Bell Laboratories **RECORD**

Volume 41 • Number 9 • October 1963

Contents

Cover *An interior view of the newest* TOUCH-TONE *Calling receiver. Connectors and nylon runners support the circuit boards in a mechanical design that is simple, inexpensive, and compact.*

H. M. Kalish

Machine-Aided Preparation Of Electrical Diagrams

Graphic diagrams are automatically prepared from basic input data.

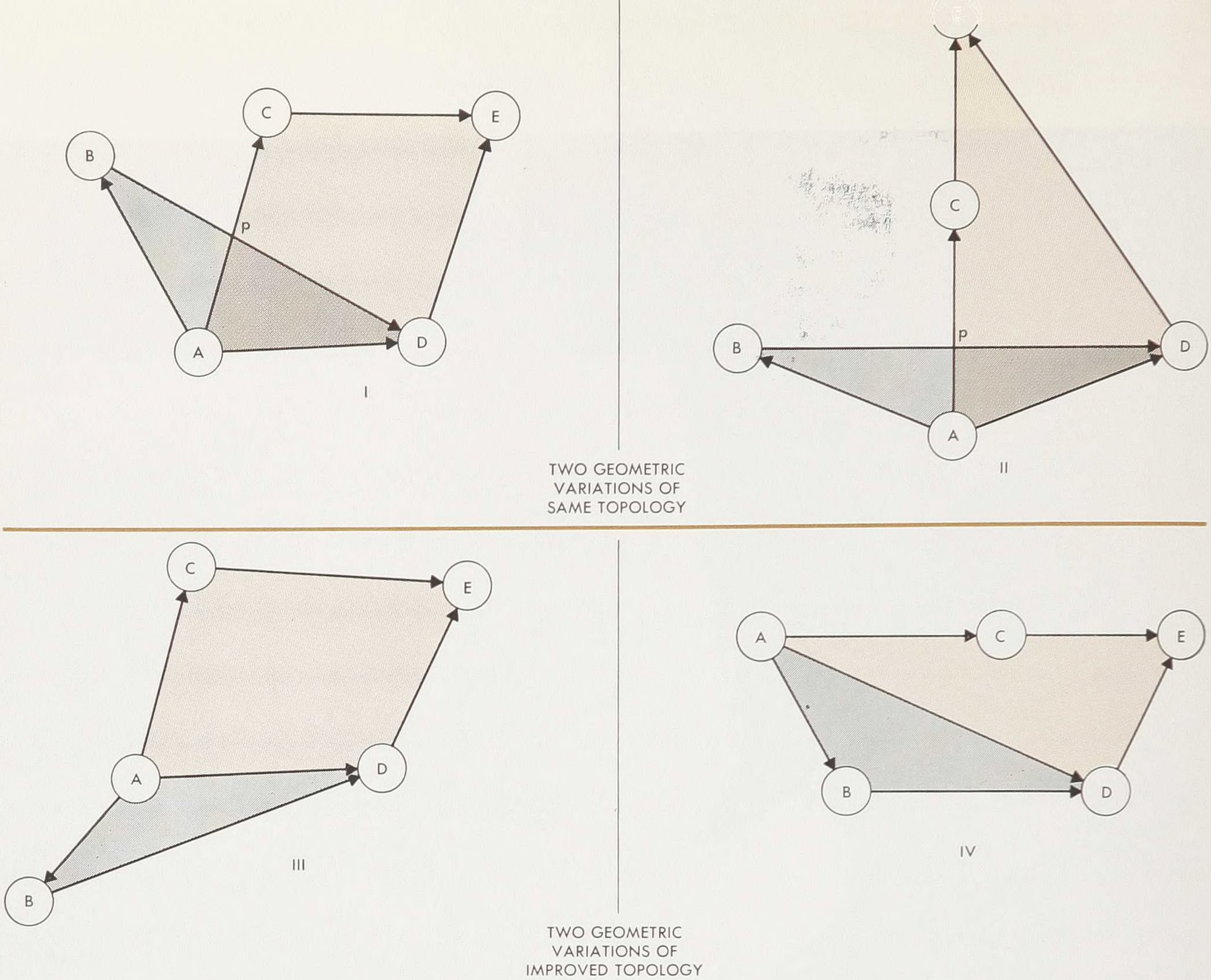
In this day of increasingly complex and sophisticated systems, the need for effective engineering information is greater than ever. To be of practical value, engineering information must be accurate, legible, and current. It seems appropriate, therefore, that the feasibility of using machine aids in this area should be fully explored.

