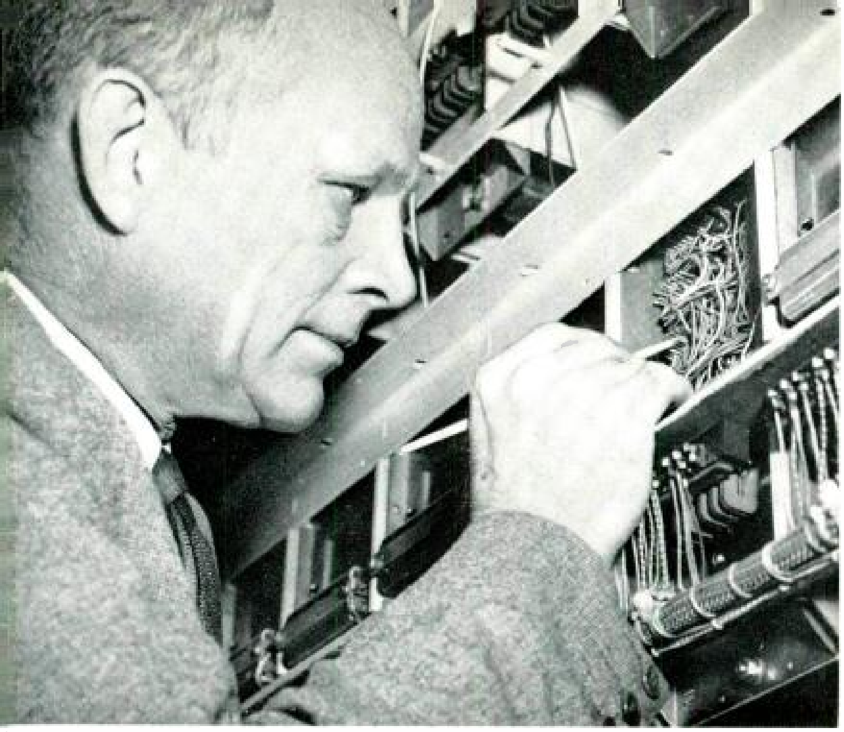


Solderless Wrapped Connections

J. J. KUHN, SR.
Switching Apparatus Development

In a single year, approximately one billion wires are connected to terminals in telephone equipment. The standard method of making such connections is to wrap the wire around the terminal by hand, and solder it into a permanent position. With the development of the wire-spring relay, a new method had to be devised since the relay terminals are closely spaced wires and wrapping by hand was found to be unsatisfactory. Soldering was accompanied by hazards to insulation on conductors. In the new method, a power-driven tool wraps the wire tightly around suitably shaped terminals and sharp edges of the terminal lock the wire in place. This technique is already being used and it is expected to become standard in the Bell System.

A familiar adage, "Necessity is the mother of invention," certainly applies to a new method of connecting wires to telephone apparatus terminals. Soldering is the time-honored method used for such connections, but it was found to be impractical for connections to the recently introduced wire-spring relay.* The terminals of a wire-spring relay are simply the projecting ends of the wires, and it would seem a simple matter to make a good soldered connection. The first designs for these relays had the wire-ends bent into loops, to form terminals. However, for one reason or another, all attempts to satisfactorily attach wires to them were found either impractical or too costly.

Later designs had the terminals (wire-ends) jutting straight out from the plastic parts of the relay, and H. A. Miloche† proposed wrapping a conductor around the wire terminal with a special tool before soldering. This proved so successful that, although wire-spring apparatus had not yet been produced in substantial quantities, the wrapping procedure was adopted rather generally in Western Electric shops for use on conventional terminals of certain standard apparatus.

Several advantages resulted from the use of this wrapping procedure. Western production engineers designed suitable wrapping tools, and operators with very little training could then attach wires to existing apparatus terminals faster than with the older method using pliers. Furthermore, with a wrapping tool, a wrapped connection needs no clipping – the wire is skinned to the correct length. Although clipping wires after soldering is not par-

* Record, *November*, 1953, *page* 417. † Record, *July*, 1951, *page* 307.

ticularly costly, it is objectionable because the clippings may fall among the conductors and exposed conducting parts of the apparatus. Even though equipment assemblies are vibrated to dislodge such clippings, it is difficult and time-consuming, and therefore expensive, to search for clippings that remain. Sometimes clippings produce intermittent troubles that may not be found until the equipment has been in service for some time. Eliminating the clipping operation, and therefore these possible electrical crosses and grounds, results in a higher quality product at less cost.

Realizing that the wrapping method offered these and other advantages, Western Electric decided to employ power-driven tools instead of pliers to attach wires to terminals. Figure 1 illustrates the electrically-driven tool used at some Western Electric plants; other plants, such as Hawthorne, use an air-driven tool. Results with both tools are the same. Figure 2 shows the construction of one type of tip used in these tools.

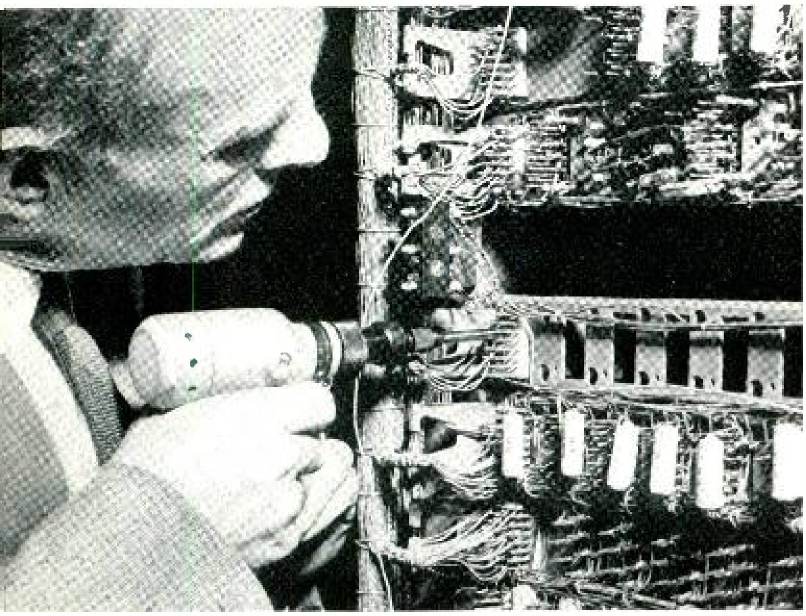


Fig. 1 — V. F. Bohman uses an electrically-driven wrapping tool on a D-type molded terminal strip. This strip is mounted in an experimental installation of wire-spring relays.

During experimental work at the Laboratories, it was found that with a suitable number of turns and a properly designed wrapping tool, it was possible to wrap wire so tightly around a terminal having reasonably sharp edges that a reliable connection could be obtained without solder. This immediately suggested the possibility of using solderless connections for practical applications. The important question involved in solderless connections was the question of reliability. Would there be a risk of these connections becoming unreliable – especially with a life objective of forty years? A solderless wrapped connection, compared with one that is soldered, has greater uniformity because of the use of a calibrated tool. Although soldering gives an excellent connection when properly done, a poor soldering job is also comparatively easy to do. A soldering copper of the wrong temperature or a joint that is not clean can mean a poor connection, and solder-splashes dropping onto apparatus or wiring may cause crosses or grounds. In addition to being more compact, the solderless wrapped connection also eliminates a hazard from hot soldering

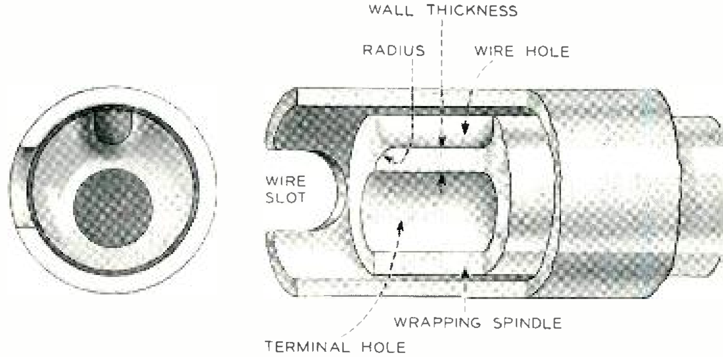


Fig. 2 — The tip of a wrapping tool has two parts. A central core has two holes, one each for the wire and the terminal, and an outer sheath has a slot for locating the wire relative to the tool.

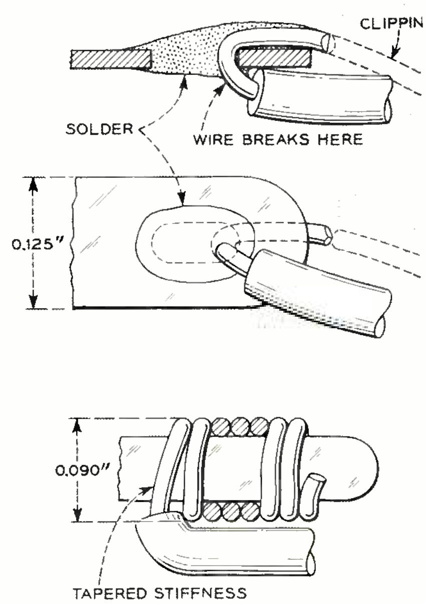


Fig. 3 — A soldered wire connection produces an abrupt change in cross-section at the point where the wire and solder join. A solderless wrapped connection, on the other hand, provides a tapering approach to the connection, with a gradual increase in its rigidity.

coppers — possible damage to heat sensitive material in circuit components and contact contamination from soldering fumes. The solderless wrapped connection can also be more readily disconnected, especially where the terminals are closely spaced.

While data indicate that solderless wrapped connections are satisfactory at the time of manufacture, how long will they remain so? Fortunately, the Laboratories had had previous experience with such connections. For over twenty-five years, spade-type cord tips had been attached to tinsel cords by forcing a sharp point, sheared out of the shank tip, through the textile insulation of the cord and into the body of the conductors. About 1942, this general idea was applied to the wiring of step-by-step banks. Today, millions of such connections are turned out by the Western Electric Company in automatic machines. The experience and testing techniques resulting from this development provided a background upon which to proceed with the "solderless wrapped connection" project.

To enumerate all the steps taken, the pitfalls and problems encountered, would serve little purpose. However, the manner of making wrapped connections and the method of test are of interest. With some tools, a wire could be wrapped so tightly onto certain terminals that it was impossible to remove it by unwrapping without the wire breaking; it could, however, be removed by a tool similar to a wheel-puller. Also, if a wire were wrapped too tightly, there was the hazard of its breaking as it was being wrapped.

Breakage during wrapping or unwrapping is not the problem; a wire that is prone to break has been overstressed, and such a wire might well break in subsequent service if subjected to vibration. Control of the wrapping action by the design of the tool avoids such excessive over-stressing. In a soldered connection, Figure 3, the abrupt change in cross-section from the wire to a lump of solder localizes stresses in the wire. In a wrapped connection, there is no abrupt change in cross-section and less localization of stresses. Tests have shown that a properly wrapped solderless connection is less likely to fail from breakage of the wire than is a connection that is soldered.

In the process of wrapping a wire to a terminal having a round cross-section, the wrapping forces are distributed fairly uniformly over the terminal surface but the wire tends to unwrap slightly after the connection has been wrapped. However, when the cross-section is square, or nearly so, the forces are concentrated at the edges, Figure 4. Under this condition, the wire will cut through the edges and the terminal will simultaneously cut into the conductor, locking the turns on the terminal as the connection is being wrapped. This leaves a number of bright and clean metallic surfaces in contact with each other, and such a connection is gas tight. After it is exposed to high humidity or to corrosive fumes for extended periods, the surfaces continue to remain in intimate contact and, when unwrapped, show a bright untarnished surface.

The Bell System must annually provide new apparatus for customer lines and for central offices, not only to take care of new customers but also to maintain existing facilities in first-class operating condition, and interconnecting all the apparatus and lines requires many millions of connections. To

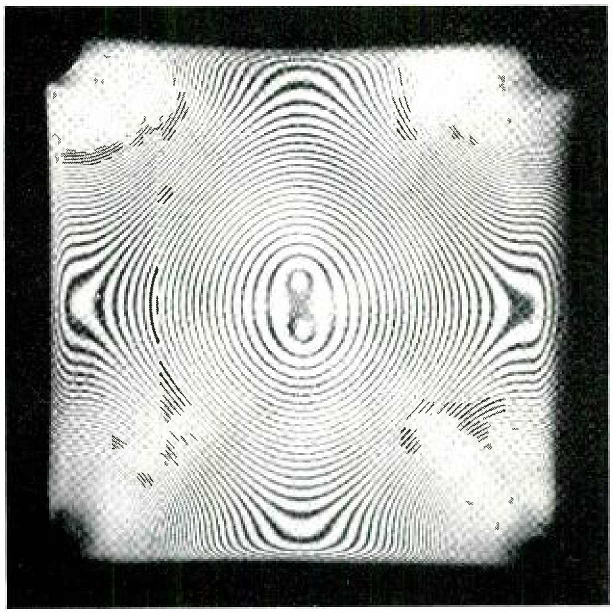


Fig. 4 — A photoelastic model of a square terminal shows this pattern of internal stresses when the terminal is wrapped.

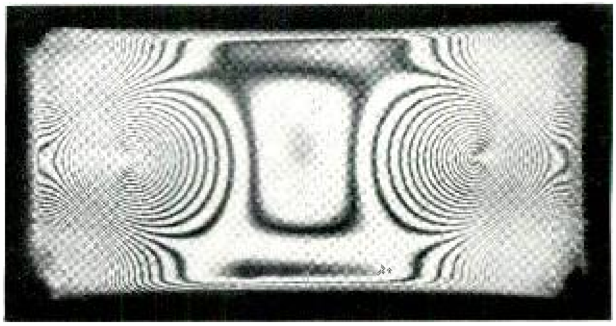


Fig 5 — A rectangular photoelastic model of a terminal shows these stresses.

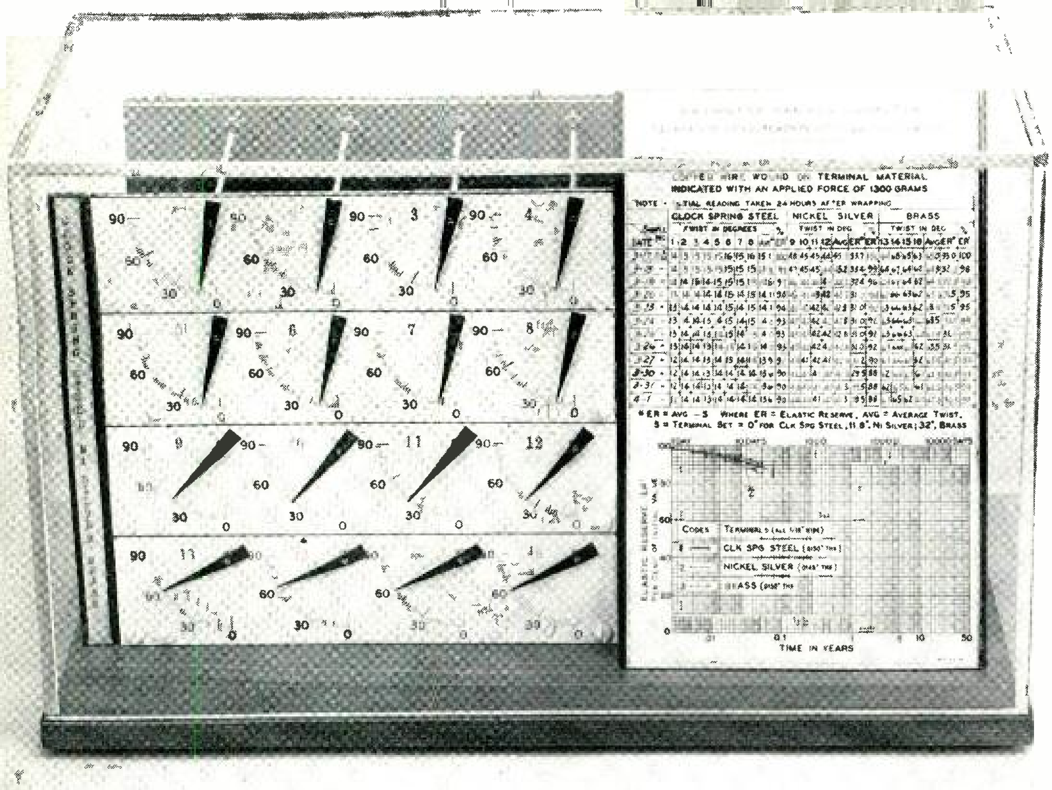


Fig. 6 — Four types of terminals are under a semi-permanent test in this device. These sealed connections provide a continued check of extrapolated data throughout the next forty years.

maintain a high quality of service performance, it is important that there be few, if any, failures of these connections. The question arises, how can we be sure that in replacing a soldered connection with a solderless wrapped connection we are not jeopardizing the performance of the telephone system? This matter has been given considerable study at the Laboratories; in so doing, the skills of many Laboratories and Western Electric engineers have been called into service. It is not purely a matter of making a wrapped connection and testing it; obviously it is not possible to wait for many years to find out whether or not a connection remains a good one. Fundamental studies were made by the Laboratories' Research Department of stress relaxation in materials used for wires and terminals. In these studies, over-sized terminals and wires made of plastic materials were employed, so that photoelastic analysis of the connections could be made, such as shown in Figures 4 and 5.

It was concluded from these tests that residual forces in the connections were sufficiently large and stable to insure a satisfactory life with the types of connections tested. In addition, a large number of actual connections were exposed to extremes of temperature, humidity, vibration, gas fumes and excess current over extended periods of time. Contact noise measurements were made over a wide

THE AUTHOR

John J. Kuhn, Sr., started his Bell System career forty-four years ago at the Western Electric Company where he was concerned with the design of telephone and telegraph apparatus and later engaged in supervisory work on the design of public address equipment. He continued in the same field in 1925 when his Western Electric department was incorporated in the Laboratories. He has since supervised design work on sound recording and reproducing equipment, station apparatus, and switching apparatus. During World War II he was in charge of production design of several military projects including the electrical gun director for which he shared the award of the Medal of Merit. In 1946 he resumed responsibility for a group engaged in switching apparatus development, later taking charge of the design work on central office apparatus and tools. He was transferred to Whippany in August, 1953, as Director of Electromechanical Development of Military Apparatus. Mr. Kuhn is a life member of the New York Microscopical Society, and a member of the American Ordnance Association.

range of frequencies and electrical current values. Mechanical tests were made to insure that such a connection was mechanically capable of withstanding the handling it would receive in manufacture, shipment, and installation.

Trial installations were made of wired equipment in which wrapped connections were employed along with soldered connections, and some of these have been in service in central offices since 1951. Subsequently, the Western Electric Company was authorized to introduce solderless wrapped connections on the full production of some selected equipment items in step-by-step and crossbar systems, as well as in cable terminals. This was done to permit the shops and the Installation Department of Western Electric to obtain first-hand experience with this new type of connection, and thereby to enable the production organizations to obtain advance information in preparation for a large scale introduction of this method. By this step, they could determine such factors as the time elements involved, facilities needed for making such connections, the best arrangement of apparatus, wire, and tools, and thereby obtain the most efficient working arrangement.

