test, and the AOIT determines whether the trunk is busy. If the trunk is available for the test, the AOIT automatically makes it busy for all other calls. The AOIT then causes a marker to select a path through the office switches to the trunk. If for any reason the marker does not perform its function properly, an appropriate lamp display on the test panel indicates marker trouble and operates an alarm.

Next, the AOIT performs a test that determines whether the outgoing link frame is supplying a ground connection necessary in holding the connection. If this test is passed successfully, the AOIT awaits a "go ahead" signal from the distant office, and checks whether it has received a true signal or a false flash. After a true "go ahead" signal is received, the AOIT then performs a continuity test to detect open leads, and, if the multifrequency type of pulsing* is used over the trunk, performs a test to determine whether the talking path has been cut through to the distant office.

At this point the AOIT now pulses out the code to get the 103 test line at the distant end necessary for the rest of the test. When the 103 is attached to the circuit, it informs the AOIT of the fact by sending back another signal. The final two tests are then performed — the first, to determine whether ringing is properly received at the distant end, and the second, a disconnect test to see whether the trunk will drop the connection within prescribed time limits.

If the AOIT determines that the trunk has passed all of the test requirements, it goes on to the next trunk and tests it in a similar manner. If any malfunctioning is detected, the AOIT stops testing and operates an alarm and a lamp display.

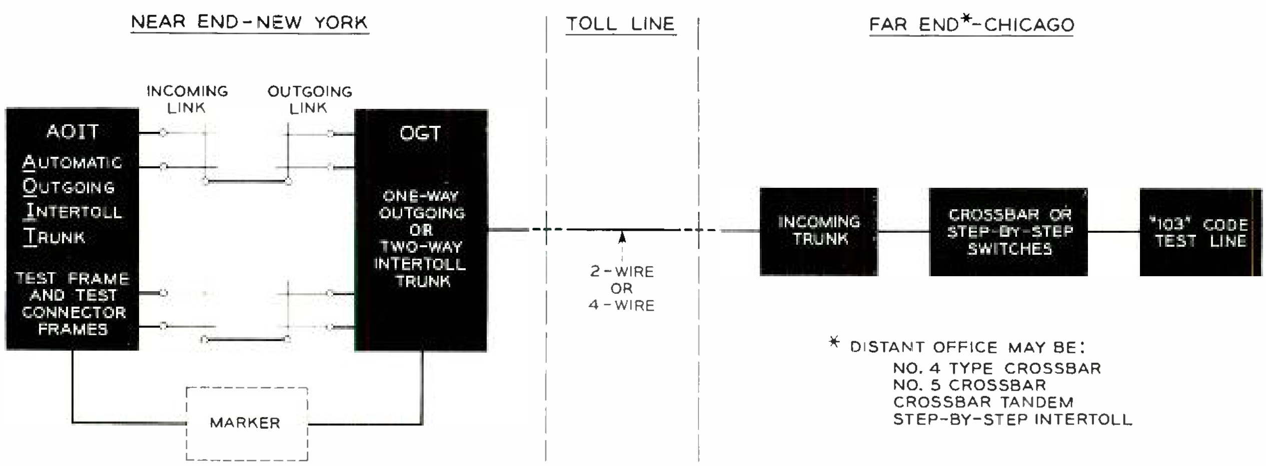


Fig. 3 — Simplified block diagram showing the position of the AOIT in an automatic telephone switching system. In one hour, about 350 intertoll trunk circuits are tested.

* Record, *December*, 1945, *page* 466.

The AOIT provides a variety of test cycles on an automatic, semi-automatic and manual basis. For instance, on an automatic basis, it is possible under control of lever-type keys, to test only idle trunks and to pass busy and spare trunks, or to pass all idle trunks when searching for falsely busy trunks. A test cycle may be started on any trunk group by operation of particular circuit keys provided, and individual trunks may also be tested by the same manner of selection. Keys are provided which cause the AOIT to repeat the tests continuously on the same trunk until the test circuit is advanced by restoration of the key. This "repeat test" is valuable when attempting to diagnose intermittent troubles. It is also possible to perform a test twice on each trunk before advancing to the next trunk. The "repeat twice" test is valuable in determining whether the far end of the connection restores to normal quickly enough on disconnect.

The AOIT can also perform two test cycles on dial trunks. The first is an "early release" test to determine, in case of an abandoned call, whether the outgoing dial trunks can release successfully while an outgoing sender is attached. The second is a reorder test which tests the ability of the outgoing dial trunk to accept a reorder signal from an outsender.

In addition, there are other features incorporated into the design of the AOIT which are beneficial in the performance of certain maintenance operations. Keys are provided to advance the test circuit manually if the frame has blocked in a trouble condition. A lockout key is provided which enables the attendant to take a trunk out of service from the test frame position. Another key permits manual ringing over the trunks under test. Provisions are also made for manual transmission measurements on the trunks in conjunction with other transmission measuring equipment.