Much progress has been made toward adapting machine aids to the preparation of engineering information in tabular form (Record, *September* 1963). Many applications, however, require the use of graphics for satisfactory presentation. Schematic diagrams, particularly, require the use of graphics to impart the true function of a circuit. Wiring diagrams, although presently prepared in tabular form by machine, frequently have greater value in graphic form when used for troubleshooting. A Machine-Aided program for the Preparation of Instruction Data (MAPID) represents one effort to bridge this gap. The MAPID program, which automatically prepares conventional-type graphic diagrams from basic input data, is described in this article.

If accuracy is a prime prerequisite in the preparation of graphic-type diagrams, *reader-comprehension* is the second most important consideration. Every aspect of a diagram influences reader-comprehension to some degree from line weight and lettering height to functional grouping and logical signal flow. The *layout* of a diagram, which includes *topology* and *geometry*, has a particularly strong influence on reader-comprehension. Consequently, any attempt to develop a machine-aided program for preparing graphic-type diagrams must come face-to-face with the problems of layout.

The topology of a diagram pertains to the relation of its lines, nodes, and areas. In the illustration on page 340 (I through IV) diagrams I and II have the same topology (areas ABpA, ApDA, and CEDpC) although their geometries, or shapes, are quite different. Diagrams III and IV, on the other hand, have an improved topology over I and II as a result of the elimination of node p. In attempting to represent a three-dimensional circuit in a two-dimensional diagram, undesirable

W. J. Nicholas, SC 4020 operations leader, makes final adjustments on the system (top) and observes (left) a sample diagram on the cathode ray tube.



The topology of a diagram shows the relation of its lines, nodes and areas.

nodes, called *crossovers,* invariably enter the picture. Optimum topology, for the purpose of MAPID, is the configuration which has the fewest crossovers within given restrictions such as functional grouping and uni-directional flow.

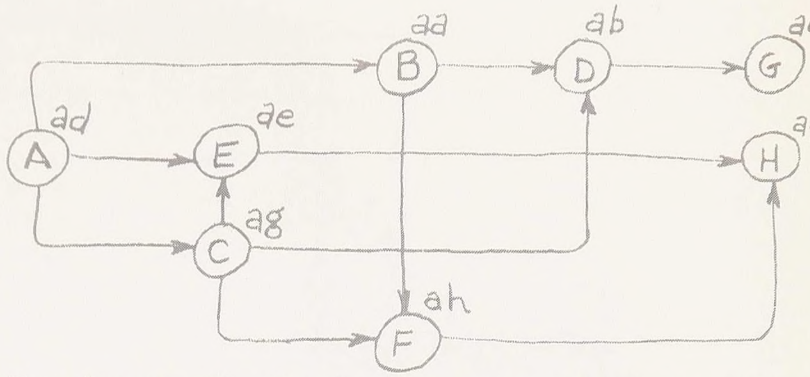
The geometry of a diagram pertains to the placement of elements and the routing of runs within a specified topology. For example, the topology specified in diagram III remains the same in IV although the configuration has been improved through a geometry change. Good geometry is based on both functional and aesthetic considerations. Functional considerations emphasize the true purpose of the circuit being illustrated and include such factors as grouping by function and uni-directional flow. Aesthetic considerations contribute to the clarity and readability of the diagram and include such factors as spacing of elements and runs, routing of runs, and placement of elements. A final consideration which is more subtle and frequently overlooked must be included in the geometry if the basic intent of the diagram is to be recognized. This consideration requires that the shape or form of the completed diagram establish it as a distinct functional unit as opposed to a collection of interrelated elements.