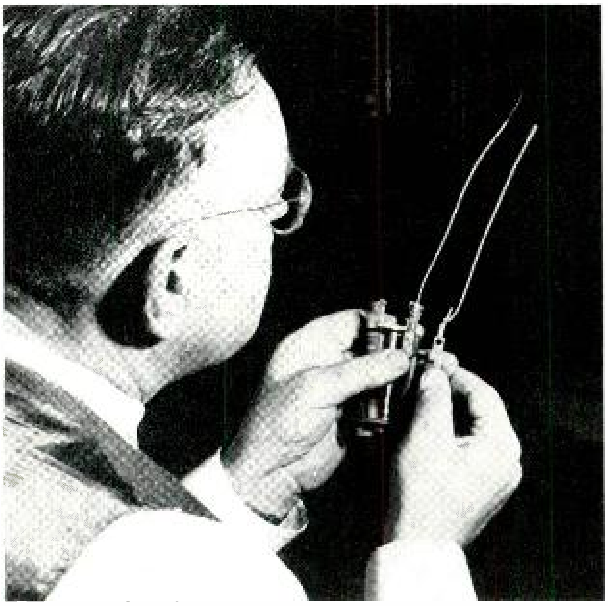


Fig. 7 — L. Soucek compares the old and new types of terminals for standard relays.

Coincident with the approval, on a limited production basis, of this method of connecting No. 24 gauge copper wire — employed for ninety-five per cent of connections between coded units — Western Electric was also given an inspection procedure by the Laboratories' Quality Assurance Department by which the quality of a finished connection could be evaluated. This procedure provides for checking the ability of wrapping tools to make satisfactory connections on samples of terminals rather than on production connections thereby avoiding disconnections on finished products.

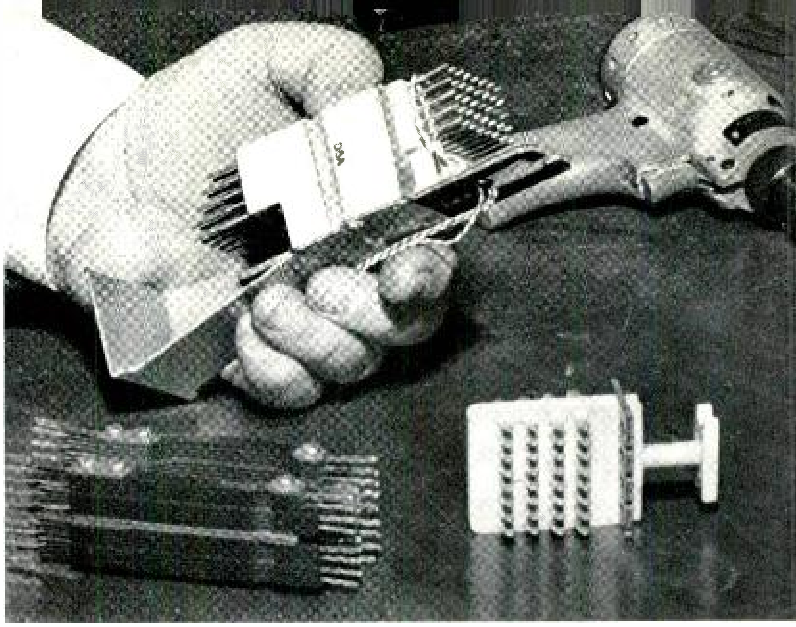


Fig. 8 — The D-type molded terminal strip shown here is used with wire-spring relays. It will replace either of the two types of terminal strips shown in the foreground.

It is expected that adopting this new method of connecting wires to apparatus will eventually result in changes in practically all apparatus terminals. However, new terminal designs are still being developed and continual tests are being made. As an example, Figure 6 shows a life test of four solderless connections on different materials. This apparatus is sealed, and will be a continuous and accurate check on present estimated life figures extrapolated from the results of many studies.

In the interim, wire terminals modified to accommodate solderless connections have been specified for wire-spring relays. Furthermore, a new plastic-covered wire with a smaller outside diameter than that previously used has been developed to complement the use of solderless connections where terminals are closely spaced. On relays used with step-by-step equipment, the flat terminals have been changed as shown in Figure 7. On other relays such as the U, Y, and UA, the terminals can be similarly modified. A new connecting block with cast-in square wires, Figure 8, is replacing conventional punched-terminal connecting blocks. Investigations of connections employing other than No. 24 gauge wire, in addition to new terminal designs, are now in progress.

E. J. Flannery heat treating vacuum tube parts ***in a tube laboratory oven.***

Making Tubes for Research

J. R. PIERCE *Electronics Research*

All researchers in the field of vacuum tubes, whatever the exact nature of their work, must have special, novel and usually difficult tubes made for them. To make such experimental tubes, a well equipped tube laboratory has been established where highly skilled workers using precise machines and techniques fabricate individual tubes to meet specified requirements.

Members of the Electronics Research Department at Bell Telephone Laboratories are engaged in a variety of projects. The ultimate object of all of them is to enable us to do new things, or to do old things better, in some part of the communications field. In this general effort to advance the art, some research physicists and engineers are seeking fundamental knowledge concerning such things as noise in electron flow, focusing of electron streams, and the non-linear behavior of electron flow at large signal levels. Such knowledge is necessary in order to understand the behavior and to help remedy the failings of existing electronic devices. It may also point the way toward new and useful inventions. Other scientists, having thought of new ways to accomplish useful results, are trying out and evaluating their ideas. Still others have marshaled their knowledge and are making a few advanced, experimental tubes which may enable researchers in other departments to accomplish new things.

Although part of the work of these men is concerned with theory and design, and can be done with pencil and paper, the actual building of experimental vacuum tubes is essential to all of these activities. Network designers, who compute the requirements for filters and equalizers, can, in their calculations, take into account essentially all the physical properties that are important to the electrical performance of their devices. Vacuum tubes are much more complicated. Theories are always incomplete, and although they may point the way toward what should be done to get a desired result, they neither solve a problem exactly nor take account of interfering phenomena which continually plague those who work with electron tubes.

Furthermore, the actual fabrication of electron tubes is an extremely difficult art. The internal parts of many of these devices are as complex as any piece of microwave plumbing. Yet, they have to be clean enough and tight enough to maintain a high vacuum; they have to withstand baking at several hundred degrees centigrade, and they must accommodate a hot, electron-emitting cathode which is extremely susceptible to contamination by small traces of various chemical elements or compounds.

Thus, the success of an electronics research department is completely dependent on the ability to fabricate complicated objects with great accuracy and cleanliness. In tube manufacture this is successfully accomplished after a long period of design, trial lots, and life tests. In electronics research each

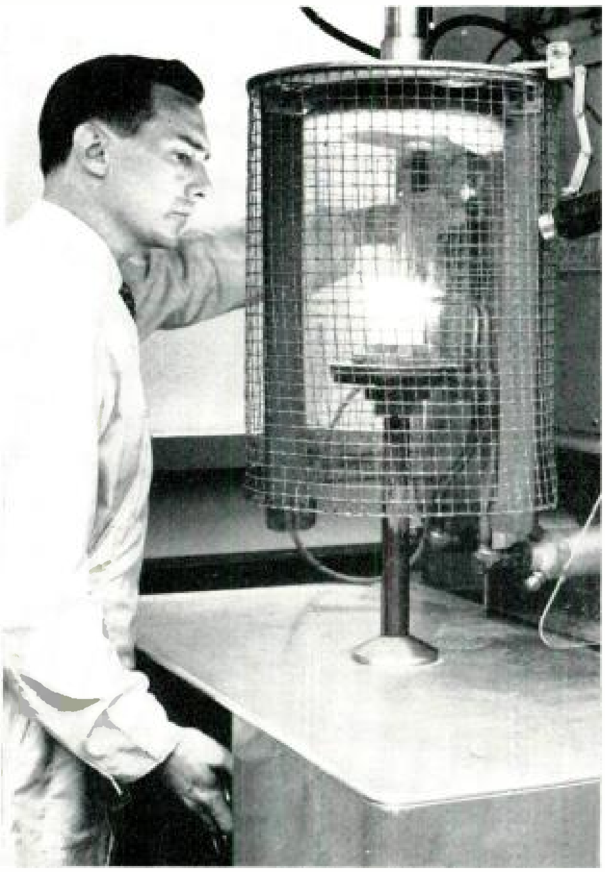


Fig. 1 — P. M. Ness working with a radio-frequency induction heater.

Fig. 2 — Miss M. R. Daly spraying a cathode.

individual worker must somehow be provided with the facilities for making these difficult and exasperating devices quickly, without an undue amount of drafting and engineering, and in a way that fits in with his own individual approach to his work.

This is particularly difficult because the trained engineer or physicist cannot be expected to master fully the knowledge and art needed to make the tubes he requires for his experiments. Nor can he set simple requirements which will assure that his aims will be accomplished. A man who wants a piece of precision machine work can, on one drawing, indicate tolerances which, if a part meets them, will assure its functioning properly. It is completely impractical to specify electrical, chemical and thermal as well as mechanical requirements in such a way that fabrication of an experimental vacuum tube becomes a mere matter of mechanical skill checked by measurement.

Necessarily faced with this difficult problem, the Electronics Research Department has provided a well-equipped, air-conditioned tube laboratory, in which all the processes necessary in fabricating a tube from accurately made metal, ceramic and glass parts are carried out by skilled men and women.

In order to avoid the need for the elaborate drawings and written instructions which would be required if various operations of tube making were done by different workers skilled in various arts, each worker performs all the work on an individual tube in close cooperation with the engineer or physicist for whom the tube is being made, excepting glass blowing only. This is done by a few expert glassblowers.

Thus, the making of a particular tube involves the skilled use by each worker in the tube laboratory of a great deal of common equipment. Although particular workers are given the responsibility for maintaining certain pieces of equipment and for

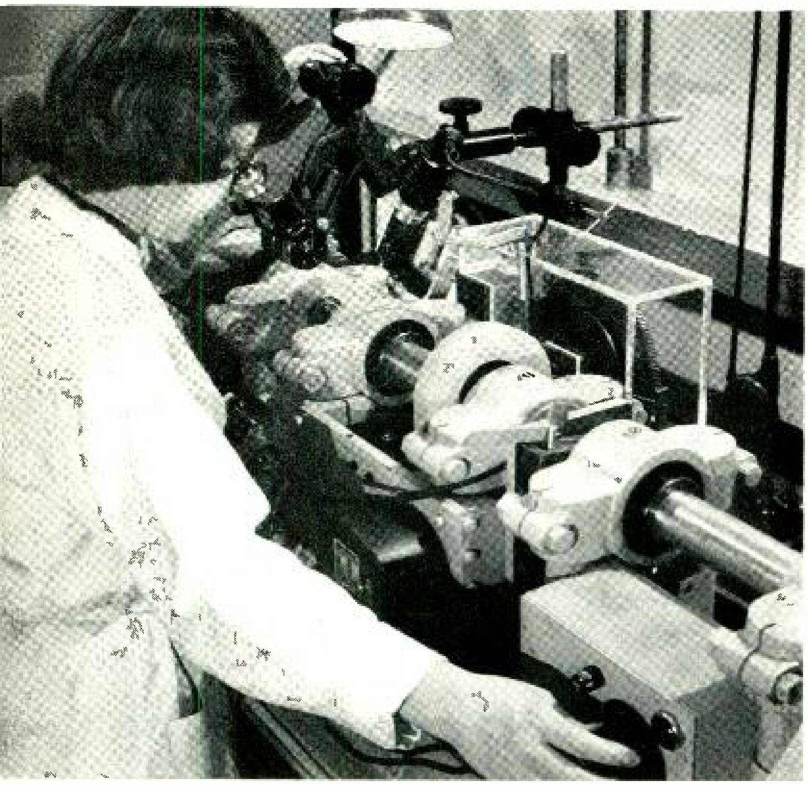


Fig. 3 — Miss A. A. Sciarrillo winding a vacuum tube grid.

consultation in regard to their use, the person who is making a particular tube is responsible for the use of the equipment in its fabrication.

What are some of the equipment and their functions? One thing absolutely essential in the making of successful tubes is the inspection and measurement of parts. One tube, for instance, involves machining into a copper ridge an array of many slots, each four-thousandths of an inch wide, spaced twenty-thousandths of an inch apart. Such structures must not only be inspected, but sometimes they must be straightened and deburred. For such work, the laboratory is provided not only with ordinary microscopes and a toolmakers' microscope, but with optical projection equipment of greater accuracy as well. A polariscope is also provided for inspecting glass parts for strains.

There is a special room in the tube laboratory for chemical cleaning and plating. Here parts can be degreased with various solvents, cleaned with a device known as a "liquid honer" which is a sort of water-and-sand-blast, or chemically cleaned of oxides before they are assembled, after they are heated, or prior to electroplating or other cleaning. Parts are also plated with various metals in this room. Sometimes jig or spacers of one metal must be dissolved out of a completed structure with acids. Each worker must know how to carry out these processes safely and must have some idea of why they are used and when they should be used. If difficulties arise beyond the skill or knowledge available in the tube laboratory, the workers may consult members of the Chemical Department.

Ovens such as that shown in the first page of this article are located in another part of the laboratory. All metal and ceramic parts must be cleaned prior to their use in vacuum tubes by heating them to a high temperature in hydrogen or in a vacuum. For some purposes, chrome or stainless steel must be deliberately oxidized by heating it in wet hydrogen. Carbon may be removed from nickel by treatment in wet hydrogen. Sometimes the hydrogen must be dried to avoid oxidation. Heating serves other purposes as well. Helices wound of springy tungsten or molybdenum wire must be fired to "set" them. Metal parts are joined to metal with a variety of hard solders which melt at various temperatures. In making a complicated structure, several solders with different melting points may be used as various parts are successively added. Ceramics are also soldered to metal by a complicated process of many stages. Tube laboratory workers must be able to understand and carry out all these processes.

In some cases tube parts are heated, not in ovens, but by radio frequency heating, as shown in Figure 1. For this purpose, a 25-kw, a 10-kw, and a 5-kw radio frequency induction machine are made available, together with auxiliary equipment such as a bell jar in which parts may be heated in a mixture of nitrogen with a little hydrogen (forming gas),

Fig. 4 — J. J. Darold assembling the minute parts of an experimental vacuum tube.

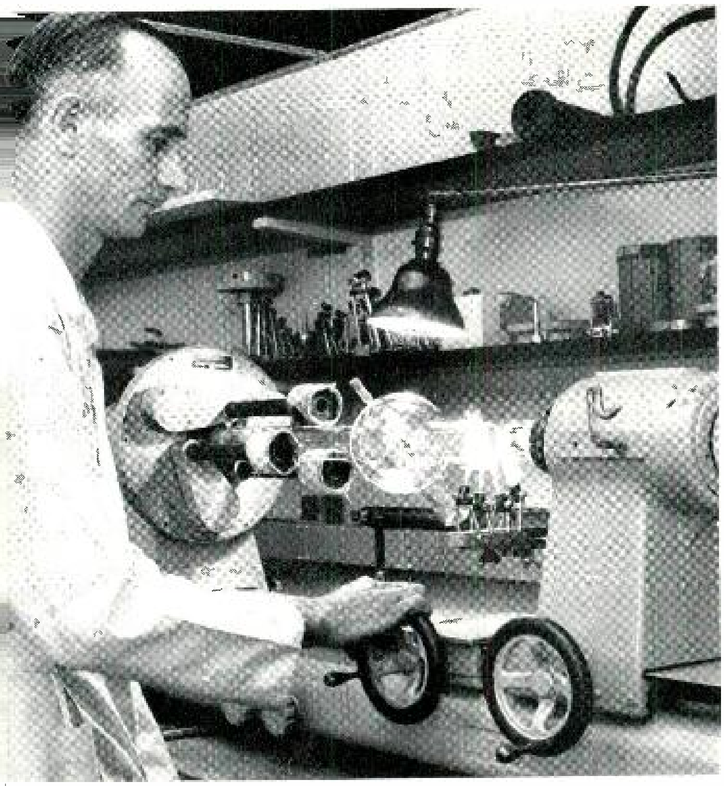


Fig. 5 — E. F. Schneller making a glass trap on a mercury diffusion pump.

and vacuum pumps so that parts can be heated in a high vacuum. Radio frequency heating is used to clean and to solder metal parts and sometimes to make tube stems (through which lead wires go) by a molding process, using powdered glass in graphite molds.

Cathodes, which emit the electrons necessary for the operation of vacuum tubes, are formed by spraying just the right amount of emissive coating on properly treated nickel, under conditions of scrupulous cleanliness. Figure 2 illustrates this coating process. A special room is provided for this work, and a chemical balance is included for weighing the part before and after coating to determine the coating thickness. In this room, fine coils of tungsten wire which are used to heat the cathodes are also sprayed with aluminum oxide, to insulate them.

Sometimes, grids or helices must be wound, and for this the special winding machine illustrated in Figure 3 is provided. This machine can hold fragile work supported at both ends between two rotating chucks. Sometimes the wire is annealed by heating it electrically as it passes through a hydrogen-filled box just before winding. With this machine it has been possible to wind 800 turns per inch of wire 0.0003 inches in diameter around a wire 0.005 inches

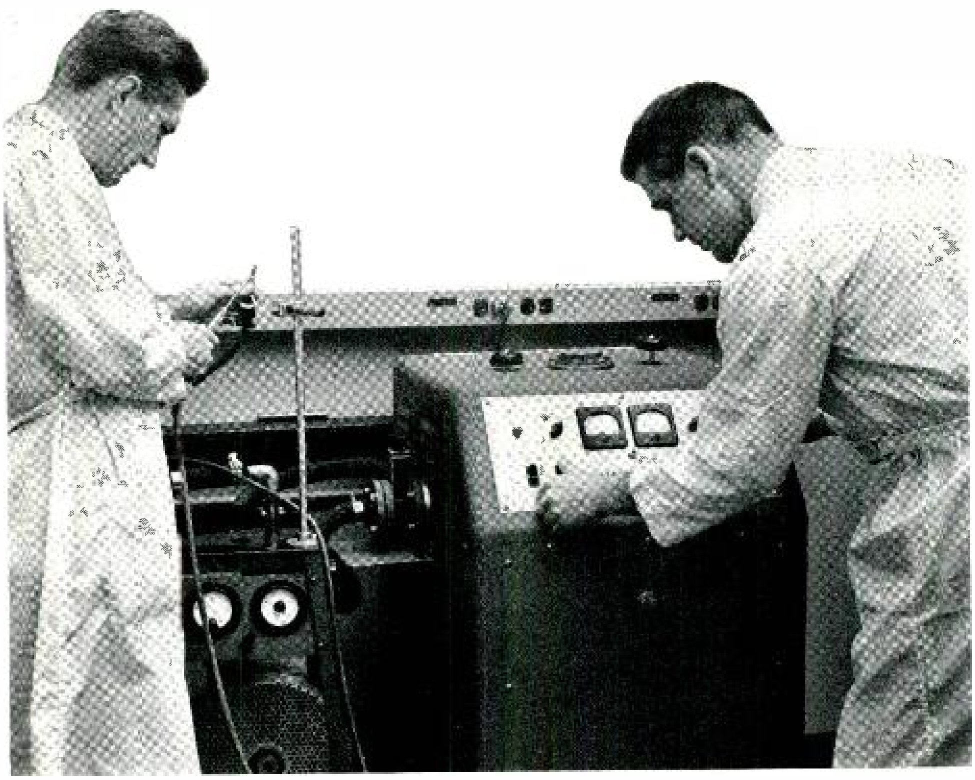


Fig 6 — W. H. Yocom (right) and A. R. Strnad testing for leaks in a metal-ceramic seal.

in diameter. Other special pieces of equipment which must sometimes be used include a surface grinder, a buffing surface for polishing, and a Pistorious wheel for cutting glass and ceramics.