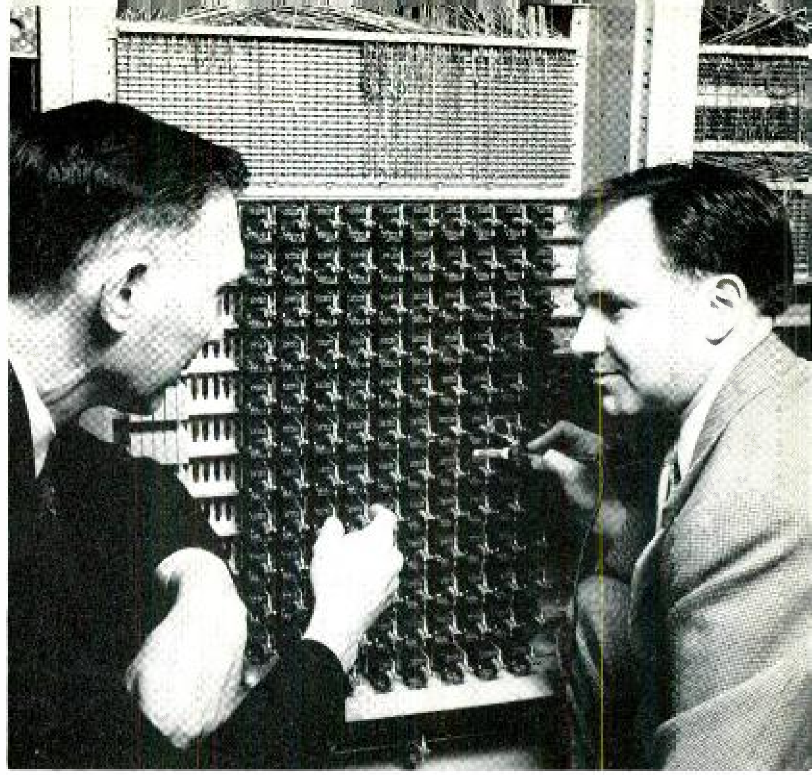
Use of the AOIT with its testing speed of about 350 trunks per hour provides maintenance personnel with an invaluable tool to augment those already at their disposal, and thus to give prompt indications of plant irregularities. Consequently, an entire inter-toll trunk array can be rapidly tested in a matter of hours. The number of circuits actually out of service because of undetected operational troubles should therefore be greatly reduced, and the over-all efficiency of the plant should correspondingly increase. In addition, the AOIT provides the attendant with a usable hint or lead as to where he should look first for the detected troubles, thereby expediting the actual maintenance action required.

THE AUTHOR

R. C. Nance joined the Laboratories as a messenger in 1936, and became a draftsman before taking military leave from 1941 to 1945 to serve the Signal Corps in the Pacific Theater. Shortly after his return to the Laboratories he did design work on switchboard trunk circuits and toll crossbar trunk circuits. In 1953 he became a Member of Technical Staff, concerned with the design of automatic intertoll trunk test frames and the associated recording printer circuit. His current work also includes further attention to toll crossbar intertoll circuits. Mr. Nance attended evening classes at Newark College of Engineering to receive the associate E.E. degree in 1940.

Code Translation in No. 5 Crossbar

J. A. CEONZO *Switching Systems Development I*



Telephone customers ordinarily dial a total of seven "digits": two letters and a number, to identify the called central office, and four numbers to identify a particular customer served by that office. However, there are variations. Customers dial the single digit zero to reach an assistance operator, various 3-digit codes alone, such as 411 for information, and 3-digit office codes followed by 4 or 5 customer digits to reach other users in the same area. Now, with nationwide dialing, they dial 3-digit area codes in addition to the 3-digit office codes followed by four customer digits. In order that the switching equipment may properly complete each call, these codes require accurate translation.

Calls handled by any dial central office are directed so as to reach a called number by means of a combination of "digits" (letters and numbers) usually subdivided into "code digits" and "numerical digits." The code digits, sometimes called "office code" or "directing digits," precede the numerical digits and identify the particular office serving the called customer's line. By examining these digits, automatic switching equipment such as that used in No. 5 crossbar offices, can obtain the information necessary to complete calls. The numerical digits that follow the code digits are used in the terminating office to identify the customer's line to which connection must be made.

In the No. 5 crossbar system, code translator circuits are provided in the marker, register, foreign area translator, and pretranslator circuits, as indicated in Figure 1. All of these translators contain "relay tree" circuits and, except for the register translator, usually receive an input of three digits – one thousand possibilities – and filter these digits to obtain an individual output. A pictorial representation of a simple 3-digit translator circuit of this type is shown in Figure 2. This translator receives the code digits on three sets of ten leads each. These leads are labeled A0-9, B0-9, and C0-9 where the letters A, B, and C identify the first, second, and third digit, and the numbers zero through nine indicate the value of each digit.

When a particular 3-digit office code is to be translated, a ground signal is placed on one lead in each set corresponding to these digits. The grounded A0-9 lead, representing the 100's digit, operates the corresponding one of 10 "A" relays, and thus narrows the choice of outputs to those having the indicated 100's digit. Each of these "A" relays have ten contacts providing electrical paths

Above — C. F. Knepper and the author (right) examine a relay-tree translator.

to a total of 100 "B" relays which are also equipped with ten contacts each. The grounded B 0-9 lead, representing the 10's digit in the sequence, follows a path through the corresponding contacts in each "A" relay. Since only one "A" relay is operated, however, this ground can operate only one of the "BO 0-99" relays. In this way the choice of outputs is further reduced to those having the proper 100's and 10's digits. The grounded C 0-9 lead follows a path through the corresponding contact in each "B" relay, but again, since only one of these relays is operated, the ground appears on a single output terminal in a field of 1,000. Thus, a 3-digit input is translated into a single output.