Final assembly work is carried out in rooms with special fluorescent ceiling lights which give a light level of 120 foot-candles at the bench top. This avoids the use of local lighting except for microscope lights. Assembly work, shown in Figure 4, may consist of stacking or bolting parts together accurately, of welding them together with a variety of spot welding machines, of a long series of jigging and soldering operations, of welding with a Heliarc welder, and of other operations. Much of the finer work is done by using special tools and jigs under binocular microscopes. This assembly, of course, involves careful measurements and checks.

There is a good deal of glass work in the making of most tubes. This is partly in the blowing of bulbs and in the fabrication of stems and in sealing these together on horizontal or vertical glass lathes or on a vertical seal-in machine. Figure 5 shows the use of a horizontal lathe. Glass work includes much more besides. Wires must be sealed through metal eyelets with accurate glass beads. Optically polished windows must be sealed into the holes in metal caps. Glass bulbs must be shrunk onto accurately ground metal mandrels which give them their final shape. Glass or quartz must be shrunk on fine coils or helices to support them. Most of this work is done by skilled glassblowers.

The final tube, presumably vacuum tight, is tested for leaks with helium, using the mass-spectrometer type leak detector shown in Figure 6. This leak detector, is also used to test the individual parts of the tube during assembly.

As a final step an experimental tube must be pumped, baked, and the cathode activated. Usually the technician follows this process with interest, for only when it has been completed does the process of tube-making truly cease. Beyond that point his direct responsibility does not extend, but one doesn't wonder when he finds a man from the tube laboratory hovering around the test apparatus with personal solicitude. For, together with the engineer or physicist for whom the tube has been built, W. H. Yocom who is in charge of the tube laboratory, A. R. Strnad his assistant, and D. J. Brangaccio who plays an important part in the functioning of the laboratory, he is part of a team which is jointly responsible for the successful completion of a research project.

THE AUTHOR

John R. Pierce, Director of Electronics Research, has been a member of the Laboratories since 1936, specializing in the development of electron tubes and microwave research. During the war years his efforts were devoted almost exclusively to the development of electronic devices for the armed services. Since then he has been engaged in research on the traveling-wave tube and other electronics devices. He assumed his present position early in 1952. Mr. Pierce received his B.S. (1933), M.S. (1934) and Ph.D. (1936) degrees in E.E. from the California Institute of Technology. He is a member of Tau Beta Pi, Eta Kappa Nu and the A.I.E.E., as well as a fellow of the I.R.E. and the American Physical Society. He was voted "Outstanding Young Electrical Engineer of 1942" by Eta Kappa Nu and in 1947 he won the Morris Liebmann Memorial Prize of the I.R.E.

Equipment installed in the Newark 4A toll office, for which a large amount of automatic alternate routing is provided.

Automatic Alternate Routing of Telephone Traffic

C. CLOS *Switching Engineering*

Automatic alternate routing is one of the more important features of switching equipment that permits the dialing of dial toll calls to points in the United States and Canada. This equipment determines the destination of the call and finds a communication channel in the proper direction. If the more direct paths are busy, it then selects a channel to a intermediate toll switching center, which in turn will send the call forward over this alternate path. These switching machines can, moreover, search for an idle channel from among several alternate routes. An extensive body of traffic theory and mathematical analysis lies behind the techniques used and the safeguards provided to permit flexibility, insurance against delays, and economical use of toll communication paths.

In the present expansion of toll dialing facilities in the United States and Canada, there has been a modest and almost unheralded introduction of automatic alternate routing of operator-dialed intertoll traffic. It is expected, however, that full scale operation of this feature will occur in a few years for both operator and customer dialing when many automatic toll switching systems will be in service and when there will be sufficient outside plant facilities in the so-called final or backbone routes. This article explains some of the features, theory, economics and applications of this switching method.

Actually, alternate routing is not a new concept. It may be thought of as a helping hand. When one means for accomplishing a task is unavailable, an alternate one may be called upon for assistance.

Fig. 1 — The author inspecting a card translator, which is the heart of the equipment necessary for the automatic alternate routing of traffic.

In non-telephone fields, there are many illustrations of the use of alternate routing; a familiar one is a motorist's use of secondary roads to avoid congested highways. It has also been in use for many years in telephone switching on a manual basis. For instance, a New York long-distance operator might try to complete a call to Pensacola. If all the direct trunks to Pensacola are busy, she may then look for an alternate route and finally complete the connection by switching the call via Atlanta. Operators at PBX switchboards also frequently use alternate routing. A PBX operator at Bell Telephone Laboratories, for example, has a number of tie lines direct to the PBX at the American Telephone and Telegraph building. If all these tie lines are busy, it is not unusual for her to route a call over an outside line; that is, over the regular telephone switching facilities.

With dialed calls where the operator or customer can dial only one code or group of numbers on a given call, a more involved concept is required. This is because dial equipment lacks the judgment possessed by operators which permits them to select an alternate route without misrouting the call. As a consequence, intelligence of limited scope must be built into the dial equipment. With alternate routing of the automatic variety, the machine is endowed with the power to decide when an alternate route is necessary and to select the route, with neither the operator nor the telephone customer knowing that an alternate route has been selected.

On many highways, motorists are kept from going astray by the use of road blocks where side roads are to be avoided. In an analogous manner, dialed calls that have reached an alternate route require a "road block" to keep them from creating an unnecessary buildup of circuits. Two such situations may occur — one causes a call to be shuttled between two offices and thus makes all available circuits in between busy, and the other situation, known as "ring around the rosie," results in one or more rings of circuits being built up around the desired terminating office. To prevent these situations, arrangements equivalent to highway road blocks are provided.

Figure 2 illustrates both situations. Consider a call from New York City to Scranton. If the alternate route for traffic from New York to Scranton is via Philadelphia, and if the alternate route for traffic from Philadelphia to Scranton is via New York, it is possible to shuttle a call back and forth between New York and Philadelphia when all trunks from these two cities to Scranton are busy. The call could go out from New York to Philadelphia and be switched back to New York on a sec-

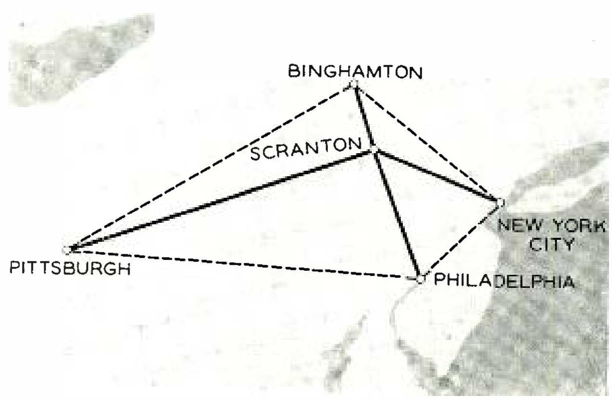


Fig. 2 — Arrangement of direct and alternate routes that might result in "shuttling" or "ring around the rosie" if no routing restrictions were imposed upon the circuit.

ond trunk; it then could be switched to Philadelphia again on a third trunk, and so on until all the spare circuits are engaged and the call reaches an NC (no circuit) trunk. If, however, before an NC circuit is reached, a circuit to Scranton becomes free, it will be seized and the call completed, with a monstrous built-up connection remaining in use for the duration of the conversation. This condition would make otherwise idle circuits unavailable for other traffic.

For the "ring around the rosie" situation, consider another call from New York to Scranton. The alternate route is again Philadelphia, and in addition, the alternate from Philadelphia is Pittsburgh, the alternate from Pittsburgh is Binghamton, and finally, to complete the circle, the alternate route for calls from Binghamton to Scranton is via New York City. If all the direct trunks from the four cities to Scranton are busy, the call from New York City would be switched clockwise around the circle. As in shuttling, undesirable build-ups would occur.

There are several plans for preventing the foregoing situations. All involve some form of "road block" or restriction in the routing plan. For instance, the restriction might be that at Philadelphia, no further alternate routing would be permitted for traffic from New York to Scranton.

With such limitations in an alternate routing plan, the simple qualitative helping hand concept must yield to a more formal one based on mathematical data. From the theory of probability concerning the traffic-carrying capabilities of trunks, two facts can be obtained. The first is that if a given amount of traffic is offered to a trunk group, and if the trunks are selected in consecutive order, each succeeding trunk carries a smaller share of the traffic. That is, the efficiency of each succeeding trunk diminishes. This is illustrated by Figure 3 for five "erlangs" of traffic, which is a traffic load equal to an average of five simultaneous calls offered to the trunks. The grade of service is here assumed to be three calls delayed in every hundred calls that are made.

The second fact can be seen by considering a situation where the traffic increases, instead of remaining at a given level. If more trunks are added to maintain a constant grade of service, it can be shown mathematically that the additional traffic is handled at a high degree of efficiency in terms of the extra trunks added. This fact is seen in Figure 4, which, like Figure 3, assumes a grade of service of three calls delayed in every hundred.

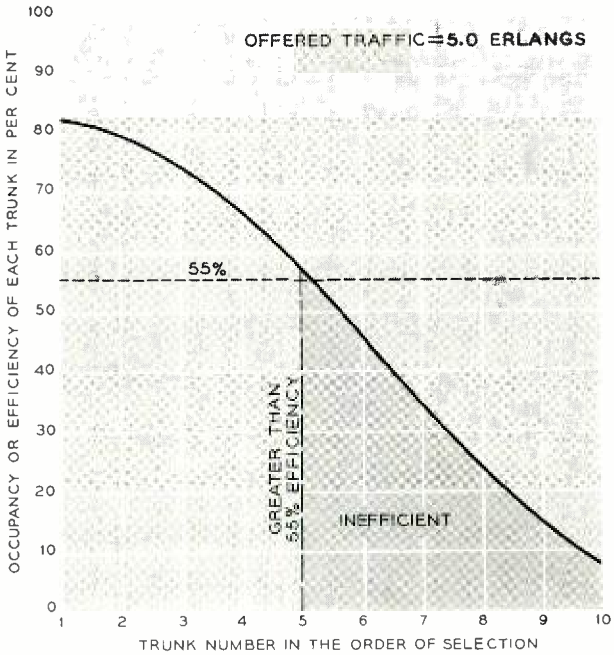


Fig. 3 — This curve shows that for a given amount of traffic offered to a trunk group, each succeeding trunk carries a smaller share of the traffic.

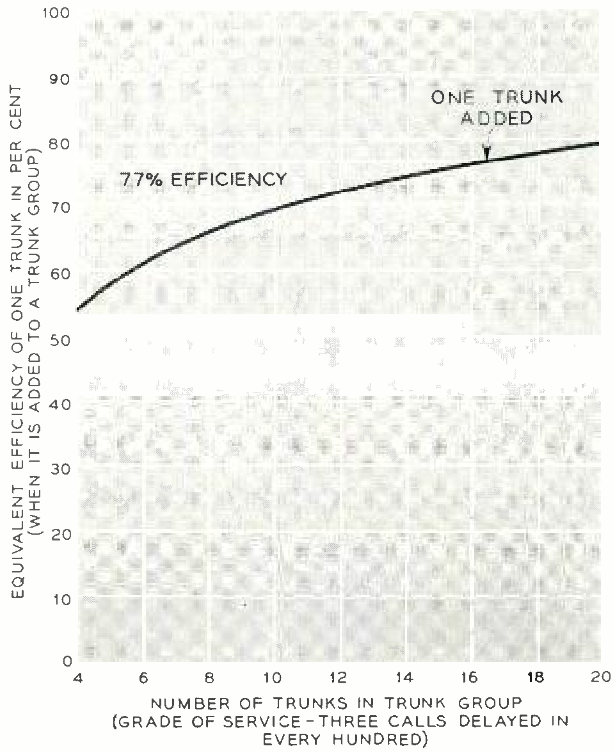


Fig. 4 — Curve illustrating the increased efficiency of a trunk when added to other trunks during periods of increased traffic.

The theoretical justification for alternate routing stems from these two facts. Consider the trunking layout shown in Figure 5. Here it is assumed that, with no alternate routing, ten trunks are required in the A-B route and sixteen trunks in the A-C and C-B routes. By eliminating five trunks in the A-B group and by routing via C the traffic the five trunks would have carried, it can be shown that only two additional trunks are required in each leg of the alternate A-C-B route.

This saving, however, must be balanced against additional expenses not encountered in providing direct routes. Figure 5 shows the alternate route to be longer than the direct route. This is a cost penalty chargeable to alternate routing. Other items involving cost penalties are (1) more complicated switching control equipment at the originating office, (2) switching equipment on the alternate route, and (3) in some switching systems, more stringent transmission requirements for the alternate route. Before we can visualize the savings resulting from alternate routing, we must consider these items individually.

(1) The control equipment at the office where automatic alternate routing is to be accomplished is an important element in any automatic alternate routing scheme. It consists of equipment for receiving and storing code information, for testing trunks and selecting an idle one, and for transmitting code information to the switching office on the alternate route. Depending upon the codes used, the complexity of the routing problem, and the types of switching equipment used, the control equipment may take on many different forms with respect to its components, how they function, and where they are located. Where complete freedom exists between the coding scheme and the trunking layout, senders and markers, and in some cases, decoders and card translators will be found.

(2) Many types of dial equipment are available for use at the switching office on the alternate route. These are—step-by-step selectors, No. 5 crossbar, crossbar tandem*, panel sender tandem or one of the No. 4 toll crossbar systems†. In the local field the calls are customer-dialed with the usual switching equipment being a crossbar tandem office. For long distance calls, the usual arrangement provides

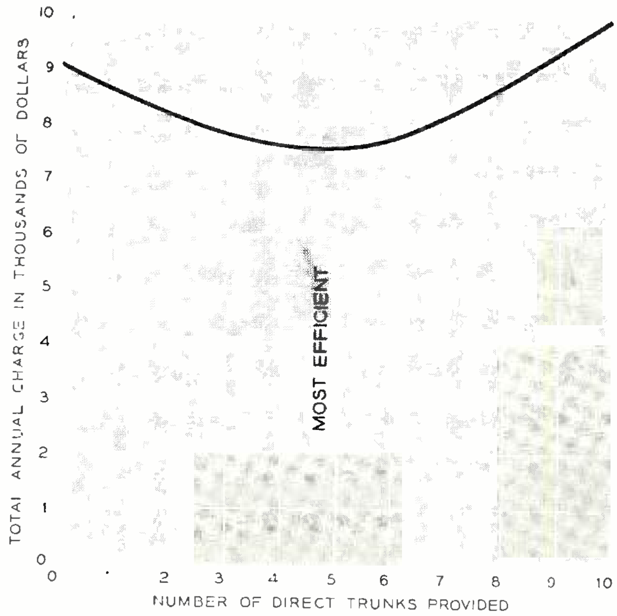


Fig. 6 — Example of how the total annual charge may vary with the number of direct trunks provided. The dip in the curve shows that the most economical operation is achieved when only five direct trunks are provided, and when the rest of the traffic is automatically alternate routed.

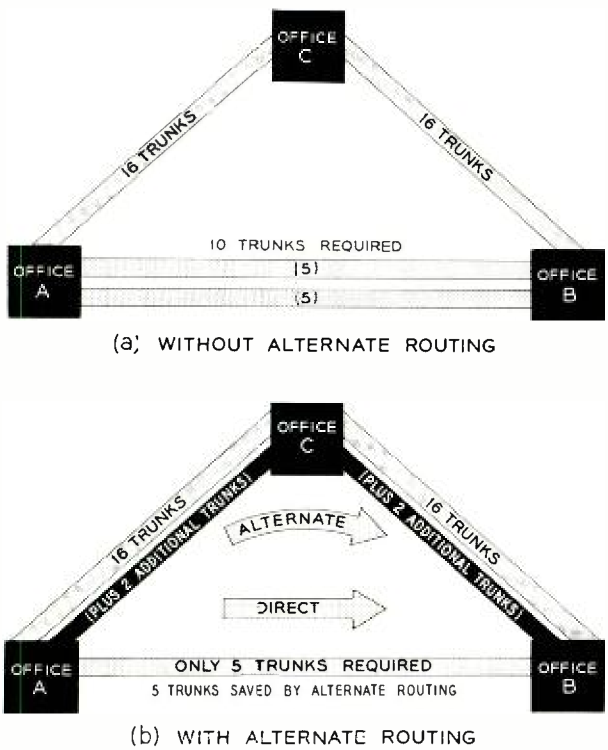


Fig. 5 — Diagram illustrating the saving of trunks accomplished by alternate routing.

* RECORD, *August*, 1942, *page* 286. † RECORD, *April*, 1944, *page* 355, and *October*, 1953, *page* 369.

for either one of the No. 4 crossbar systems or the crossbar tandem system, all of which accept alternate routed traffic and in turn select alternate routes to other offices.

(3) Because the trunks used on alternate routes must meet transmission and signaling requirements for a larger variety of offices, the better grades of circuits are in general assigned to the alternate routes. This, plus the fact that alternate routes are generally longer, may result in costlier trunks than those required for the direct routes.

Even though there are the above three disadvantages for automatic alternate routing, it is still economically advantageous because the traffic engineer is able to substitute more efficiently used alternate route trunks for less efficiently used direct trunks. This substitution can be made even though an alternate route trunk is more costly than a direct trunk. Specifically, the substitution can be made up to a break-even point. This will be demonstrated for the trunking layout shown on Figure 5, using the data assumed on Figures 3 and 4 and assuming that the cost of an alternate route – consisting of a trunk from A to C, switching equipment at C, and a trunk from C to B – is 1.4 times that of a direct trunk. Actual studies show that the cost ratio usually lies somewhere between 1.0 and 2.0.

Figure 4 indicates that when one trunk is added to sixteen other trunks to provide for increased traffice, it has an efficiency of 77 per cent. To find the efficiency of the less costly direct trunk at the break-even point, it is necessary to divide 77 per cent by the 1.4 cost ratio. The result is 55 per cent. In other words, when a direct trunk is 55 per cent efficient, it is at the break-even point. Referring to Figure 3, the fifth trunk is slightly more efficient than 55 per cent, the sixth and subsequent trunks are less efficient. Hence, for this case, the greatest economy for alternate routing occurs when five direct trunks are provided.