Translation is necessary to obtain information

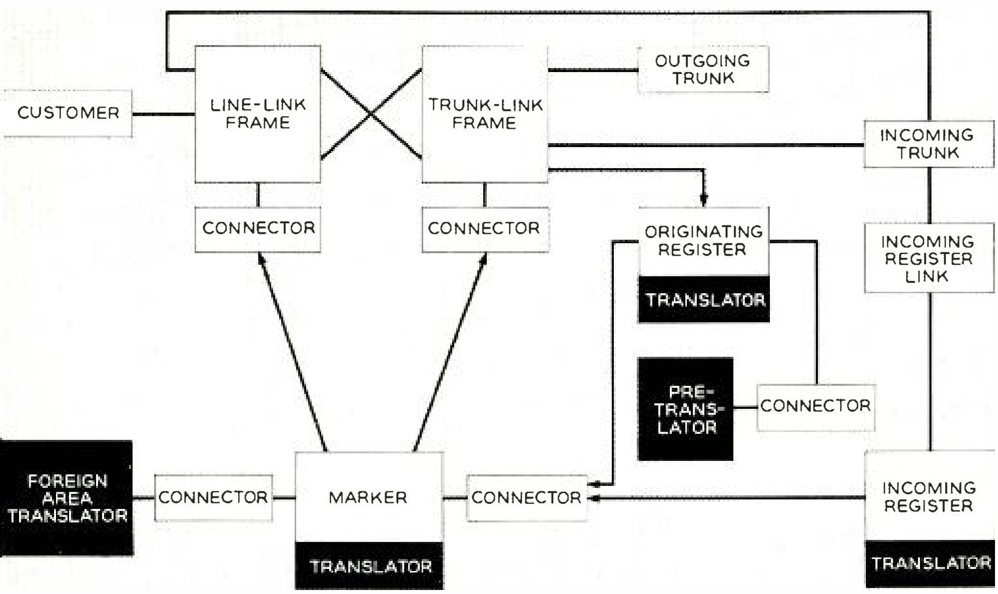


Fig. 1 — A No. 5 crossbar system showing the location of the various translator circuits.

from code digits for handling calls in the automatic switching equipment within a central office, and for subsequently routing the calls out of the office. In the first instance, information is obtained from translator circuits provided in registers and pretranslators, and in the second, from those in the marker and foreign-area translator.

Translator circuits in the registers are used to determine the end of a series of digits. These registers – both originating and incoming dial-pulse – are capable of recording from one to eleven digits. Since the number of digits involved may vary with each call, however, the register must know when the last digit has been dialed so that it can connect to a marker and proceed to set up the call. In multi-frequency registers, also able to record from one to eleven digits, an "end of pulsing" signal is transmitted after the last digit to indicate that registration is complete.

Since no such signal is received by dial-pulse registers, they must determine within themselves when registration has been completed. Therefore, they are equipped to examine a call for any clues that might indicate when the complete called number has been registered. For calls entering an office over trunks that carry traffic for local completion only, an incoming register can determine the number of digits to be recorded from the trunk class.* For calls received over tandem and long-distance trunks, and for calls originating within the office, however, a more detailed examination is needed. On such calls, the register receives code digits preceding the line number or a 3-digit service code. Although this is an indication that digits must be recorded, it does not specify the exact number. This number may vary with each call since office codes consisting of two or three digits may be used in the same local office area, and some of the called offices may use line numbers that include party letters. In addition, on some long-distance calls, a 3-digit national area code may prefix the call number. Where these variations occur, and where identification of the incoming trunk class is insufficient to determine the total number of digits to expect,

* RECORD, *March*, 1950, *page* 104.

this information can be obtained by translating the code digits received. In areas where there are relatively few central office names, this is done by translator circuits provided in the dial-pulse incoming and originating registers.

In other areas, however, where the numbering plan is rather involved, it is not feasible to equip all originating and dial pulse incoming registers with adequate translators. Instead, with originating registers, the translating functions of all are concentrated in the more elaborate pretranslator circuit. Where this pretranslator is provided, the originating register, after recording three digits, connects to the pretranslator and transmits the digits to it. These digits are translated and information as to the total number of digits to expect is returned to the register.

With dial pulse incoming registers, if neither the trunk class nor the simple translation of the code digits yields any indication of the number of digits to be registered, no further attempt is made to determine this information. Instead, the register is arranged to wait approximately four seconds after the receipt of each digit subsequent to the second. When four seconds have elapsed without receipt of a digit, it is assumed that registration of the numbers has been completed.

After the register has completed registration it signals a marker connector to seize an idle marker and connect it to the register. Each digit stored in the register is then transferred to the marker where it is recorded. Following this the marker passes the first three code digits of the called number through a relay tree translator (Figure 2) to one of 1,000 outputs or "code points," each of which is associated with the routing a call may follow. If the code point involved on a particular call is associated with a local area office code, or with a national area code having a single connecting route, the marker establishes a connection to the proper trunk.