A slightly different aspect of the economy of alternate routing is shown in Figure 6. Here the total cost of handling a given volume of traffic is shown. The cheapest arrangement occurs when five direct trunks are provided and when the overflow traffic is handled over the alternate route. An interesting feature is that the curve is relatively flat in the region of greatest economy. This indicates that one direct trunk more or less does not upset the over-all economy. This provides the routing engineer with leeway in engineering an alternate routing layout. Within limits he can substitute direct trunks for alternate route trunks and vice versa depending upon a specific surplus or shortage in a given route. The chart also indicates that automatic alternate routing is more economical than handling all of the traffic over direct trunks or all of it over the switched route. Without alternate routing, the only options available are those represented by the ends of the curve. With alter-

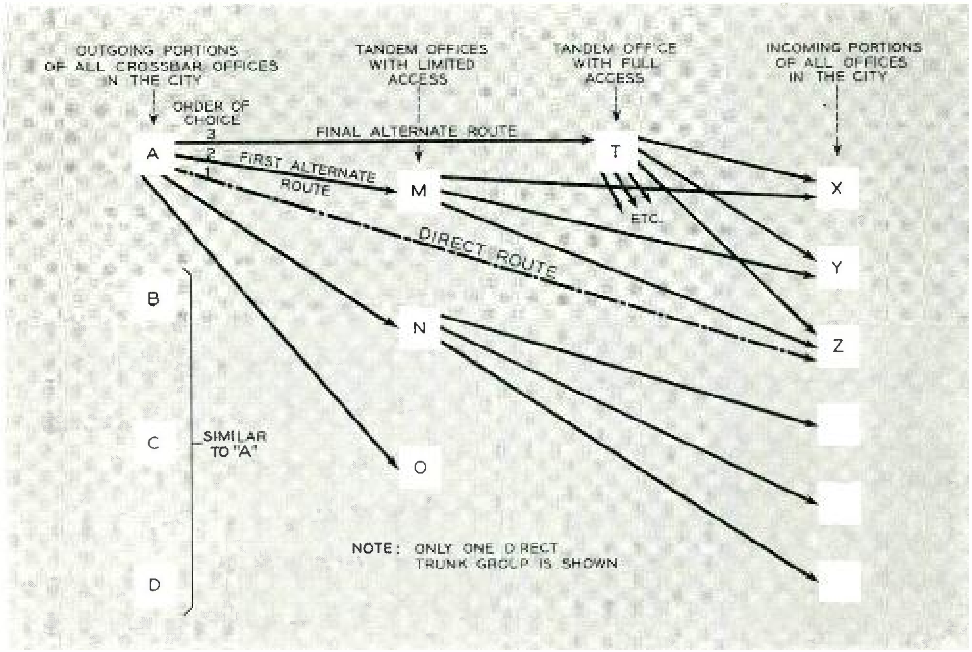


Fig. 7 — Multi-automatic alternate routing scheme used in a metropolitan area. The automatic equipment first tries a direct route, then an alternate route through a tandem office with limited access, and third, a tandem office with full access.

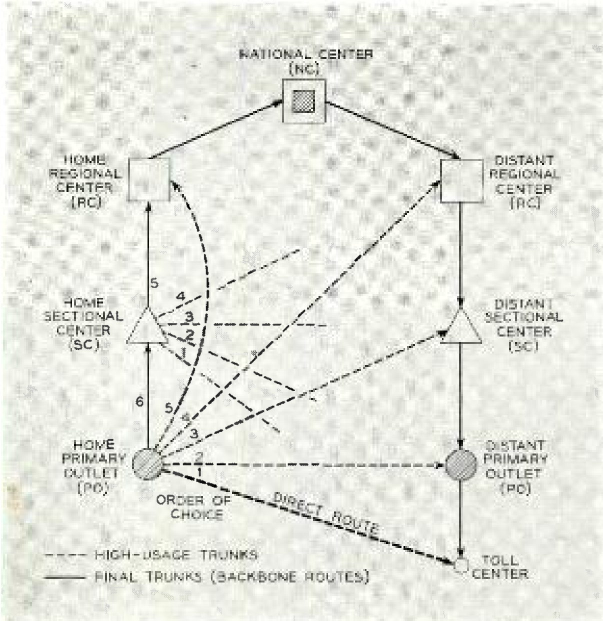


Fig. 8 — Automatic alternate routing with nationwide toll dialing. The automatic equipment tests various alternate routes according to a definite order of preference.

nate routing, the options represented by the broad central portion of the curve are available.

The ways in which these economies can be achieved fall into three broad categories, depending chiefly on the complexity of switching involved. The first can be termed "Single Automatic Alternate Routing," and can be expected in a city with a single tandem office. On a given call, local crossbar offices first test the direct trunks to the desired destination. If these trunks are busy, the tandem trunks are then tested. The route relays for the direct routes indicate that no office code digits should be transmitted. The route relay for the tandem route indicates to the sender the code information to be transmitted to the tandem office. Step-by-step areas, where the selectors are controlled directly from the dial pulses, do no use automatic alternate routing. But if step-by-step equipment were provided with senders or directors, it would be possible to use automatic alternate routing.

The second type, "Multi-Automatic Alternate Routing," is found in large metropolitan areas like New York City. In such areas there may be several tandem offices, some of which can reach only a few of the other offices in the area, while one or two can reach all offices. Figure 7 illustrates the routing scheme. Take for example a call from A to Z. At A the direct trunks to Z are tested first. Then trunks to a tandem with limited access are tested, such as those to M. Finally trunks to T, a tandem having full access to all offices, are tested.

With this type of multi-automatic alternate routing, the trunk groups in all alternate routes except the final one are reduced in size to avoid the inefficiencies that occur on last choice trunks of a trunk group. This reduction makes these trunk groups "high usage." At the tandem locations where outgoing trunks are liberally provided, when all outgoing trunks to a desired location are busy the tandem sender causes an NC (no circuit) signal to be returned to the customer. This is the "road block" on the routing plan, so that no further alternate routing takes place.

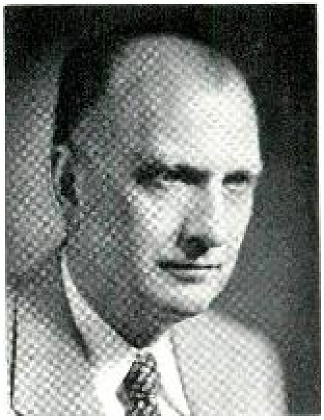
The third and most complex use of automatic alternate routing is found in nationwide toll dialing. This plan is an outgrowth of the multi-alternate routing scheme now in use in New York City and is made possible with the technical improvements furnished by the 4A toll crossbar system. This system can translate three and six digits, can spill (that is, transmit) all digits forward or all digits except the first three or first six; can prefix one, two, or three digits; and, by combining the spill forward and code prefixing features, can change a three or a six digit code into a one, two, or three digit code. By means of these features, this system has the ability to alternate route traffic in almost any conceivable pattern. It can also accept alternate routed traffic and in turn alternate route it some more.

To prevent "ring around the rosie," a definite routing pattern has been established within the framework of the General Toll Switching Plan. This is shown in Figure 8. This plan classifies each switching location, known as a control switching point CSP, into a primary outlet PO, a sectional center SC, a regional center RC, or the national center NC. The PO is of the lowest order of CSP and the NC is of the highest order. As shown in the figure, a definite pattern of final trunks along "backbone" routes will be established. The high usage trunks can be selected in a definite pattern, the order of selection being "around the clock" from the lowest order of distant CSP's to higher ones, until the first home CSP is selected; thereafter the order is from the highest one to succeeding lower ones. The last possible trunk group which can be selected is a final group, and if all of the final trunks are busy a "road block" or NC (no circuit) signal is returned.

Advances in the switching art have resulted in important economies in trunking by means of alternate routing. The particular type of routing scheme employed depends on the traffic characteristics of the area, on the state of its telephone development, and on its geographical peculiarities. With modest requirements, a relatively simple scheme can be employed, but with comprehensive requirements, a versatile system like the 4A is needed.

As we look toward the future, it is apparent that automatic alternate routing will become increasingly important. Customer toll dialing will, of course, require more liberal access to trunks than is considered necessary with operator handling. The use of alternate routing as now planned will make it possible to provide this grade of service at very little higher costs than with the previous conventional routing.

THE AUTHOR



CHARLES CLOS spent twenty years with the New York Telephone Company before joining the Laboratories in 1947. His work with the New York Telephone Company included plant extension engineering, valuation and depreciation matters and intercompany settlements. In connection with tandem and toll fundamental plans, he was concerned with the economy of automatic alternate routing. At the Laboratories, he has continued in similar fields, engaging in development planning for local and toll switching systems, and for a time conducting probability research in switching. His recent projects in toll switching systems include No. 4 crossbar. Mr. Clos received a C.E. degree in 1927 from New York University. He is a member of the A.I.E.E. and currently Chairman of the Membership Committee. He also holds membership in the Mathematical Association of America, the American Association for the Advancement of Science, the American Statistical Association, Iota Alpha and Tau Beta Pi.

World Telephones Total 84 Million

With the number of telephones in the world climbing to a record-breaking 84,000,000 at the beginning of 1953, the world now has twice as many telephones as it did at the outbreak of World War II. This information, which takes almost a year to collect from some 200 countries, was published recently by the American Telephone and Telegraph Company, in its annual survey, "Telephone Statistics of the World."

As in the past, the United States led all other countries in the number of telephones, with more than 48 million at the beginning of 1953 (the 50-million mark was reached in November). The United Kingdom (Great Britain) was second with nearly 6 million telephones. Among the areas having no commercial telephones are Greenland, where four-fifths of the area is ice-capped, and tiny Pitcairn Island in the Pacific, still inhabited by descendants of the "Bounty" mutineers.

In the U. S., the distribution of telephones between metropolitan and other areas is more even than in most countries. For example, New York City, with its 3½ million telephones, contains only 7 per cent of this country's total. In other countries, however, large cities have the bulk of the telephones – Greater London, with 1¾ million telephones, has about 30 per cent of the United Kingdom's total, Paris has 27 per cent of France's telephones, and about 64 per cent of Argentina's telephones serves Buenos Aires.

In the U. S., there is one telephone for every 3 persons compared with one for every 64 people in the rest of the world. With only 6 per cent of the earth's population, the U. S., has nearly 60 per cent of the telephones. A telephone user in the United States can be connected with about 96 per cent of the telephones in the world.

Dr. Kelly Discusses "The Contributions of Industrial Research to National Security"

M. J. Kelly, President of the Laboratories, recently declared that, through a unified program of research, the nation's various research laboratories – government, academic, philanthropic and industrial – are making America "the arsenal of the free world and the leader in its struggle to maintain its security." At the same time, he said, their output is helping to maintain a healthy and expanding economy in which all citizens share the social and economic benefits.

Dr. Kelly spoke before the American Association for the Advancement of Science at its annual meeting in Boston on "The Contributions of Industrial Research to National Security."

In his talk, Dr. Kelly summarized America's expenditures for research: The nation is now spending about $3.6 billion a year on basic and applied research. Of this, some $2.4 billion is financed by the government and $1.2 billion by industry and private citizens. About $2.2 billion, or 60%, is primarily devoted to the military and $1.4 billion to the civilian economy. Industrial laboratories are doing about 65% – roughly $2.4 billion – of the nation's basic and applied research, with $1.3 billion financed by government for military needs and $1.1 billion financed by industry for civilian needs.

While these astronomical dollar-volume figures are impressive, Dr. Kelly said, the contributions to military strength and the civilian economy this money produces are even more impressive. During World War II, research revolutionized warfare with such developments as radar, sonar, proximity fuses, acoustically homing torpedoes, and atomic bombs. But since the war, he continued, new developments have been made at as great a pace; the combined effectiveness of new weapons is "appalling." As a result, military manpower can actually be reduced with no sacrifice in military strength.

Dr. Kelly emphasized that at the same time, research had made equally important contributions to an abundant economy and a steadily rising standard of living, both of which are most unfavorable to the revolutionary philosophy of communism.

"These qualities of our society are of greatest importance to national security," he said. "A military potential of greatest strength will not suffice for the preservation of our free and democratic society unless it maintains and gradually enhances the qualities of living of all its people."

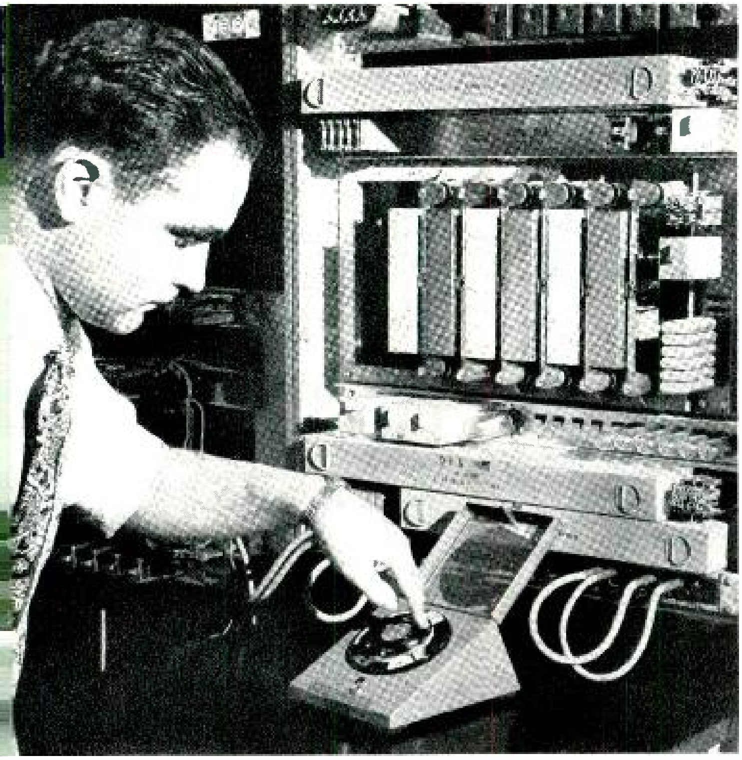
Dr. Kelly declared that the nation's basic and applied research is the most essential of all the elements that contribute to these qualities of our nation's life. He cited two examples:

(1) *Agriculture*. During the past thirty years, world food production has increased less than 10 per cent while population has increased about 30 per cent. In the United States, however, applied research and technology have expanded food production more than 50 per cent with no increase in farm acreage and with a significant decrease in farm population and the individual farmer's working hours. Advances in farm machinery and agricultural chemistry have played important roles in this phenomenal progress.

(2) *Communications*. Thirty years ago, the Bell System, for example, served about 8 million customers; today, it serves 41 million. But this five-fold increase is an inadequate measure. Technology has so extended the physical range of telephone communication that "our whole nation has become a neighborhood," and there will be more than a million overseas telephone calls this year. Better, faster, more economic telephone service has been matched by nationwide radio and television networks, all this with only a three-fold increase in operating personnel, through the application of new scientific knowledge by industrial research and technology.

In these days of utmost peril to western civilization, Dr. Kelly said, America, with its great strength and dedication to freedom, must make the largest contribution to the preservation of the values inherent in our western society.

"The continued security of our nation is vital to this leadership and contribution. The research of the nation is essential to the maintenance of this security. Industrial research is carrying out some two-thirds of the nation's research program. Looking to the future, its responsibilities are increasingly great. The nation's industrial research is strong and is virile. I am confident that it will continue to measure up to its responsibilities."



With the disaster at Pearl Harbor still strong in the memory of most people, the outlook regarding a possible atomic war in the future is far from a happy one. Learning from past mistakes, the nation has set up a tremendous network of ground observers and radar stations to continually scan the skies for aircraft. In the event that an air raid should become imminent, some means of warning civil defense personnel, hospitals, schools, factories, and the general public should be available. The Bell System has provided a warning system, nicknamed "Bells and Lights," capable of warning all concerned by colored lights, ringing bells, and wailing sirens.

Bells and Lights for Civil Defense

R. D. WILLIAMS *Switching Systems Development*

Conflicting philosophies and the threat of heavy armaments have produced a condition of uneasiness and apprehension in the world today. In this country, memory of the disaster at Pearl Harbor and knowledge of the destructiveness of atomic weapons have created a general desire to avoid the consequences of the widespread panic and damage that might occur if this country were attacked without warning. Responsible authorities recognize the fact that adequate preparation, training, and communications can considerably reduce both the panic and the destruction resulting from such an attack.

An important aspect of the communications problem in civil defense is adequate warning. Large areas, containing great numbers of people, must be warned of the imminence of an air raid so that preparations can be made calmly and efficiently. The facilities of the Bell System are uniquely qualified for this warning service. In the course of serving the public, the Bell System has established a communications network capable of interconnecting almost all points in the country through many diverse paths. In addition, it has an organization of highly intelligent, well trained men and women, capable of maintaining and operating this network in an efficient manner. The application of these facilities and personnel to civil defense is an example of the Bell System's recognition of its obligation to the public.

The collecting of warning information is a complex job. Air defense information originates from ground observers of the civil defense organizations and from radar, and is coordinated by the Air Defense Control Center, generally from telephone reports. The control center analyzes reports of detected aircraft, determines the identity and course of the craft and, if necessary, sends a warning to civil control points over a private wire circuit.

To distribute air defense warning alerts in a manner that will be effective against the blinding speed of jet-powered aircraft and guided missiles, the Bell System has utilized its vast interconnecting network to provide a warning system. This system, the "Civil Air Defense Warning System," has been nicknamed "Bells and Lights," and can transmit audible bell signals and visual light signals to warning stations located over a large area. A Public Signal Control auxiliary provides for warning the public by the sounding of sirens.

This civil air defense warning system can interconnect a civil defense community of any size, from a small town to an entire state or larger. In less than ten seconds after the key-point has received the warning, the system can provide air defense warning alerts to civil defense personnel, institutions such as hospitals, schools, and factories, and to the general public.

At the present time, air defense warnings consist of three degrees of alerts: yellow, red, and white. The yellow alert is, in general, transmitted only to civil defense personnel, key industries, municipal agencies, and to hospitals and schools. It is a warning that an air raid may be in the offing, and that preliminary steps should be taken in case the danger becomes more certain. A red alert is the attack warning. This alert is transmitted to all warning stations and public sirens once it is determined that a raid is impending in that area. The white alert is the all-clear signal, sent to all stations and sirens, indicating that the danger is over. A fourth alert, blue, is reserved for possible future use. Decisions as to the "color" of the alert, and the area that is involved are the responsibility of the Air Defense Control Center.

Figure 1 is a block diagram of a typical "Bells and Lights" network showing both a primary and an alternate Control Point, and six telephone central offices interconnected. These central offices could be in the same city or in a number of different towns. The Control Points are usually located where someone connected with civil defense is on duty at all times. The particular location selected might be a police station or a fire house or, perhaps, a civil defense control center.

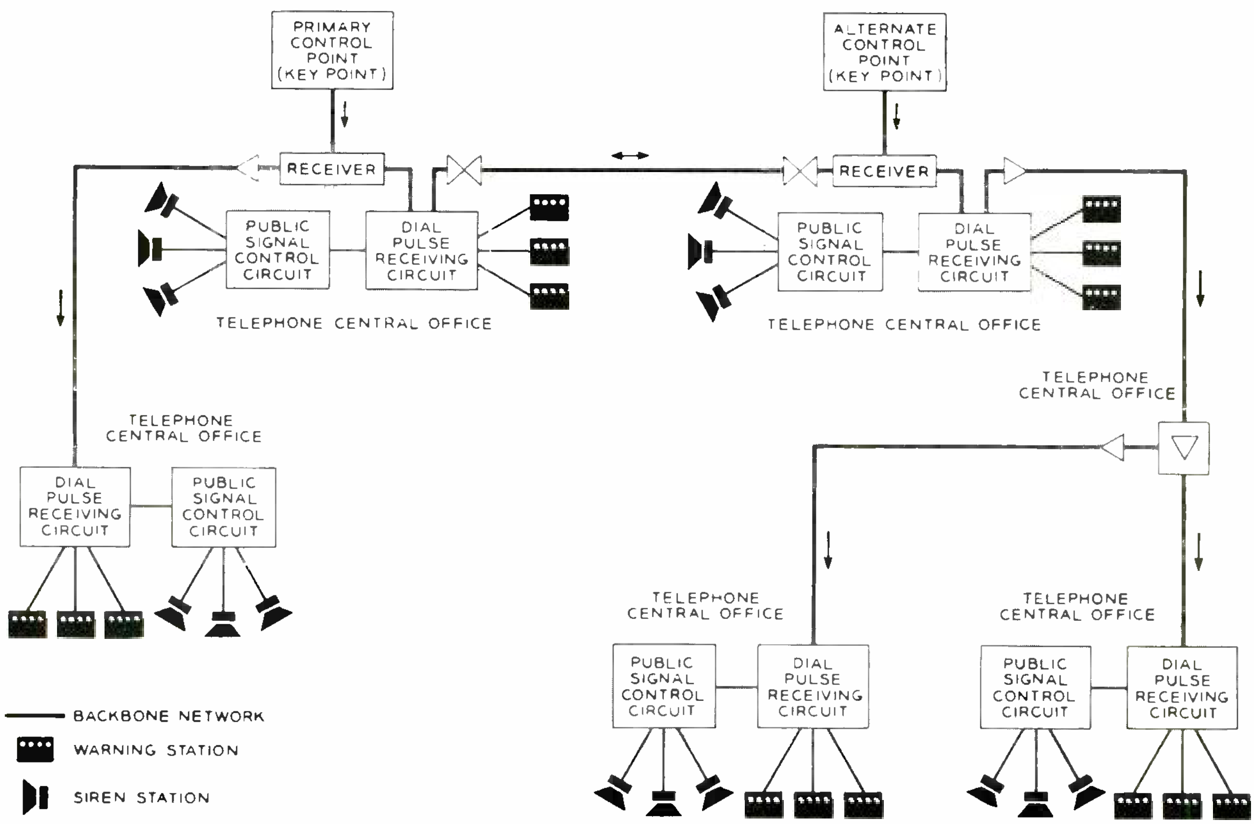


Fig. 1 — Both a primary and an alternate key-point are shown connected to six central offices. The offices connect to both colored-light warning indicators and to public sirens.

In the "Bells and Lights" system, the operation of a dial, shown in the headpiece, at the civil Control Point warning station, causes the distribution of simultaneous alert signals over the entire warning network. This warning will continue until either "stop" or another color of alert is dialed. An indicator at each warning station shows a visual, colored-light signal corresponding to the "color" of the alert, and an audible bell signal. In addition, the audible signals are coded so that they can be recognized from the sound alone. For instance, two short rings is a "yellow" alert, three short rings is a "blue" alert, continuing short rings is a "red" alert, and a long (16 second) ring is a "white" alert. An alert generally continues for two or three minutes.

The civil air defense warning system makes use of a backbone network of one-way and two-way telegraph type repeaters. This type of network provides exceptional flexibility in the transmission of pulses over a variety of signaling channels, and with little distortion. Dial pulses from the Control Point dial are received in a telephone central office by a one-way receiving circuit, and retransmitted through repeaters to dial-pulse receiving circuits in each telephone central office connecting to warning stations. The dial-pulse receiving circuits translate the dial-pulse signals into alert signals; these are in turn transmitted to the warning stations. Typical central office equipment for the system is shown in Figure 2.

This system provides for alternate Control Points as shown in Figure 1, to be used in the event of damage to the primary Control Point or the interconnecting facilities between these points. Also, the backbone network is continuously tested for continuity so that in the event of any trouble, an immediate alarm is given. Suitable indicating lamps aid in quickly locating and repairing the trouble. The general layout of the system has been arranged in such a manner that a damaged section of the network may be isolated so as not to affect the rest of the network.

The Public Signal Control circuit may be used with any dial-pulse receiving circuit to control warning sirens for alerting the general public. This circuit "warbles" the sirens for "red" alerts and sounds them continuously for "white" alerts. Safeguards are incorporated into this circuit to prevent false sounding of alerts on "yellow" or "white" following a "yellow." However, the sirens will always be sounded for a "red" alert, a "white" following a "red," or for an initial "white" alert that may be used for a siren test or a civil defense test.

In addition, provision is made in the Public Signal Control circuit for maintaining a continuous test on all siren lines to insure that they are in operating condition. Any condition of a line that might prevent the siren from operating will immediately signal the maintenance force that repairs are needed.

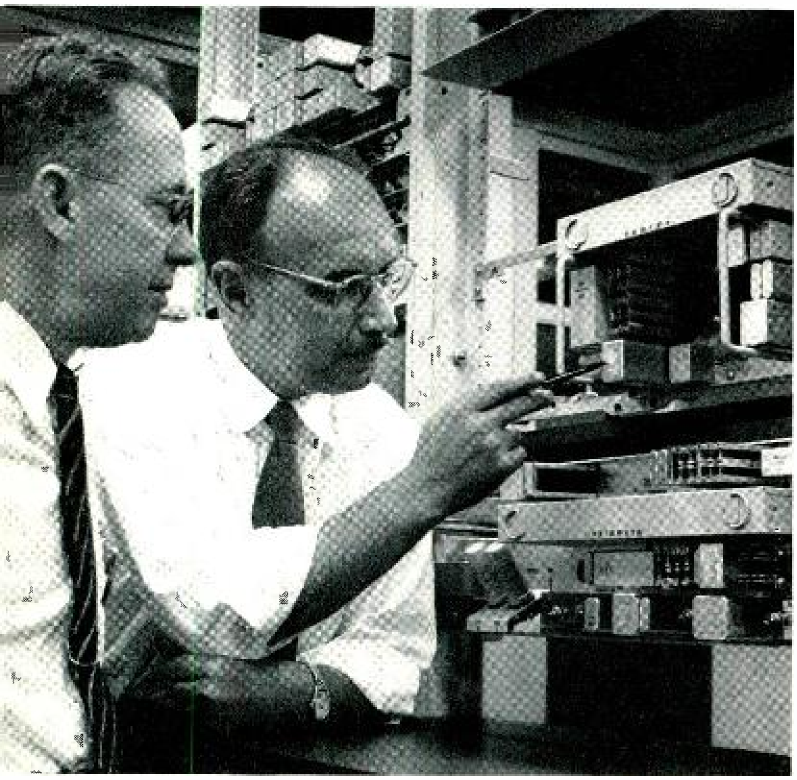
Fig. 2 — Francis B. McKeon of the New England Company makes a routine test on "Bells and Lights" central office equipment.

AUTHOR

R. D. Williams was graduated from Case Institute of Technology in 1945 with a B.S. degree in E.E., spending three of his years there in the V-12 program. After a tour of duty with the Navy as a Radar Officer, he joined the Laboratories in 1946, engaging in trial installations of No. 5 crossbar. In 1947 he was concerned with equipment engineering on dial PBX and small community dial offices, and then turned his attention to circuit engineering on step-by-step circuits. Currently he is with a PBX circuit group. Mr. Williams is a member of Tau Beta Pi, Eta Kappa Nu, and Theta Tau.

A New Single-Frequency Signaling System

A. WEAVER *Switching Systems Development*



With a single frequency — a tone in the audible range — dial pulses, busy, and other signals can be sent over the same channel used to carry the customer's conversation. When used for operator- or customer-dialed long distance calls, this arrangement is therefore more efficient than other methods that would require extra channels for dialing and supervisory purposes. As a part of the over-all program toward continent-wide dialing of calls by operators and customers, the equipment needed for such a signaling system has been redesigned, and a less expensive and more easily maintained unit is now in production.

The successful completion of a toll telephone conversation between two customers requires more than switching equipment and channels necessary for the transmission of speech. The over-all system must provide a path for the dial pulses, for busy signals, and for other signals that pass important information to the customers or to the operators handling the call.

For the new continental dialing networks, it has been found convenient and economical to transmit both speech and these supervisory and dialing signals over the same channel, and development work over a number of years has resulted in the present single-frequency (SF) system.* When the multifrequency pulsing system† is used for the transmission of the digits representing the telephone number, the SF system provides the supervisory and other necessary signals. On toll lines where multifrequency pulsing is not used, SF permits the transmission of all three signals – voice, dialing, and supervisory – over the same channel. As a result of an attempt to simplify and economize the SF equipment, a new, smaller unit that more than halves the first cost and greatly simplifies maintenance, has been made available.

The new unit mounted above the older one for comparison is shown in the headpiece (the author is at the left and W. W. Fritschi at the right). The more compact size of the new design reduces the weight to an easily transportable ten pounds. The new unit is set in a plug-in type die-cast mounting plate, so that in case of failure the entire unit can be

*RECORD, *July*, 1951, *page* 319. †RECORD, *December*, 1945, *page* 466.

pulled out, as seen in Figure 2, and a new one installed immediately with only a minimum of service time lost.

Some of the problems involved in using the same band for both voice and signaling, and the answers that this new unit provides, can be envisaged by referring to Figure 3. This diagram represents the situation involved in a long-distance call on an operator toll dialing network. The call must be serviced by many other pieces of equipment, but only the single-frequency units and the channels are indicated here. It is assumed that we have a four-wire or two-channel transmission arrangement and that it is desired to use these two channels for both the necessary signals and the conversation of the two customers.

The calling customer first reaches the long-distance operator who is to dial the call. Single frequency units are located in the calling and the called toll centers, with others in intermediate toll centers through which the call may be routed. Each unit includes a transmitter, which transmits a continuous tone in each direction as long as the channels remain idle. This continuous tone is detected by the receiver at the opposite end, which in turn indicates to the switching apparatus that a trunk is available for a call. Then, when the toll operator initiates the long-distance call, this tone is removed from the outgoing channel, the absence of tone being considered the "connect" signal. The operator then dials the number, and the dialing signals are transmitted in the form of tone pulses of the same frequency as the "idle" signal. The telephone of the called customer rings, and when he picks up his handset to answer, the signal tone is removed from the incoming channel. This extinguishes a lamp on the board of the dial operator to tell her that the customer has answered and that conversation can begin. Busy signals or other supervisory signals that may be required will be sent over the voice channel in the same manner. At the end of the call, the handsets are replaced, and the continuous tones are again transmitted over the two channels during the idle condition.

This is essentially the method of single-frequency signaling, but the problem, as in any design, is how the engineer can use this method in the most efficient and economical manner. In particular, since both speech and signals are to be transmitted over the same channel, a major problem is the ability of receiving equipment to distinguish between the two.

The previous signaling unit used a 1,600-cycle tone. This frequency was chosen because it was about the highest that could be used on the narrow channels available after World War II, when band widths had to be decreased to supply extra channels for the emergency. But since an appreciable amount of speech energy in normal telephone conversation is transmitted in the 1,600-cycle range, a severe requirement was placed on the receiver. Without effective safeguarding circuits built into the receiver, there would be situations where it would mistake a speech tone for a supervisory signal and thus cause an error. As an example, the toll operator sometimes must "re-ring" or call back an operator at the receiving end, and to do this she sends a short tone-pulse over the outgoing channel. In normal telephone conversation, however, there occasionally are short bursts of speech of a similar nature, and to avoid confusion, the older 1,600-cycle unit had to incorporate circuits that greatly lengthened the "re-ring" signal to make it unlike anything that is normally encountered in speech.

The new signaling system employs a 2,600-cycle tone. With the greater availability of wider transmission bands, the older 1,600-cycle system could be restricted to the narrower bands, and the higher frequency tone could be used. Normal speech has much less energy at this frequency, and it therefore is easier to design a unit able to discriminate between speech and signal tones. One of the resulting simplifications was the elimination of the relay control circuit involved in lengthening the re-ring signal.

Fig. 1 — J. M. Wiswall (right) and E. M. Hoffman testing the pulsing characteristics of the new single-frequency equipment.

This and other simplifications permitted by the use of the higher frequency resulted in a smaller and less expensive signaling unit.

A simplified diagram of the new signaling circuit is shown in Figure 4, with the transmitting portion in the upper part of the figure and the receiver in the lower part. The entire circuit can be thought of as being situated in TOLL CENTER B of Figure 3. This circuit connects in series with the transmitting and receiving paths of the four-wire line circuit as shown by the heavy lines, with two extra leads, designated E and M, carrying the necessary dc signals to and from the switching equipment.

The transmitting portion employs three relays designated M, HL, and CO which are interconnected to perform the following functions: Relay M is used to key the oscillator tone used for the various single frequency signals; relay HL (high level) adds 12 decibels to the tone power at the beginning of each signal tone application to improve signal reliability in the presence of line noise and variations in attenuation; and relay CO (cut off) cuts the line to prevent noises originating in the switching equipment from interfering with signaling.

The operation of the receiver will be explained by describing what happens (except for pulsing which will be described later) when a tone of signal frequency is received. This ac tone is amplified (or limited if it is too large) and then passed on to the signal detector and guard detector where positive dc voltages are developed and passed on to the dc amplifier tubes. The RF relay operates first and cuts in the band elimination filter, thereby preventing signaling tones from entering a connected toll line and interfering with the signaling there. However, a short spurt of tone will get through because of the finite time required to operate the RF relay, and the R relay must therefore be made slow enough so that it will not operate on this tone. This slowing up results from the action of the capacitor-resistor network (O7 and C3) in the grid circuit of the associated dc amplifier.

Fig. 2 — R. E. Staehler pulling a single-frequency unit out of its frame to illustrate the rapidity of maintenance changes.

The blocking amplifier seen on Figure 4 has zero gain and is used to prevent noises originating in the signaling equipment from interfering with the operation of the receiver.

Among the new features in the new unit, one of the most significant is a considerably less expensive

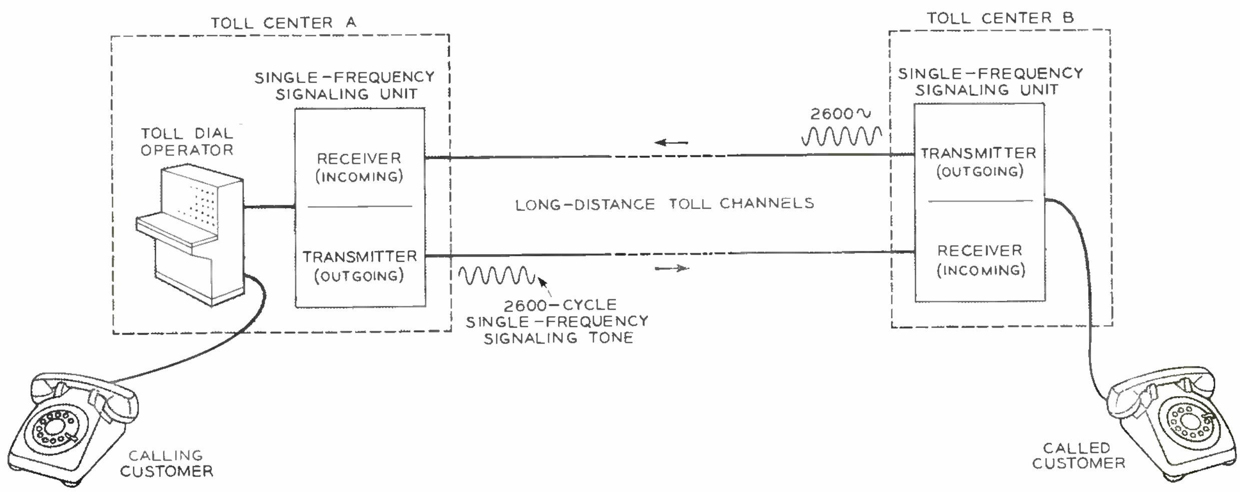


Fig. 3 — Diagram representing the single-frequency signaling system as used for an operator-dialed long distance call. Only the single-frequency units and the channels are shown.

pulse-correcting circuit. This feature is a very important element in the entire long distance hook-up, since it serves to keep the length of the dial pulses within specified time limits. The dial pulses on many calls may have to go through a number of central offices and all their associated equipment, and in each stage of the transmission path the ideal 60-millisecond dial pulse may be distorted so that it becomes too long or too short. The new pulse-corrector keeps the pulses close to 60 milliseconds, and does so mainly by the use of electronic methods.

Figure 5 shows in greater detail the pulse-correcting circuit indicated on Figure 4, and includes some of the signal-guard network associated with it. The pulse-correction is accomplished by generating appropriate transient voltages, whose timing is determined by capacitor-resistor networks. These transients are then applied to the grid of dc amplifier B in Figure 5 to perform the elongation or shortening of the pulses as required.

Dial pulses of 2,600-cycle tone with various degrees of distortion enter the circuit at the left of the diagram. It is desired that they be corrected, converted to an interrupted dc current in circuit E for switching reasons by means of relay R, and then passed on through the toll office. This break in the dc current will effectively key the next outgoing tone transmitter, which faithfully reproduces the break intervals. The R and RF relays are shown to be operated as would be the case if an originally short dial tone pulse were being converted into a longer dc current break in circuit E, i.e., closer to 60 milliseconds in duration.

In Figure 5, currents of signal frequency will build up voltages across the "signal network," while currents of any other frequency, such as those from speech, will build up voltages across the "guard net-

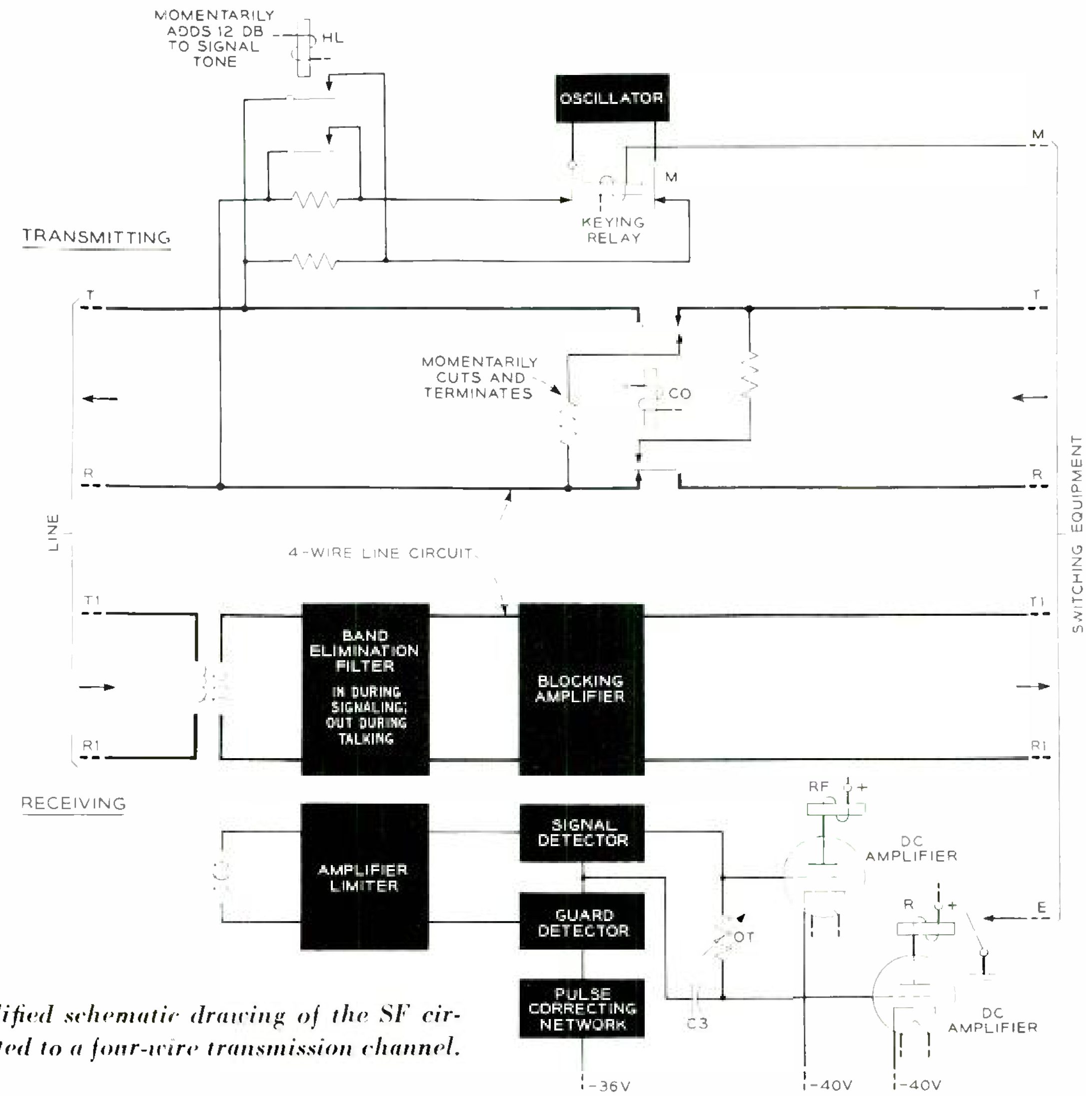


Fig. 4—Simplified schematic drawing of the SF circuits as connected to a four-wire transmission channel.

work." These voltages are rectified separately, as shown, to obtain oppositely poled dc voltages across the signal capacitor and the guard capacitor respectively. During normal speech, the voltages across the guard capacitor will dominate and, being negative, will keep the grid of dc amplifier B negative to prevent operation of the R relay at this time.