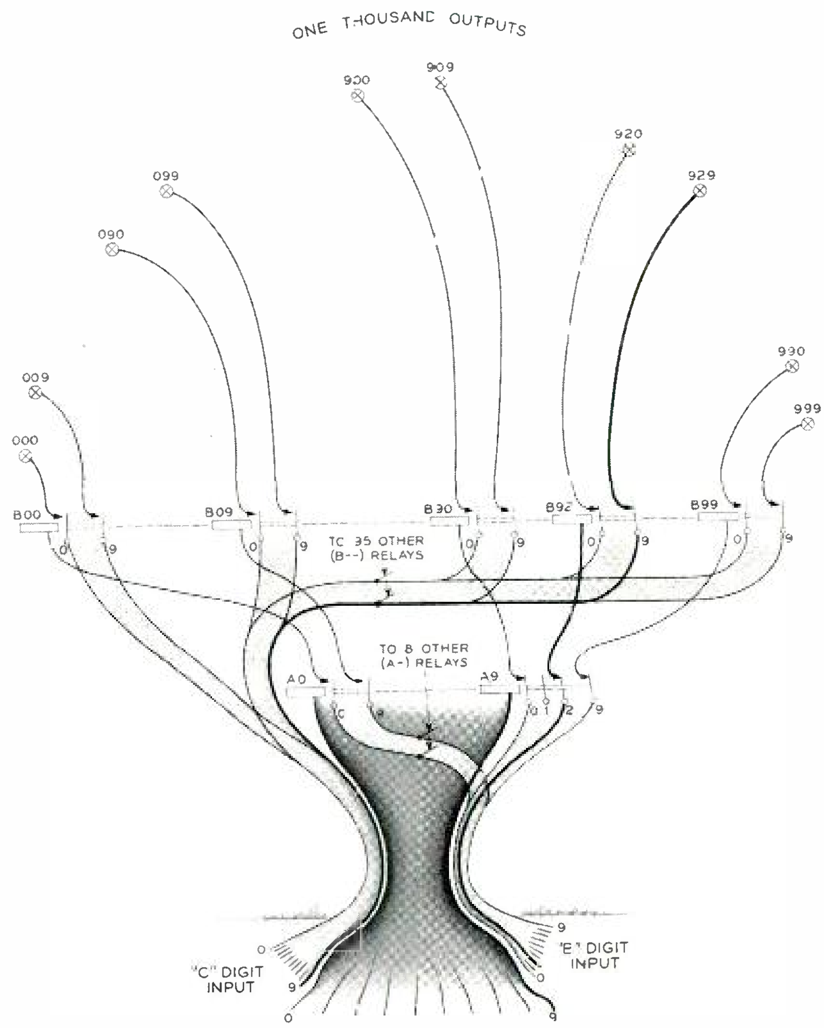


Fig. 2 — Pictorial representation of a simple three-digit relay tree circuit illustrating its use in selecting the proper output point for the WAtkins-9 central office. Ground on the A9 lead operates relay A9; ground on the B2 lead operates relay B92 through the No. 2 contact of the operated A9 relay; ground on the C9 lead selects the 929 output point through the No. 9 contact of the operated B92 relay.

If a national area code is involved with several routes to the area available — the choice of route depending on the particular office in the area being called — the marker must obtain a translation of the office code as well as the national area code.

To translate both of these codes, "6-digit" translators could be included in all markers. However, since traffic requiring six-digit translation is relatively light, such an arrangement would be uneconomical. A circuit that is called the foreign area translator is provided for this purpose, and is available for use by all the markers in an office. When 6-digit translation is necessary, the marker itself translates the first three digits to identify the area. It then transmits the second three digits to the foreign area translator where they are filtered through another translator relay tree. The resulting output indicates the routing for the call, and the marker proceeds to set up a connection to the proper trunk circuit. Foreign area translation is, however, the subject of another article to be published in a subsequent issue of the RECORD.

THE AUTHOR

J. A. CEONZO started working for Bell Telephone Laboratories in 1942 after being graduated from Brooklyn Technical High School. He was a draftsman for one year when he enlisted in the Navy in 1943. He returned to the Laboratories in 1946 as a draftsman and in 1947 began working on the No. 5 crossbar marker circuit. Three years later, in August, 1950, he was called up from his Navy reserve status as a result of the Korean war. He served as a Chief Sonarman until November 1951. Mr. Ceonzo is now a technical staff associate and is presently engaged in continuing development work aimed at adding new features to the No. 5 crossbar marker circuit. He attends night classes at the Brooklyn Polytechnic Institute.

Plaque of Alexander Graham Bell Unveiled

A bronze bas-relief honoring Alexander Graham Bell was unveiled on November 10 in the lobby of A.T.&T. headquarters at 195 Broadway, New York City, by the inventor's daughters, Mrs. Gilbert Grosvenor of Bethesda, Md., and Mrs. David Fairchild of Coconut Grove, Miami, Fla. The plaque, which shows Bell in his early attic workshop in Boston, is the work of sculptor Paul Manship.

Cleo F. Craig, president of A.T.&T., presided over the ceremonies marking the unveiling. As part of the program a quotation from Mr. Bell was read over an exact replica of his first telephone. Then the same quotation was read over a 500-type telephone set powered by the Bell Solar Battery, the recent Laboratories invention which converts light into useful amounts of electricity. Mr. Craig, who paid tribute to the "daring imagination" with which Mr. Bell predicted the development of the telephone system, said the inventor would have appreciated the glimpse into the future that the Bell Solar Battery afforded the audience.

At the close of the ceremonies, Walter Hampden, the actor, read *The Vision of a Man Named Bell* over a small radio transmitter also powered by the Solar Battery. Transistors were used instead of vacuum tubes in the radio transmitter.

Polyethylene Cable Guard

Where aerial cable is fastened to telephone poles, it is frequently necessary to provide an abrasion shield to protect the cable sheath. Before the introduction of alpeth cable,* such a shield consisted of a rectangle of sheet lead about 8 inches wide by 1/16 inch thick, wrapped around the cable and secured by wire servings as in Figure 2. Four sizes of shields were required to accommodate the complete range of cable sizes.