However, when dial tone pulses are applied, the main voltage will appear across the signal capacitor, with a small transient voltage appearing across the guard capacitor due to sidebands of the dialing frequency. This transient, being negative, produces an effect shown at (a) in Figure 6, the middle diagram of which represents the voltage on the grid of the dc amplifier B. The voltage on the grid of this amplifier will thereafter build up slowly, because of the OT (operate time) resistor and C3 capacitor, as shown at (b) in Figure 6. In this illustration it is assumed that the incoming dial pulse has a duration of only 40 milliseconds, which is shorter than desired. In this particular case the RF relay operates about at time (b) and the R relay at point (c), which is just prior to the end of the pulse. It is therefore necessary, if one wishes a corrected output signal, to delay the release of the R relay. This is accomplished by causing current to flow into the grid of the dc amplifier tube B from time (c) to time (d). This current comes from energy stored in C2 from battery D prior to time (c) and from the positive transient at the plate of tube A generated by the end of the pulse. At time (d) the RF relay releases, and the voltage on the grid of the dc amplifier B decays along the line from (d) to (e), at which point relay R releases. The result is that the R relay has sent on a pulse that has been corrected from an original 40 to a final 50 milliseconds. It is possible but uneconomical to build a unit that would achieve perfect pulse correction to 60 milliseconds, but when a number of toll lines are in tandem, the pulses will have to pass through several SF units, and the pulses will therefore be brought close to 60 milliseconds by the successive corrections.

The action of the pulse corrector where the incoming signal is too long will be explained with the help of Figure 7. Here the cycle of events will be assumed to start at (a), just at the end of an incoming dial pulse. From (a) to (b) current will flow into the grid of the dc amplifier B, at (b) the RF relay will release, and the voltage will start to decay, all actions so far being the same as in Figure 6. In this instance, however, a new pulse would come along before the R relay has had a chance to release, and unless something is done about it, it would not release at all.

This "something" consists of using the large negative transient voltage generated at the plate of tube A resulting from the application of a positive pulse to its grid. This transient, shown at (c) of Figure 7, drives the grid of B rapidly and heavily negative, thereby forcing the R relay to release. The remainder of the pulse-correcting action consists in using this same transient to delay the reoperation of the R relay. This is accomplished by storing some of the energy in the R1 C1 network. This slows the building up of the voltage as shown at (e), and the relay R reoperates at (f). The resultant repeated signal is shown

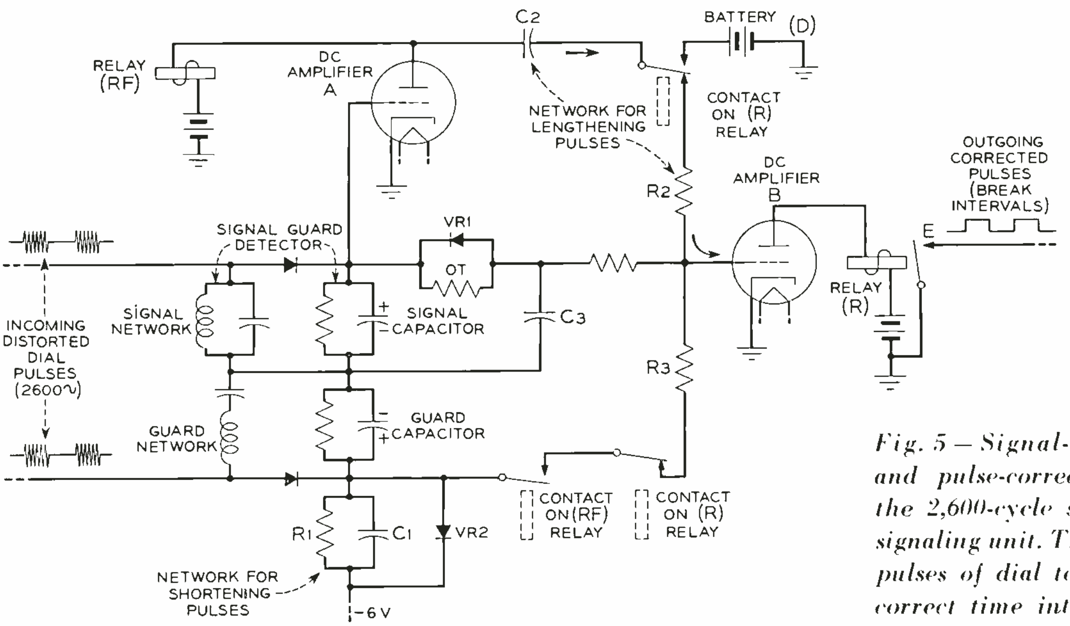


Fig. 5 — Signal-guard detector and pulse-correcting circuit of the 2,600-cycle single-frequency signaling unit. This circuit keeps pulses of dial tone close to the correct time interval of 60 ms.

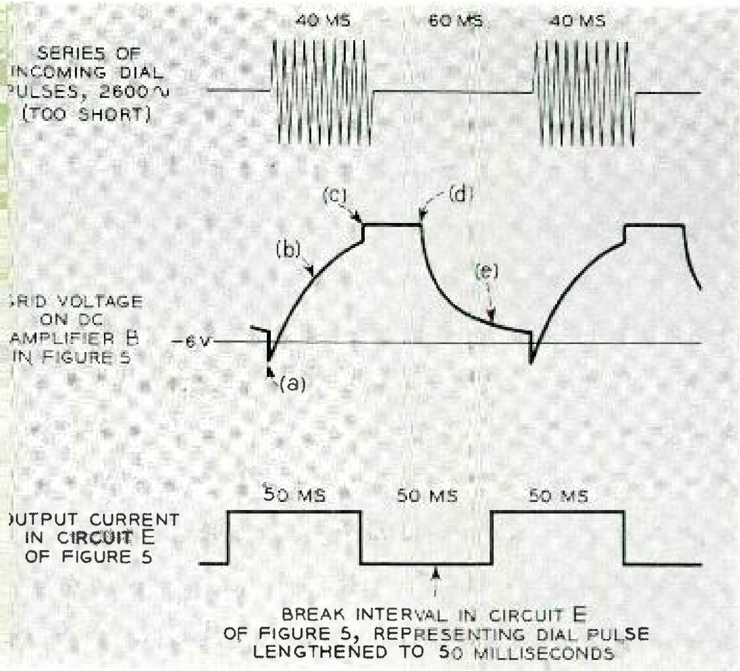


Fig. 6 — Wave forms — lengthening of a dial pulse.

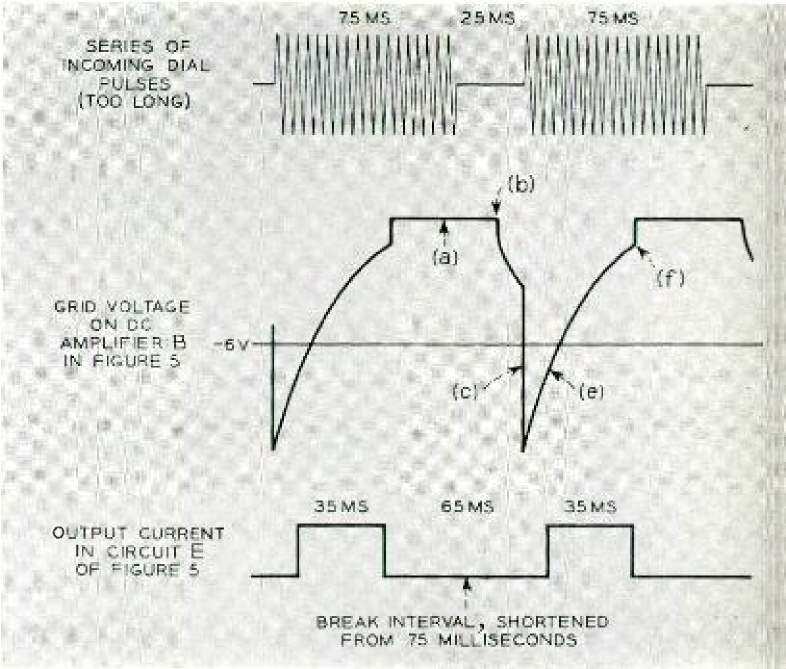


Fig. 7 — Wave forms — shortening of a dial pulse.

below, where a 75 millisecond signal has been pulse-corrected to 65 milliseconds, further corrections being effected in the subsequent SF units.

To a large extent the new 2,600-cycle single frequency signaling system will supersede the 1,600-cycle system. In 1952 the old and new equipments were produced in about equal numbers, approximately 10,000 each. Production goals for 1953, however, call for 16,000 of the 2,600-cycle units, as compared to 4,000 of the older type. The new SF system will provide economical signaling for operator and customer dialing of long distance calls over two-wire and four-wire voice circuits and over carrier and radio derived channels.

THE AUTHOR

Allan Weaver received his B.S. degree in E.E. from the University of Nebraska in 1921 and after 13 years with the A. T. & T. Co., transferred to the Laboratories in 1934. His early work both at A. T. & T. Co. and the Laboratories was centered on the development of telegraph, telephotograph and teletypewriter systems. During World War II he was assigned to radar development work for the military and since 1945 has concentrated on toll signaling with particular attention to the development of single frequency signaling for use in connection with nationwide dialing systems. Mr. Weaver is a member of the A.I.E.E., I.R.E. and Sigma Xi.

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Governors for Dials

W. PFERD *Station Apparatus Development*

As a telephone dial "runs down" from its wound-up position, the dial mechanism generates pulses which operate relays at the telephone central office. To compensate for pulse distortion during transmission over the telephone line, the dial pulses must be closely controlled in frequency and form. Thanks in part to a new type of governor, which provides improved pulse control, accurate dialing is obtainable over the considerably longer transmission loops permitted by the 500-type telephone set.

One billion times a day throughout the Bell System, a little mechanism, about the size of a bottle cap, swings into action. It is the governor, the heart of your telephone dial, regulating and restraining, to control the run-down speed of the moving parts. Why regulate and restrain? During run-down the dial mechanism produces from one to ten interruptions in the line current by the opening and closing of a pair of contacts. In turn the pulses created in the line give directions to central office switching apparatus which then completes the call. By controlling the run-down speed the governor keeps the pulses uniform. The governor and pulsing arrangement for the new 7-type dial mechanism used in the 500-type telephone set are shown schematically in Figure 1.

If the pulses reaching the central office were exactly like those generated by the dial, the designers of dials and central office apparatus and circuits would find themselves far less restricted. Unfortunately the dial pulses are distorted by the electrical characteristics of the customer's loop. To compensate for this distortion and insure accurate registration of the pulses at the central office, the dial and central office equipment must be designed to operate to close limits of performance. The designs must also be such that there is negligible change of adjustment due to use, time, or weather conditions, which might affect the ability to accurately send or receive dial pulses. The near-perfect performance of dial telephone systems is due in no small measure to the dependable job of the governor in closely controlling the run-down speed of the dial so that the pulses delivered at the central office are of acceptable frequency and form.

The need for speed control was recognized in a signaling transmitter patented in 1894 where "in order that the motion may be regular and not too rapid, the train has attached to its remote member a fan necessary to obtain the desired speed of rota-

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In the photograph at the head of the page H. J. Hershey attaches specimen material to friction tester. Test results reveal a material's coefficient of friction and resistance to wear — important factors in the operation of governors.

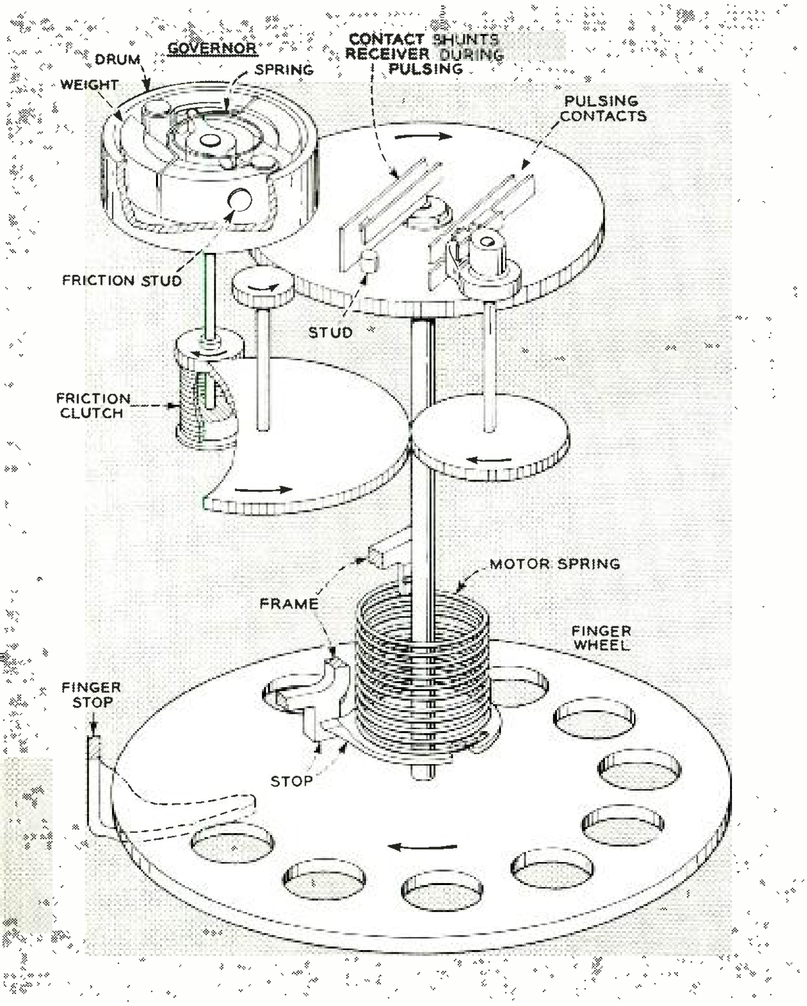


Fig. 1 — Simplified diagram of 7-type dial mechanism: governor appears top left.

tion." In 1897, another patentee described the regulation of his device by stating, "I employ the atmospheric dash-pot to control the movements of the spring contact fingers which otherwise might be too rapid." This was in turn followed in 1898 by a device having "parts returned to the normal position, limited by an escapement mechanism to a moderate rate of speed." As indicated, the necessity for speed regulation was well recognized in these early devices, but the mechanisms employed for this purpose were soon found to have undesirable manufacturing and operating limitations.

Better control of speed was soon made available by the application of centrifugal-friction governors for controlling customer pulse-sending equipment. The first centrifugal-friction governor appeared in pulsing apparatus in 1906, and was used in the first Bell System dial patented in 1915. The speed controller used in the 5-type dial, standard for about the past fifteen years, Figure 2, is also a centrifugal-friction governor. Speed controllers of this type generally involve two arms which constitute a "fly-bar." At the extreme ends there are pivoted weights which are so moved by centrifugal force during rotation that friction studs are brought into contact with a stationary surface, resulting in friction that retards rotation.

A continuing part of dial development has been the provision of mechanisms capable of producing pulses timed sufficiently to insure service over ever-longer telephone lines or over smaller gauge cables. Since the degree of timing is primarily dependent on the action of the governor, it was recognized that a general theoretical analysis for governors would help in pointing the way to improved designs. The late C. R. Moore investigated this problem in the thirties, and derived from theoretical considerations, general equations of motion relating to governors. The relationships derived by the Moore analysis are extremely useful in that they can be used to indicate the influence of various design factors on the performance of a governor.

In deriving the general equations of motion for a governor, two assumptions are made concerning the action. During the interval of time that the governor is approaching the critical velocity, ω_o, when contact of the friction surfaces first occurs, the motion is assumed to be that of a simple fly-wheel, constantly accelerating. The angular velocity of the governor during the time from rest to the critical velocity, ω_o, is then given by

$$\omega = \frac{Gt'}{I} \qquad (1)$$

where G equals applied torque, t′ equals time from start of motion, and I equals moment of inertia of the governor assembly about the shaft.

After stud-to-drum contact occurs, it is assumed that there is no further pivoting of the weights or the fly-bar, and the assembly rotates as a rigid body. During this time the general equation of motion is in the form

$$\frac{d\omega}{dt} + g\omega^2 = h$$

which can be solved for the angular velocity, ω, to give

$$\omega = q \tanh\left(\frac{ht}{q} + ln\sqrt{A}\right) \qquad (2)$$

where q equals regulated or terminal angular velocity, t equals time measured from moment of braking, h equals design constant, and A equals design and adjustment constant.

This theory was applied in developing the governor used in the 7-type dial* for the 500-type telephone set† and has resulted in an improved governor which controls the return speed of the mechanism more accurately than in any previous Bell System station dial.

Figure 3 shows a plot of these equations of motion for the new drive-bar type governor used in the 7-type dial. The curves show the theoretical angular velocity of the governor at any time from the moment of release. As indicated, the pulse train is designed to start well after the critical speed has been reached. This avoids the objectionably long pulse which would be formed while the governor is gathering speed.

As shown in Figure 4, the weights of the new governor are free to pivot at the ends of the fly-bar which, in turn, is allowed to rotate with respect to the shaft. Rotation is imparted to the system by the drive-bar which presses against each weight at a specific point. As the mechanism begins to rotate during dial run-down, the two weights are caused by centrifugal force to move outward against the tension of a spring. Movement of the weights about their pivots continues until the friction studs touch the drum. At this instant governing begins, and controls the dial speed until the end of the run-down. The speed attained by the governor will be dependent on the friction between the studs and drum, the magnitude of the driving torque, and the tension to which the spring of the governor has been adjusted.

Since dials are used throughout the telephone plant, it is necessary that they be capable of maintaining the required rundown speed under the wide variety of service conditions encountered. The governor depends on stud friction in controlling the speed, and therefore changes in the coefficient of friction between the stud and drum will affect the degree of speed control. Also, the governor must be able to respond to and compensate for changes in the applied torque. Because of the different service conditions encountered, friction and torque vary from dial to dial and over the life of a dial. For best dial pulse regulation, changes in the value of these factors should have a minimum effect on governor speed.

Each station dial is adjusted initially for speed

* Record, *May*, 1952, *page* 211. † Record, *September*, 1951, *page* 414.

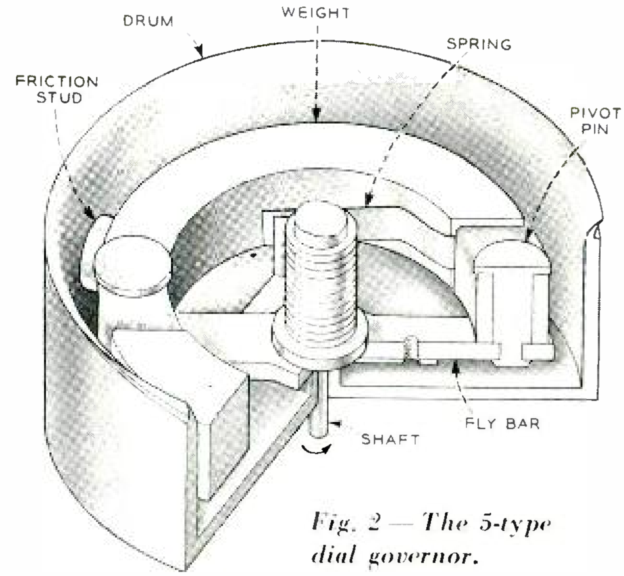


Fig. 2 — The 5-type dial governor.

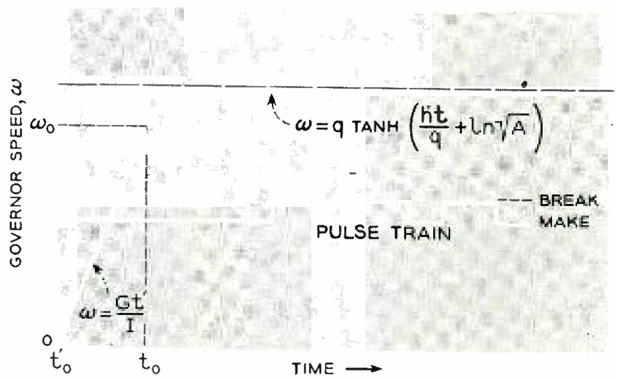


Fig. 3 — Equations for motion of 7-type governor.

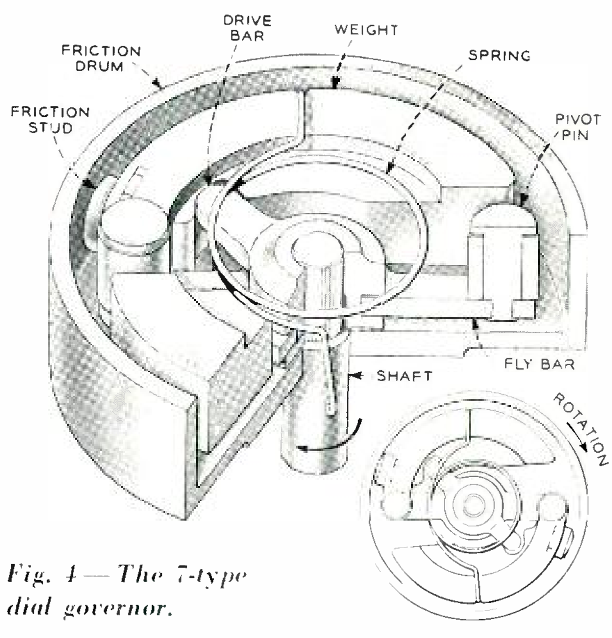


Fig. 4 — The 7-type dial governor.

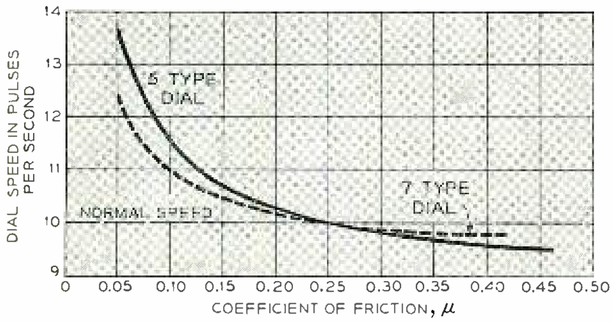


Fig. 5 — Pulsing rate versus coefficient of stud-to-drum friction.

so that the contact springs will function at 10 ±0.5 pulses per second, a rate suitable for system-wide application. At the time this speed adjustment is made, a particular friction condition exists between the governor studs and drum. At any subsequent time, there is always the possibility of a change occurring in this friction value. Such factors as very high humidity, lubrication products traveling to the stud operating region, or the accumulation of foreign material or wear particles, may produce different values of friction, and hence, result in variations in governor and dial speed from the initially adjusted value. The change in pulsing rate for the 7-type and 5-type dials resulting from changes in stud-to-drum friction in the governors is shown in Figure 5. Improved speed control is indicated for the 7-type dial for all values of friction. This has been brought about in part by operating the new governor at increased terminal speed which results in a higher centrifugal force.

The initial speed adjustment of the governor is also dependent on the driving torque which in turn depends on the efficiency of the dial mechanism at the time of adjustment. Subsequently, this torque will vary as the friction within the dial mechanism varies. Initially, the mechanism is lubricated and the moving members operate smoothly. During the early life of the mechanism, the running-in process may result in an increase in efficiency and a corresponding increase in torque on the governor. Over a long period of time, however, the accumulation of dirt and wear products may affect the mechanism so that more torque is needed to drive the moving parts. This results in a decrease in the torque going to the governor. Fluctuations in torque must be sufficiently compensated for by the governor to maintain proper speed of the dial.

The governor must also be capable of maintaining adequate speed when subjected to gross changes in torque, such as that induced by the customer when forcing the fingerwheel to shorten dialing time. This habit of some customers can completely dissipate the benefits derived from normal speed regulation and cause faulty detection of the number dialed. To forestall this arbitrary shortening of the pulse, and the possibility of wrong numbers, the governor should be capable of limiting the forced rundown of the dial to a reasonable speed. The effect of changes in governor input torque on pulsing rate for the 7-type and 5-type governors is shown in detail in Figure 7.

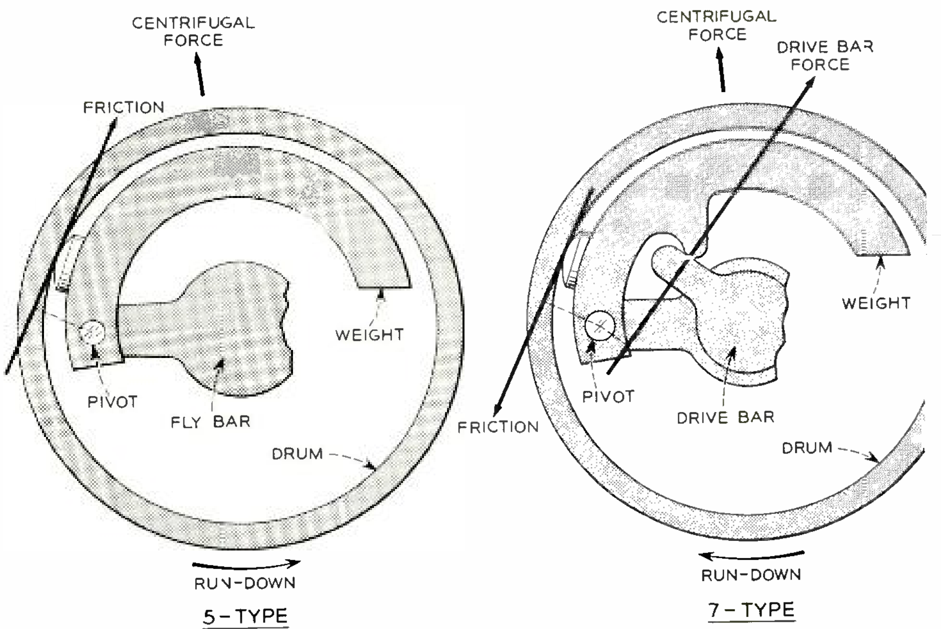


Fig. 6 — As pivoted weight rotates centrifugal force presses the stud against the drum. Depending on the direction of rotation the centrifugal force is aided or opposed by the torque produced by the stud-to-drum friction about the pivot. In the 5-type governor, this torque opposes the centrifugal force, hence reduces braking action. In the 7-type it aids the centrifugal force, and thus strengthens the braking which is further assisted by the torque produced by the pressure of the drive bar on the weight.

The marked improvement in ability to compensate for changes in input torque achieved for the new drive-bar governor over the 5-type governor results primarily from two considerations. First in the 7-type governor, the mechanism rotates opposite in direction to that of the 5-type governor. As illustrated in Figure 6 this causes the braking action to assist centrifugal force in keeping the friction studs against the drum. Second, the centrifugal force is aided still further by the driving force transmitted to the assembly by the drive bar. This force produces a component acting about the weight pivot in the same general direction as the centrifugal force which also helps increase the braking action. Although the governor and other dial parts are designed to have substantial margins for reliable performance under heavy or abnormal usage, long continued or excessive forcing will almost certainly result in rapid wear or breakage.

At the present time there are more than 30,000,000 dials in use throughout the Bell System. Current production for new installations and replacement is almost 4,000,000 dials per year. For production of this magnitude, design of apparatus easily suited for mass manufacture at low cost is obviously required. Through close cooperation with engineers of the Western Electric Company, this has been achieved to a very satisfactory extent for the new governor. For example, the problem of close dimensional tolerances required for proper action of the drive bar and weights was solved by manufacturing the parts of sintered powdered metal. This method of manufacture, semi-automatic assembly and machining of the friction studs, and simplified holding of the governor assembly on the shaft have all contributed to enable the new design to be produced at favorable cost.

Experience with the drive-bar governor in 7-type dials shows that the performance of these dials

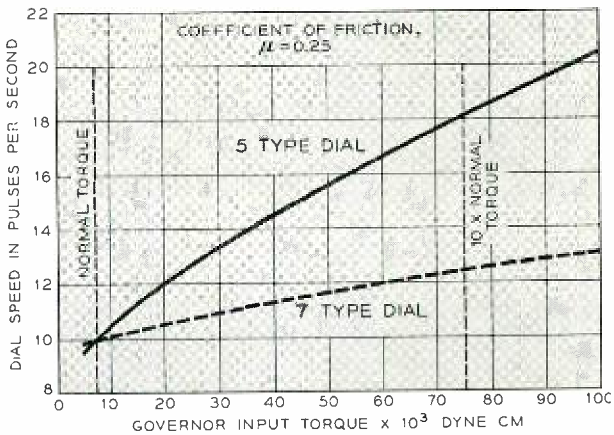
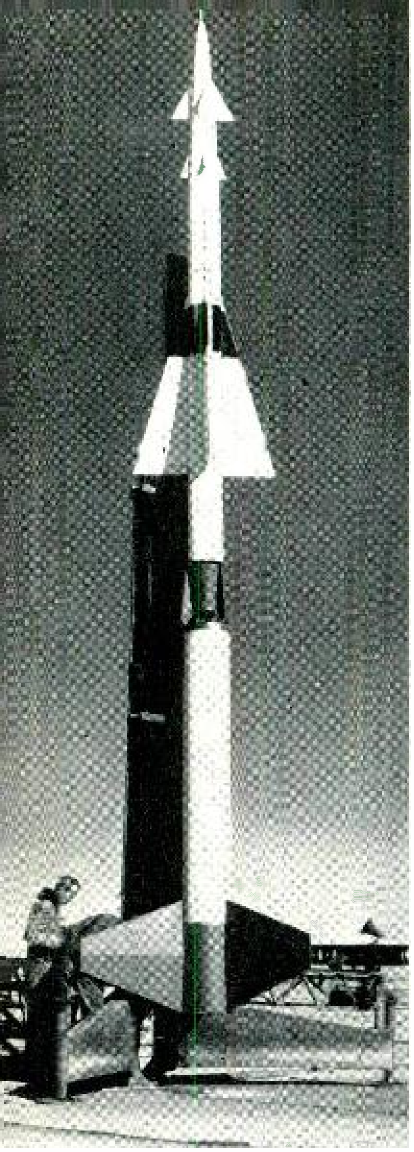


Fig. 7 — Pulsing rate versus input torque.

under service conditions represents a material improvement over earlier designs. The response of the dial to changes in friction between the governor stud and drum is well within the design objective and the compensation by the governor for changes in applied torque is fully realized. Because of the degree of speed control exercised by the drive-bar governor, dialing over the longer telephone lines permitted by the 500-type telephone set is satisfactorily achieved.

THE AUTHOR

After serving three years in the Army Air Corps, William Pferd attended Rutgers University, receiving the B.S. degree in M.E. in 1947. He joined the Laboratories that year, later continuing his studies to receive an M.S. degree in M.E. from Newark College of Engineering in 1951. His time at the Laboratories has been devoted to the design and development of the station ringer for the 500-type telephone set and, more recently, the dial mechanism for the same set. At present he is concerned with new coin collector development.



Nike Added to Nation's Defense Arsenal

Nike — one of the Laboratories' outstanding military projects — is being added to the nation's defense arsenal. Nike is the Army's first combat-ready supersonic anti-aircraft missile designed to follow and destroy an enemy target regardless of evasive action. A complex system of mechanical and electronic equipment, Nike is the first guided missile system to help defend American cities against attack from the air.

The first installation of Nike is being made at Fort Meade, Maryland, according to a recent announcement from the Department of the Army, and additional installations for the anti-aircraft defense of continental United States are planned.

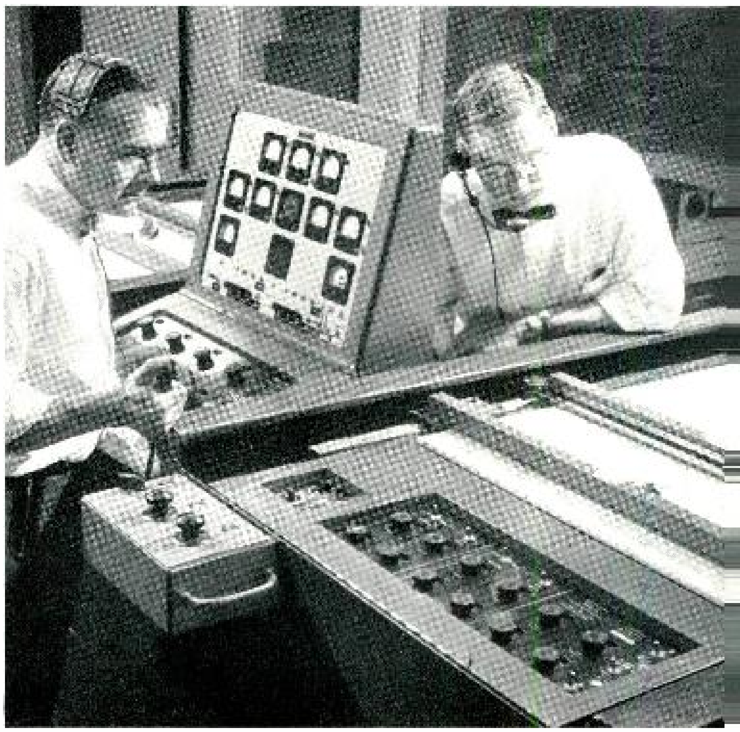
Named after the Goddess of Victory in Greek mythology, Nike is the end product of eight years of intensive research, development, and engineering in the field of guided missiles. The Laboratories, as part of a service-industry team also including Western Electric, Douglas Aircraft Company, and the Army Ordnance Corps, carried out the conception, design, and final development of Nike.

Essentially a defensive weapon, the Nike system will provide defended areas with a far greater degree of anti-aircraft protection than was ever before possible with the more limited ranges and altitudes of conventional anti-aircraft guns.

The Nike system consists essentially of two parts: First, an expendable missile capable of maneuvering while in flight, and second, an elaborate and highly complex control system requiring approximately 1.5 million individual parts. The twenty-foot, liquid-fueled missile is fired from its launcher by a remotely-controlled launching mechanism. It contains, in addition to an explosive warhead, a rocket propulsion unit and guidance equipment. Two sets of fins provide for guidance and steering, and a booster rocket gives an initial impetus during firing. To assure maximum safety, the warhead is so constructed that it will explode only when the missile is in flight.

The missile, however, is only one of many integral parts of the complete Nike system. Guidance and control of the missile is handled from the ground; the system uses electronic equipment to

Setting up a simulated firing course, J. J. Oestricher, left, and J. F. Yost are shown with equipment built o study the action of Nike.

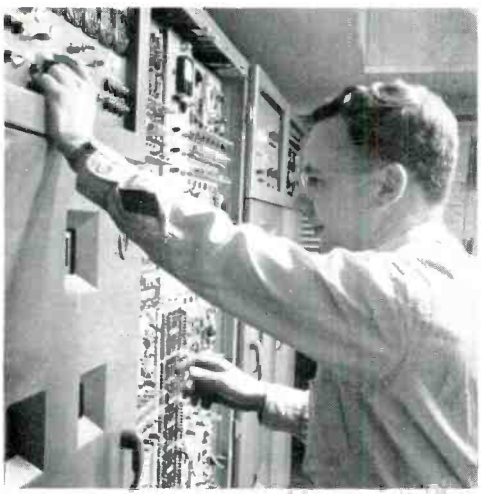


J. F. Yost, left, and J. J. Oestricher, extreme right, introduce typical flight problems into electro-mechanical equipment which simulates Nike.

pick up the target, control the missile, and cause it to intercept the target. The system is mobile; other than the launching racks, all its units are housed in specially designed, all-weather, van-type trailers. If necessary, the system can be transported by air.

In operation, a Nike battery receives an early warning from the nation's air-warning network that hostile aircraft are approaching the defended area. The enemy target is then picked up and tracked by electronic equipment. Nike missiles are readied in vertical position in their launching racks, and their control mechanisms and stabilization and navigational gear are checked. Certain safety mechanisms are disengaged.

A continuous running account of the enemy plane's position is transmitted, and as it crosses Nike's distant and invisible deadline, the missile is fired. The Nike missile, twenty feet long and about one foot in diameter, uses a booster rocket to assist in takeoff. The booster subsequently is discarded and Nike roars toward its target on the power of its own liquid-fueled rocket engine. Within seconds after its launching, Nike exceeds the speed of sound.



J. N. Wright, above, and R. C. Scerrato, at right, at control panels of the equipment built to simulate the action of Nike. With this equipment, accurate data can be obtained, in the laboratory, on the way an actual missile would behave in the air.

Check-out tests of Nike I ground equipment performed by the Western Electric Company, prior to delivery to the government.

In flight, it is fully maneuverable and converges on its target in spite of any evasive action. It can outmaneuver bombers, fighters, or transport planes, and can operate regardless of weather conditions or visibility. When it intercepts the target, the Nike missile explodes.