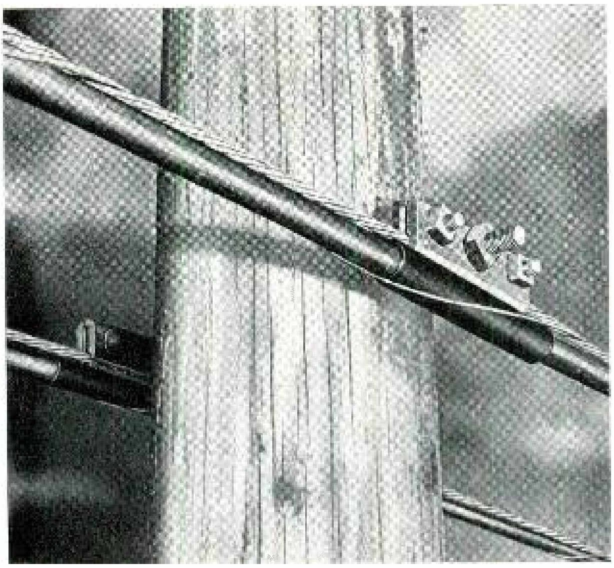


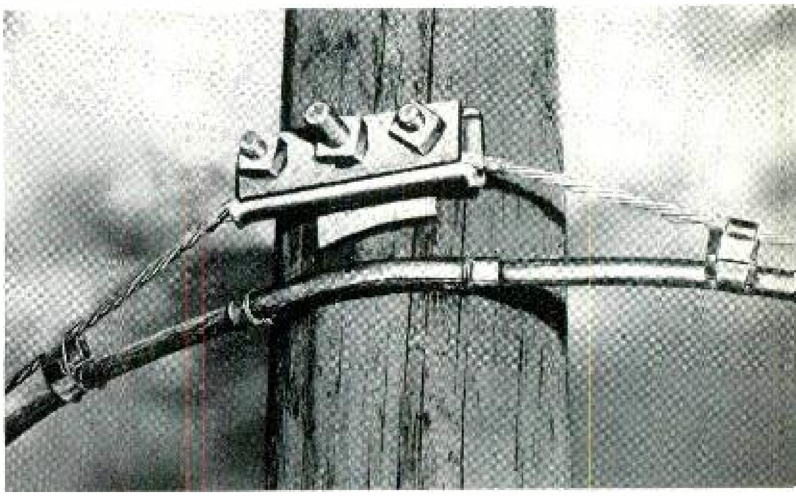
Fig. 1 — With pre-lashed cable, the polyethylene cable guard is slipped around the cable under the lashing wire and suspension strand.

Prelashed cable, with its tightly-wrapped continuous lashing wire, requires a form of sheath protection that can be easily installed after the cable is in place. For this purpose a short length of polyethylene tubing is provided, of a suitable size to fit the cable and split lengthwise to permit its insertion under the lashing wire. Field experience with the new cable guard, Figure 1, has been favorable. Also, its lighter weight (approximately 1/12 that of lead) promises substantial savings in shipping and handling costs. This new cable guard is another in the growing list of items in which new materials are being substituted for old in the interests of better telephone service.

W. R. Kelly of the New York Telephone Company tightens the supporting bolt on a cable suspension clamp. The cable guard may be seen fitted around the cable just below the wrench.

R. J. Skrabal
Outside Plant Development

Fig. 2 — On previous aerial cables, a piece of sheet lead was wrapped around the cable for protection.



* Record, *November*, 1948, *page* 441.

GEORGE A. CAMPBELL 1870-1954

The passing of Dr. George Ashley Campbell November 10, 1954, marks the close of an era that has seen the communication art grow from infancy to robust manhood.

The problems of telephone transmission were little understood when George Campbell, a young mathematical physicist, joined the American Bell Telephone Company (later American Telephone and Telegraph Company) in 1897. He had just returned from four years of study at various universities in Paris, Vienna, and Göttingen, having received his B.S. degree in 1891 from Massachusetts Institute of Technology, A.B. from Harvard 1892, and M.A. in 1893 from the same institution. In these early years at American Bell, he also continued his studies at Harvard, where in 1901, he received the Ph.D. degree.

Familiar with the work of Rayleigh and Heaviside, Campbell's first undertaking was to find some method of mitigating the attenuation of voice currents in telephone lines, which theretofore, produced a barrier against telephone communication over very long distances. Heaviside had shown that inductance, if properly applied in a long telephone circuit, should diminish rather than increase the attenuation. Campbell followed this suggestion and developed a theory of "loading," but there occurred one of those rare coincidences in the history of science of two independent investigators arriving at substantially the same result at the same time. Without knowing that, at Columbia University, Professor M. I. Pupin was studying the same problem, Campbell applied for a patent at about the same time as Pupin. After final adjudication under the technical rules of the patent law, the basic patent was awarded to Pupin, on the ground of priority of conception. As Dr. F. B. Jewett so aptly said, "It should be mentioned, however, that Campbell's analysis of the problem – actually more detailed than Pupin's – led him to formulate rules for the design of loading coils and their spacing, which were, from the very beginning, the only ones employed in this country. By this one piece of work performed within a relatively short time after his employment in the Bell Company, Campbell demonstrated his unique ability at mathematical physics, as well as his knack for stating conclusions in a form that the development engineer could use in practical applications."

As a consequence of his work on loaded lines – indeed, almost as a part of it – Dr. Campbell arrived at the idea of an electric wave filter. By a suitable network of coils and capacitors, he was able to produce a device that would allow a preferred band of frequencies to pass through it – such as those of the human voice, for example – while discriminating markedly against frequencies above and below the desired band. This development was first used in so-called "carrier" systems over long distance open-wire lines, which increased by several fold the number of telephone circuits carried by them. The principle became of even greater importance when much wider bands of frequencies were employed in the coaxial cable and in the newer forms of radio transmission designed to transmit, over the same electrical path, either many hundreds of telephone conversations, or several television programs. It will also be used in the new transatlantic telephone cable.

As the effectiveness of telephone instruments increased and the length of circuits grew, "crosstalk," the tendency for conversation in one circuit to be heard in another, became an obstacle to telephone advance. Earlier workers had shown that this crosstalk was a complex effect resulting partly from electromagnetic induction and partly from electrostatic induction. Campbell turned his attention to this problem between 1903 and 1907, and showed that crosstalk between two circuits depends to a considerable extent, and particularly for loaded circuits, on the direct capacitance between the wires of the two circuits. He termed this function the "Direct Capacity Unbalance." This work led not only to mathematical formulae, but to the development of measuring apparatus which was destined to play a great part in future telephone developments. In this period he produced his well-known shielded balance for the accurate measurement of electrical constants at telephone frequencies. This contributed greatly to the development of cables to replace open-wire lines. Out of it also grew the whole shielding technique applied today in innumerable ways in the high-frequency art.