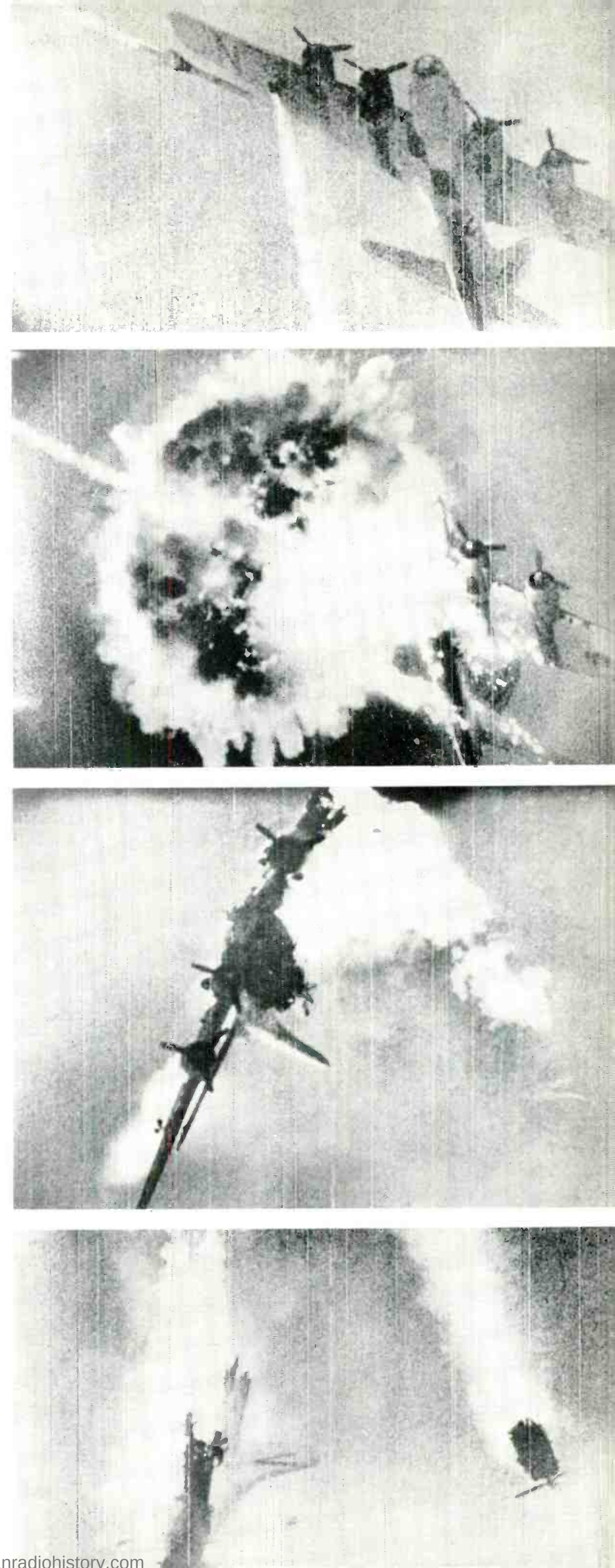
The project was initiated in January, 1944, when the Anti-Aircraft Artillery Board submitted military characteristics for a controlled anti-aircraft rocket projectile, and recommended a development program using these military characteristics as a basis. This was recognition of the fact that a new-type weapon was required to offset the speed and maneuverability of high-flying aircraft then in existence, as well as those on the drawing boards. Several conclusions were obvious. The new weapon would have to meet the target in its own element, and on its own terms. Matching speed with speed would not be sufficient, since the initiative, in this case, would still remain with the plane. The weapon would have to be able to maneuver on its own throughout its flight.

In 1945, the Army Ordnance Corps, which has the responsibility for all design, development, and procurement of the Army's weapons, asked the Laboratories to undertake a paper study of the problems involved in constructing a new anti-aircraft system. The Laboratories' recommendations were submitted to the Army five months later. Their solution was a supersonic surface-to-air missile system of a type that would keep the missile relatively simple.

A development contract was promptly authorized, and Laboratories engineers started the task of making a reality of the system their study had envisioned. Douglas Aircraft became a full partner in the enterprise and was given the responsibility for about half the development effort, including the design of the missile itself and the launching equipment that was required.

Nearly five years were required to solve the many new and complex problems posed by the Nike system. During these years, test firings were made at the White Sands Proving Ground in New Mexico, to improve launcher and booster designs. Meanwhile, development of the guidance equipment proceeded at the Laboratories. The first test firings of Nike without guidance control took place in the fall of 1946, and their immediate success confirmed some of the predictions made in the 1945 study.

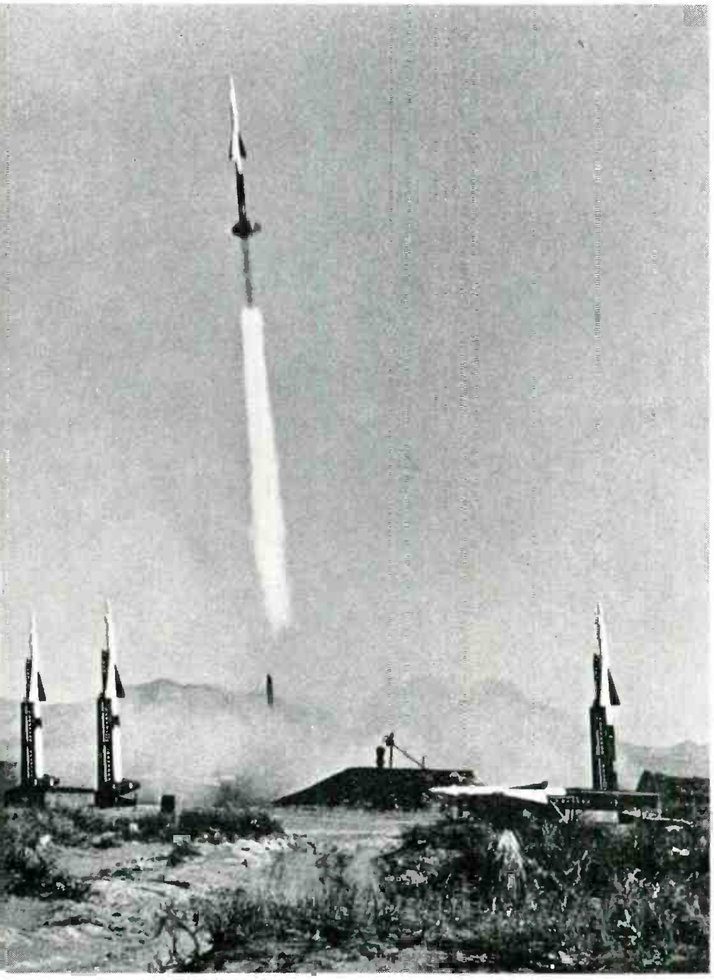
Wiring and assembly operations in the production of Nike ground guidance equipment at a Western Electric plant.



Four views of a Nike firing test are shown at the right — the missile flashing beneath the target's wing; it explodes at microsecond of intercept; wing shattered and afire, target plane starts final plunge; one of the motors tears from wing as the target plummets to earth.

Successful test firings of controlled missiles were made secretly about two years ago.

Army Ordnance promptly placed production contracts with Western Electric, whose plants in several states are producing and furnishing important elements of the Nike system. Douglas Aircraft produces the missile, and launching and handling equipment. Western Electric supplies the electronic assemblies used in the control of the missile. Both companies are aided in this project by several hundred large and small suppliers and subcontractors located throughout the country.



Nike takeoff from an Army launching area.

Patents Issued to Members of Bell Telephone Laboratories During October and November

Augustadt, H. W. – *Automatic Volume Control* – 2,657,264.

Barney, H. L. – *Inverted Grounded Emitter Transistor Amplifier* – 2,659,773.

Barney, H. L. – *Bidirectional Transistor Amplifier* – 2,659,-774.

Bollman, J. H. – *Measuring Circuit* – 2,656,506.

Bowen, A. E. – *Ultra-High Frequency Resonator* – 2,660,-667

Buhrendorf, F. G. – *Magnetic Recording Reproducing Device* – 2,658,114.

Burton, E. T. – *Semiconductor Circuit Elements* – 2,655,-625.

Callahan, V. T. and L. D. Fry – *Power Supply Apparatus for Alternately Supplying a Load* – 2,655,603.

Callahan, V. T. and L. D. Fry – *Supervisory Alarm System* – 2,655,646.

Carbrey, R. L., C. C. Cutler and C. B. H. Feldman – *Pulse Regenerator* – 2,658,997.

Crump, E. E. – *Radar System* – 2,656,532.

Cutler, C. C. – *Translation of Electromagnetic Waves* – 2,659,817.

Cutler, C. C., see R. L. Carbrey.

Darlington, S. – *Ballistic Computer Having Range Extending Adjustable Scale Factor Means* – 2,658,673.

Darlington, S. and A. A. Lundstrom – *Artillery Computer Having Deck Tilt and Gun Parallax Correction Factors* – 2,658,674.

Darlington, S. and A. A. Lundstrom – *Tilt Corrector for Fire Control Computer* – 2,658,675.

Depp, W. A. – *Multicathode Glow Discharge Devices* – 2,658,166.

Dimond, T. L. – *Electronic Induction Translator* – 2,657,-272.

Doba, S., Jr. and J. W. Rieke – *Signal Generating Device* – 2,660,676.

Doherty, W. H. – *High Efficiency Radio Frequency Power Amplifier* – 2,658,959.

Ebers, J. J. – *Semiconductor Signal Translating Devices* – 2,655,610.

Edson, R. C. – *Power Line Carrier Telephone System* – 2,654,804.

Feldman, C. B. H., see R. L. Carbrey.

Ford, G. T. – *Electron Discharge Devices and Processing Thereof* – 2,656,489.

Fry, L. D., see V. T. Callahan.

Fullerton, W. O. – *Voltage Supply Control Circuit* – 2,656,487.

Gray, F. – *Storage Device Utilizing Semiconductor* – 2,657,-309.

Gray, F. – *Reproduction of Signals from Magnetic Records* – 2,657,377.

Gray, F. – *Pulse Translation Apparatus* – 2,657,378.

Haines, W. T., and J. B. Newsom – *Cross Bar Tandem Office for Telephone System* – 2,658,108.

Harrison, C. W. – *Automatic Level Control* – 2,660,625.

Henry, L. H., – *Line Identification Trouble Indicator* – 2,657,271.

Hersey, R. E. – *Telephone System* – 2,657,274.

Holbrook, B. D. and A. A. Lundstrom – *Sight Order Computer* – 2,658,678.

Holbrook, B. D. and A. A. Lundstrom – *Computer Control Device* – 2,658,679.

Holbrook, B. D., A. A. Lundstrom and W. A. Malthaner – *Wind and Spot Computer* – 2,658,680.

Hoth, D. F. and R. O. Soffel – *Automatic Multichannel Selection* – 2,657,266.

Jenkins, R. T. – *Clapper and Gong Assembly for Telephone Ringers* – 2,658,193.

Kalin, W. and J. R. Power – *Audible Signal for Field Telephone Set* – 2,658,194.

King, A. P. – *Wave Guide Transducer* – 2,656,513.

Knandel, G. J. – *Teletypewriter Switching Systems* – 2,654,-797.

Koerner, L. F. – *Crystal Temperature Control Means* – 2,660,680.

Legg, V. E. and C. D. Owens – *Inductance Coil* – 2,659,-057.

Lovell, C. A. – *Signaling System Based on Orthogonal Functions* – 2,658,189.

Lundstrom, A. A. – *Fuze Setting Order Computer* – 2,658,-676.

Lundstrom, A. A. and W. A. Malthaner – *Regenerative Tracking Apparatus* – 2,658,677.

Lundstrom, A. A., see S. Darlington, and B. D. Holbrook.

Maloney, M. E. – *Sender Overload Control* – 2,657,273.

Malthaner, W. A., N. D. Newby and H. E. Vaughn – *Pulse Position Dialing System with Direct Time Measuring Apparatus* – 2,658,188.

Malthaner, W. A. and H. E. Vaughan – *High Speed Electronic Telephone Switching Systems* – 2,655,559.

Malthaner, W. A., see B. D. Holbrook.

Mason, W. P. – *Prismatic Directional and Object Locating Systems* – 2,658,186.

Miloche, H. A. – *Wire Connecting Tool* – 2,655,953.

Mogler, J. H. – *Cross Bar Switch* – 2,657,275.

McMillan, B. – *Bidirectional Counter* – 2,656,460.

Newby, N. D., see W. A. Malthaner.

Newsom, J. B., see W. T. Haines.

Oliver, B. M. – *Television Correcting Circuit* – 2,660,614.

Ostendorf, B. Jr., and R. A. Vanderlippe – *Communication Signal Lamp Control Circuit* – 2,657,336.

Owens, C. D., see V. E. Legg.

Power, J. R., see W. Kalin.

Rack, A. J. – *Electronic Switch* – 2,657,318.

Rea, W. T. – *Cathode-Ray Translating System for Permutation Codes* – 2,654,878.

Rea, W. T. — *Error-Indicating Code Mechanism* — 2,657,261.

Retallack, J. B. — *System for Automatically Ticketing Telephone Calls* — 2,657,268.

Rieke, J. W., see S. Doba, Jr.

Schelleng, J. C. — *Frequency Modulation Repeater* — 2,659,-813.

Schneider, H. A. — *Apparatus for Spraying Attenuation Material onto Traveling Wave Tube Helices* — 2,659,337.

Shockley, W. — *Bistable Circuits Including Transistors* — 2,655,609.

Soffel, R. O., see D. F. Hoth.

Sparks, M. — *Semiconductor Translating Devices* — 2,656,-496.

Treuting, R. G. — *Silicon-Germanium Objective Lens* — 2,659,271.

Valdes, L. B. — *Semiconductor Circuit Controlling Device* — 2,655,608.

Vanderlippe, R. A., see B. Ostendorf, Jr.

Vaughan, H. E., see W. A. Malthaner.

Wallace, R. L., Jr. — *Four-Electrode Transistor Modulator* — 2,657,360.

Walsh, E. J. — *Electron Discharge Device* — 2,660,688.

Walsh, E. J. — *Laminated Ring Lead-In for Electron Discharge Devices* — 2,656,404.

Warner, A. W., Jr. — *Crystal Units for Use at High Temperatures* — 2,656,473.

West, J. W. — *Tunable Magnetron* — 2,657,334.

Wintringham, W. T. — *Color Television System* — 2,657,254 — 2,657,255 — 2,657,256.

Ziegler, A. W. — *Piezoelectric Crystal Unit* — 2,657,320.

Dr. Kelly Appointed to Hoover Study Group

M. J. Kelly, President of the Laboratories, has been appointed by former President Herbert Hoover to serve on the committee for the business organization of the Department of Defense, part of Mr. Hoover's governmental reorganization commission. Three other members of the committee are Directors of Bell System Companies: G. C. Brainard of the Ohio Bell Telephone Company, and J. B. Hall and R. B. Robertson, Jr., of the Cincinnati and Suburban Bell Telephone Company.

H. R. Maddox Becomes Director of the Laboratories

H. Randolph Maddox, newly appointed Vice President of the American Telephone and Telegraph Company, has been named to succeed Stanley Bracken as a member of the Board of Directors of the Laboratories. He resigned his post as President of the Chesapeake and Potomac Telephone Companies to accept the Vice Presidency with A.T.&T.

Mr. Maddox began his Bell System career as a student engineer with the Chesapeake and Potomac Telephone Company in Washington in 1921, immediately after receiving his M.E. degree from Lehigh University. He served in numerous engineering and commercial capacities with the C.&P., and became its President in 1947.

Growth of Network TV

The Bell Telephone System interconnected more television stations for network service in 1953 than were receiving network service prior to that time. Network service was made available to 140 stations in 86 cities last year, compared to 114 stations in 71 cities between the years 1948 and 1952. With 7 stations added on January 1, network service has now been extended to 261 stations in 161 cities. September was a record month, with 41 stations being connected in 34 cities.

1953 was a marker for many other highlights in the field of television transmission. The most notable of these was the first coast-to-coast experimental television show using the color system recently approved by the Federal Communications Commission. The program was beamed from New York to Burbank, California over A. T. & T.'s 3,000-mile transcontinental radio relay route, to an audience of 900, on November 3.

Following approval of the color method by the FCC, the Bell System moved quickly to equip its facilities to meet the requirements of the broadcasting industry, and by the end of the year was ready to transmit commercial color programs to some 18 cities along the transcontinental route. The Tournament of Roses Parade was the first network color program received by these cities.

Another first for 1953 was establishment of a U. S.-Canada television channel. Toronto, Ottawa, and Montreal are now connected to receive network programs from the United States.

Using both radio relay and coaxial cable facilities, Long Lines completed a number of backbone telephone transmission routes and added more than 17,000 miles of intercity video channels. The Bell System now has some 50,000 channel miles of television facilities in use.

Another important event of the year was the placing in service of the first L3 telephone carrier system between New York and Philadelphia. This system is capable of tripling the telephone capacity of present coaxial cable routes. Other routes are now being equipped with L3 carrier.

2400-Mile Radio Relay

Construction work has been completed on two remaining sections of a 2400-mile radio relay system encircling most of the heavily populated northeastern quarter of the nation. The completion of the two sections, from New York City to Albany and from Buffalo to Cleveland, marks a major accomplishment in the field of communications.

The system can be used for both telephone messages and television programs, and will ultimately make available four network television channels. The radio relay follows a somewhat geographical route to make a complete loop, with Washington, New York City, and Albany on the eastern extremeties of the loop and St. Louis and Chicago on the western. The circuits in the system are so arranged as to permit any interconnected station to originate a television program and transmit it to all other stations on the system. Such an arrangement adds considerably to the flexibility of intercity facilities. This is a very important factor in the routing of television programs.

W. E. Campbell on Lubrication Subcommittee

W. E. Campbell has been reappointed to the Subcommittee on Lubrication and Wear on the National Advisory Committee for Aeronautics, to serve during 1954. In conducting scientific laboratory research in aeronautics, the Main Committee of the NACA is assisted in the determination and coordination of research programs by twenty-eight technical committees and subcommittees. Selected to serve because of their technical ability, experience, and leadership in a special field, more than 400 specialists represent leadership in virtually every branch of the physical sciences.

Talks by Members of the Laboratories

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

Corenzwitz, E., see B. T. Matthias.

Darnell, P. S., Transistors and Miniaturization of Electronic Equipment, Virginia Polytechnic Institute Alumni Association, New Jersey Chapter, Summit, N. J.

Ferrell, E. B., Control Charts Using Midranges and Medians, Rutgers University, New Brunswick, N. J.

Ferrell, E. B., Reliability and Its Relation to Suitability and Predictability, Joint Computer Conference, Washington, D. C.

Herring, C., Correlation of Electronic Band Structure with Properties of Silicon and Germanium, American Physical Society, Stanford, Calif.

Herring, C., Thermoelectric Power of Semiconductors, University of Wisconsin, Madison, Wis.

Higgins, W. H. C., Bell Telephone Laboratories and National Defense, International Lions Club, La Porte, Ind.

Matthias, B. T., E. Corenzwitz and C. E. Miller, Superconducting Compounds II, Low-Temperature Conference, Houston, Tex.

Merrill, F. G., Frequency Standards, I.R.E. Rome-Utica Section, Rome, N. Y.

Merz, W. J., Physical Properties of Barium Titanate Single Crystals and Their Use as a Storage Device, Electrical Engineering and Physics Departments Colloquium, Rensselaer Polytechnic Institute, Troy, N. Y.

Miller, C. E., see B. T. Matthias.

Monro, S., Some Aspects of Sequential Experimentation, American Statistical Association, Washington, D. C.

Murphy, R. B., Selective Assembly, American Society for Quality Control, Princeton, N. J.

Pfann, W. G., Distribution of Solutes by Zone-Melting, Columbia University School of Mines Colloquium, New York City.

Pierce, J. R., Communications Between the Earth and Space Vehicles in Flight and Between the Earth and Extraterrestrial Fixed Points, American Rocket Society Symposium, New York City.

Rolf, F. N., Telephone Switching, University of Alabama, Tuscaloosa, Ala.

Shafer, C., Jr., Prelashing Aerial Cable, Signal Corps Symposium, Asbury Park, N. J.

Terry, M. E., The Exploration and Exploitation of Response Surfaces (paper by Dr. G. E. P. Box, Institute of Statistics, North Carolina State College), Princeton Conference, Princeton, N. J.

Terry, M. E., Summation of the Six Lectures of the Study Group in Statistics, A.I.E.E. New York Section, New York City.

Walker, A. C., Growing Crystals, Queens College Chemistry Society, Flushing, N. Y.

Washburn, S. H., The Professional Development of Young Engineering Instructors, American Society for Engineering Education, Philadelphia, Pa.