Closely associated with his work on filters and line balance were problems concerning telephone repeater circuits. Early in telephone development, various experimenters and inventors had proposed circuits to accomplish two-way telephony, and from this prior work had come two fundamental repeater circuits, one in which a single repeating element amplifies messages reaching it from both directions, and one that includes two amplifier elements, one assigned to each direction of transmission. In the first, two sections of line, as nearly identical as possible, are balanced against each other as opposite arms of a bridge. In the second, each incoming section of line is balanced against an artificial line or network, thus permitting, as Campbell's analysis showed, a greater inherent flexibility as well as a greater stability. Campbell's studies closely formulated the stability limits of the circuits, and in addition, led to the use of the "four-wire circuit" as a logical extension of the one-way paths in the second type repeater, each extended path containing as many one-way amplifiers and line sections as desired. Although when it was proposed in 1912 it was looked upon as having little practical application, its later wide use at both voice frequencies and in the carrier art, shows it to be an example of a technical advance that could not be employed until a complex art had caught up with it.

As a mathematician, he was interested not only in solving problems, but also in the logical relations of mathematics itself; perhaps his most significant contribution in this field was in the table of Fourier Integrals for practical applications in the study of transients and other non-periodic phenomena.

In this brief review of Dr. Campbell's work, mention can be made of only a few of his many contributions. Those that have been chosen are representative of his more outstanding contributions to electrical communication. His career was highly productive of discoveries, inventions, and patents. His achievements entitle him beyond question to rank first among his generation of theoretical workers in electrical communication. In recognition of his distinguished contributions, he was awarded the Medal of Honor of the Institute of Radio Engineers in 1936, the Elliott Cresson Gold Medal of the Franklin Institute in 1939, and the Edison Medal of the American Institute of Electrical Engineers in 1940.

At the time of his retirement, he was a member of the American Mathematical Society, American Mathematical Association, American Physical Society, The American Association of Physics Teachers, American Academy of Arts and Sciences, and the Harvard Engineering Society. He was also a Fellow of the American Institute of Electrical Engineers and of the American Association for the Advancement of Science. In appreciation of Dr. Campbell's long and distinguished service and of his fundamental contributions to the development of electrical communication, his technical papers were collected and published by the American Telephone and Telegraph Company, in a bound volume entitled "Collected Papers of George A. Campbell" (1937).

Though Campbell's achievements are now best known by his personal mathematical contributions, he contributed to the advance of telephony in another way that should not be forgotten. He it was who hired Frank B. Jewett and Edwin Colpitts, and others, whose ability and training fitted them for leadership in the application of scientific knowledge and methods to the practical problems of telephony.

He was a gentle and retiring man, but to those who knew him best he was a lovable companion who sought, not fame or high position, but understanding. His interest in the technical problems of telephony continued to the end of a long and active life. Out of his work came useful and readily available mathematical tools for those who followed him, but more importantly a spirit of inquiry that left its enduring imprint on the character of the Bell Telephone System as we know it today.

King Frederick IX of Denmark Honors H. T. Friis

H. T. Friis, Director of Research in High Frequency and Electronics at the Laboratories, has been awarded the decoration, "Knight of the Order of Dannebrog," by His Royal Majesty Frederick IX of Denmark. This award is made by the King of Denmark on special occasions, usually to people of Danish descent. Considered the highest civilian decoration of Denmark it is made to honor noteworthy contributions in the field of the recipient.

"Dannebrog" is the national flag of Denmark and was adopted, according to legend, by King Valdemar in the year 1219.

Dr. Friis, a native of Denmark, came to this country in 1919 when he joined the Research Department of the Western Electric Company. Since then he has made notable contributions in the field of radio. He was recently named to receive the Medal of Honor of the Institute of Radio Engineers.

First L3 System Television Transmission

The super-capacity L3 coaxial cable system, capable of carrying more television programs and long distance telephone conversations than conventional systems, was placed in service on November 1 between Miami and West Palm Beach, Fla. The Long Lines Department of American Telephone and Telegraph Company said the new cable would be used initially to provide one northbound and three southbound TV channels over the seventy-mile route.

It is the first such system to be used for television. Another L3 equipped route, between New York and Chicago, was opened last spring to meet long distance telephone expansion needs. One pair of coaxial tubes in the new system can handle 1800 telephone conversations simultaneously. With a band width double that of conventional video channels, a pair of tubes in the L3 system will carry two TV programs and 600 telephone conversations simultaneously.

Talks by Members of the Laboratories

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

I.R.E. Circuitry Subcommittee, University of Connecticut, Storrs, Conn.

Bowers, F. K., A Fast Pulse Generator Using a Tetrode Transistor.

Edson, J. O., Junction Flip-Flop Design.

Linvill, J. G., Switching Performance in Non-Saturating Circuits Using Junction Transistors.

Tendick, F. H., Jr., Some Circuit Aspects of Low Power Regenerative Transistor Pulse Amplifiers.

Trent, R. L., High Speed Binary Cell.

Ulrich, W., see Yokelson, B. J.

Vogelsong, J. H., Transistor Pulse Regenerative Amplifiers.

Yokelson, B. J., and Ulrich, W., Techniques Used in Engineering Multi-Stage Diode Logic Circuits.

A.I.E.E. Fall General Meeting, Chicago, Ill.

Anderson, R. E. D., A Magnetically Regulated Portable Battery Charger.

Gilman, G. W., see Kelly, M. J.

Hamilton, B. H., Some Applications of Semiconductor Devices in the Feedback Loop of Regulated Metallic Rectifiers.

Kelly, H. P., Differential Phase and Gain Measurements in Color Television Systems.

Kelly, M. J., Radley, Sir Gordon, Gilman, G. W., and Halsey, R. J., A Transatlantic Telephone Cable.

Nordahl, J. G., A New UHF Multichannel Military Radio Relay System.

Schramm, C. W., New Military Carrier Telephone Systems.

Smith, D. H., The Suitability of the Silicon Alloy Junction Diode as a Reference Standard in Regulated Metallic Rectifier Circuits.

Other Talks

Baker, W. O., Electron Behavior in Organic Solids, Harvard University, M.I.T. Colloquium on Chemistry, Cambridge, Mass.

Barney, H. L., Recent Developments in Signal Analysis, Convention of American Speech and Hearing Association, St. Louis.

Boyle, W. S., Kisliuk, P., and Germer, L. H., Electrical Breakdown in Vacuum at Low Voltages, Seventh Conference on Gaseous Electronics, New York University.

Boyle, W. S., and Kisliuk, P., Departure from Paschen's Law of Breakdown in Gases, Seventh Conference on Gaseous Electronics, New York University.

Bozorth R. M., Anisotropy and Magnetostriction of Ferrites, Naval Ordnance Laboratory, Silver Spring, Md.

Burns, R. M., Control of Corrosion of Metals, New Jersey Section of American Chemical Society, Red Bank, N. J.

Burton, J. A., Impurity Phenomena in Semiconductors, American Society for Metals Seminar on Impurities and Imperfections, Chicago.

Calbick, C. J., Some Surface and Particle Problems in Electron Microscopy, Electron Microscope Society of America, Highland Park, Ill.

Calbick, C. J., and Koonce, S. E., Void Formation During Drying of Plastic Films, Electron Microscope Society of America, Highland Park, Ill.

Chapin, D. M., The Theory and Operation of the Bell Solar Battery, Lehigh University, Bethlehem, Pa.

Chapin, D. M., The Bell Solar Battery, Joint Meeting of A.I.E.E. and I.R.E., New York City.

Elliott, S. J., Solderless Wrapped Connections, General Electric Company, Syracuse, N. Y.

Finch, T. R., The Future of Communications, University of Utah, Salt Lake City, Utah; Denver Engineering Council, Denver, Colorado; Denver University, Denver Colo.

Fuller, C. S., Semiconductors as seen by the Chemist, Pittsburgh Chemists Club, Pittsburgh, Pa.

Garrett, C. G. B., Semiconductors and Semiconductor Surfaces, Rutgers University, New Brunswick, New Jersey.

Germer, L. H., see Boyle, W. S.

Hagstrum, H. D., Ejection of Electrons from Contaminated Metals by Positive Ions, Gaseous Electronic Conference, New York City.

Hagstrum, H. D., Electron Ejection from Metals by Slowly Moving Positive Ions, Syracuse University, Syracuse, N. Y.

Herrmann, D. B., see Williams, J. C.

Higgins, W. H. C., Project NIKE, Holy Name Society of Our Lady of the Valley Church, Orange, New Jersey.

Jensen, A. G., The Present Status of Color Television, University of California, Stanford University, University of Southern California, Calif. Inst. Tech., and U.C.L.A.

Kislink, P., see Boyle, W. S.

Kolman, G. T., The Migration of Silver Through and on the Surface of Insulating Materials, Conference on Electrical Insulation, Pocono Manor, Pa.

Koonce, S. E., see Calbick, C. J.

Kuh, E. S., Parallel Ladder Realization of Transfer Admittance Function, Circuit Theory Session of National Electronics Conference, Chicago.

Kuhlmann, E. W., Jr., and Mattingly, R. L., A Slotted Waveguide Array, First Annual Symposium on USAF Antenna Research and Development, University of Illinois, Urbana, Ill.

Matlack, R. C., The Nation at Your Finger Tips, Cleveland Section A.I.E.E., Cleveland.

Mattingly, R. L., see Kuhlmann, E. W., Jr.

McNamara, W F., see Tyne, G. F. J.

Meszar, J., Mechanized Intelligence in Nationwide Dialing, Aurania Club, Albany.

Miller, R. A., Automatic Telephone Answering Device, I.R.E. Detroit Section, Detroit.

Morton, J. A., Status of Transistors, 9255th Air Reserve Squadron of Morristown, Morristown, N. J.

Morton, J. A., Transistors Today, Joint A.I.E.E. and Franklin Institute Meeting, Philadelphia.

Mulhern, M. J., Electronic Power Equipment, Mid-State Subsection of A.I.E.E., North Carolina.

Owens, C. D., Ferrites – The New Look in Magnetic Materials, Pittsburgh Section of the I.R.E., Pittsburgh.

Pearson, G. L., The Bell Solar Battery – A Silicon p-n Junction Photovoltaic Device, Electrochemical Society, National Bureau of Standards, Washington, D. C.

Pearson, G. L., Silicon in Modern Communications, Graduate Seminar in Electrical Engineering, Polytechnic Institute, Brooklyn.

Pierce, J. R., Stellar and Interspace Communications, I.R.E. Princeton Section, Princeton University.

Pollak, H. O., On a Class of Polynomials Orthogonal Over a Denumerable Set, American Mathematical Society, Cambridge, Mass.

Raisbeck, Gordon, The Bell Solar Battery, American Society of Mechanical Engineers, New York City.

Rose, D. J., Re-Determination of the Ionization Coefficient for Hydrogen, Seventh Annual Gaseous Electronics Conference, New York University.

Shackleton, S. P., Counselling of High School Students, State and Area Committees of Engineers Council for Professional Development, Columbus, O., and Charleston, W. Va.

Shockley, W., Transistor Physics, American Ceramic Society, Washington Philosophical Society, Washington, D. C.

Tyne, G. F. J., and McNamara, W. F., Miniaturized Apparatus Components, Joint Session A.I.E.E. – I.R.E., Oklahoma City; A.I.E.E. Iowa Section, Des Moines, Iowa; Joint Session I.R.E. – I.E.S., Omaha, Neb., and A.I.E.E Iowa-Illinois Section, Rock Island, Ill.

Wadlow, H. V., Determination of Microgram Quantities of Sulfur by Hydrogen Evolution, Bell Telephone Laboratories, Murray Hill, N. J.

Walker, A. C., Growing Large Quartz Crystals, Midwest Cooperating Section of the American Chemical Society, Bloomington, Ind., Louisville, Ky., and Lexington, Ky.

Williams, J. C., and Herrmann, D. B., Surface Resistivity of Ceramic and Organic Materials, Conference on Electrical Insulation, Pocono Manor, Pa.

Wintringham, W. T., Color Television as a Transmission Problem, Morris County Association of Professional Engineers and Land Surveyors, Convent Station, New Jersey.

Patents Issued to Members of Bell Telephone Laboratories During the Month of September

Carpenter, W. W., and Collis, R. E. – *Call Data Recording Telephone System* – 2,688,658.

Collis, R. E., see Carpenter, W. W.

Cutler, C. C. – *Directive Antenna Systems* – 2,690,508.

Joel, A. E., Jr. – *Automatic Switching System for Radio Broadcasting Networks* – 2,690,548.

Kille, L. A. – *Testing System* – 2,690,299.

Kock, W. E. – *Wave Guides* – 2,688,732.

Lewis, W. D. – *Universal Scanning Mechanism for Radars* – 2,688,700.

Phair, R. J., and Platow, R. C. – *Method of Forming Laminated Sheets* – 2,688,582.

Platow, R. C., see Phair, R. J.

Rea, W. T. – *Hub Concentration Group Telegraph Repeater* – 2,690,476.

Schumacher, E. E. – *Lead Cadmium Coated Soldered Brass Cable Armor* – 2,688,652.

Papers Published by Members of the Laboratories

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

Arnold, S. M., Metal Whiskers – A Factor in Design, Elec. Mfg., **54**, pp. 110-114, Nov., 1954.

Arnold, S. M., Metal Whiskers – A Factor in Design, References Electronic Components Symposium, Proc., pp. 38-44, May 4-6, 1954.

Bennett, W. R., Sources and Properties of Electrical Noise, Elec. Eng., **73**, pp. 1001-1006, Nov., 1954.

Bonner, A. L., Servicing Center for Short-Haul Carrier Systems, Elec. Engr., **73**, p. 973, Nov., 1954.

Bozorth, R. M., Magnetostriction and Crystal Anisotropy of Single Crystals of Hexagonal Cobalt, Phys. Rev., **96**, pp. 311-316, Oct. 15, 1954.

Campbell, W. E., see Garn, P. D.

Corenzwit, E., see Matthias, B. T.

Elmendorf, C. H., Component Engineering as a Part of System Design, Electronic Components Symposium, Proc., pp. 8-12, May 4-6, 1954.

Fisk, J. B., Acoustics in Communication, Acous. Soc. Am. J., **26**, pp. 644-645, Sept., 1954.

Flood, W. F., see Hrostowski, H. J.

Garn, P. D., and Campbell, W. E., A Ball-and-Cup Absolute Microviscometer, Analytical Chemistry, **26**, pp. 1609-13, Oct., 1954.

Geballe, T. H., see Matthias, B. T.

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

Gyorgy, E. M., see Weiss, M. T.

Hagstrum, H. D., Auger Ejection of Electrons from Tungsten by Noble Gas Ions, Phys. Rev., **96**, pp. 325-335, Oct., 15, 1954.

Hagstrum, H. D., Theory of Auger Ejection of Electrons from Metals by Ions, Phys. Rev., **96**, pp. 336-365, Oct., 15, 1954.

Hrostowski, H. J, Wheatley, G. H., and Flood, W. F., Anomalous Optical Behavior of InSb and InAs, Letter to the Editor, Phys. Rev., **95**, pp. 1683-1684, Sept., 15, 1954.

Kohn, W., and Luttinger, J. M., Quantum Theory of Cyclotron Resonance in Semiconductors, Letter to the Editor, Phys. Rev., **96**, pp. 529-530, Oct., 15, 1954.

Luttinger, J. M., see Kohn, W.

Mason, W. P., Derivation of Magnetostriction and Anisotropic Energies for Hexagonal, Tetragonal, and Orthorhombic Crystals, Phys. Rev., **96**, pp. 302-310, Oct., 15, 1954.

Matthias, B. T., Geballe, T. H., Geller, S., and Corenzwit, E., Superconductivity of Nb_3Sn, Phys. Rev., **95**, p. 1435, Sept., 15, 1954.

Perry, A. D., Propagation of Electromagnetic Waves in Ferrites, Electronic Components Symposium, Proc., pp. 135-140, May 4-6, 1954.

Peters, H., Hard Rubber, Ind. and Engr. Chem., **46**, pp. 2112-3, Oct., 1954.

Remeika, J. P., New Method for Growing Barium Titanate Single Crystals, Electronic Components Symposium, Proc., pp. 61-62, May 4-6, 1954.

Sharpless, W. M., A Calorimeter for Power Measurements of Millimeter Wavelengths, I.R.E. Trans. P.G.M.T.T., MTT-2, No. 3, p. 45, Sept., 1954.

Souter, J. C., Synthetic Resins as Coatings and Castings, Electronic Components Symposium, Proc., pp. 24-29, May 4-6, 1954.

Tidd, E. D., Recent Trends in Terminals for Hermetically Sealed Components, Electronic Components Symposium, Proc., pp. 112-6, May 4-6, 1954.

Weiss, M. T., and Gyorgy, E. M., Low Loss Dielectric Waveguides, Trans, I.R.E., Prof. Group on Microwave Theory and Techniques, MTT-2, No. 3, p. 38, Sept., 1954.

Wheatley, G. H., see Hrostowski, H. J.