Like many of the things we do from day to day, the preparation of an electrical diagram is performed with little awareness of our complex thought processes. Since a machine can do only what it has been programmed to do under a given set of circumstances, the program for drawing an electrical diagram must contain rules for taking actions similar to those that would be taken manually under the same circumstances. One approach to the automated preparation of electrical diagrams, therefore, consists of analyzing the steps taken in manually preparing a diagram, and then devising rules which can be used by a machine to attain the same result. This approach is being used in the MAPID program.

Specific Format Needed

As in all machine-aided programs, input data must be prepared in a specific format. The input requirements of a generic program such as MAPID must be adaptable to the output of various automatic design programs as well as to manually-prepared data. In keeping with this, MAPID input requirements are basic and simple. The present format consists of a list of all elements in the diagram with related input and output runs. The program can easily be modified, however, to accept a list of runs with related elements, or any format likely to be used in the output of an automatic design program. The format also provides for specifying the type of circuit element, its part designation, orientation, whether a run is main-path or feedback, and other special characteristics. Most of these "refining" data are stored for later use while the more "essential" run data are molded into a basic layout.

The input data are prepared for card punching by listing all elements in *random order,* as shown in the illustration at the lower right. Two-character identifications are arbitrarily assigned to the elements as unique "handles," independent of any functional designations. Various schemes may be used to simplify the manual coding of a diagram. One scheme would be to place the elements and runs at random on a form which has been printed with row and column identifications. The elements would then acquire the two-character identifications of their respective coordinates. Previously prepared diagrams may be coded by first assigning two-character identifications to all elements in alphabetical order and then listing the elements as they are encountered while following the diagram from left to right, as in the illustration at the top of the page. In the program, each two-character identification is converted to a location which contains all data relating to the element. This includes fixed data such as type of element and designation, variable data such as horizontal and vertical positions, and interconnection data such as terminal elements and run routes.



Two-character identifications are assigned to all elements.

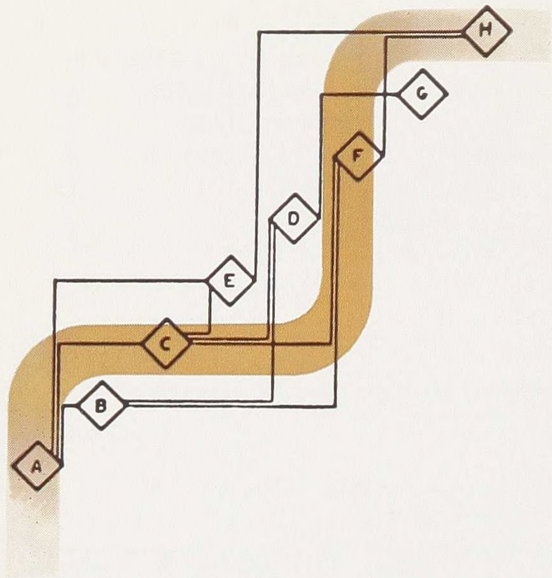
ELEMENT DESIGNATION	ELEMENT IDENTIFICATION	NUMBER OF INPUTS	OUTPUTS	INPUT ELEMENTS	OUTPUT ELEMENTS
B	aa	1	2	ad	ab, ah
D	ab	2	1	aa, ag	ac
G	ac	1	0	ab	
A	ad	0	3		aa, ae, ag
E	ae	2	1	ad, ag	af
H	af	2	0	ae, ah	
C	ag	1	3	ad	ae, ab, ah
F	ah	2	1	aa, ag	af

Input data is listed on forms in random order.

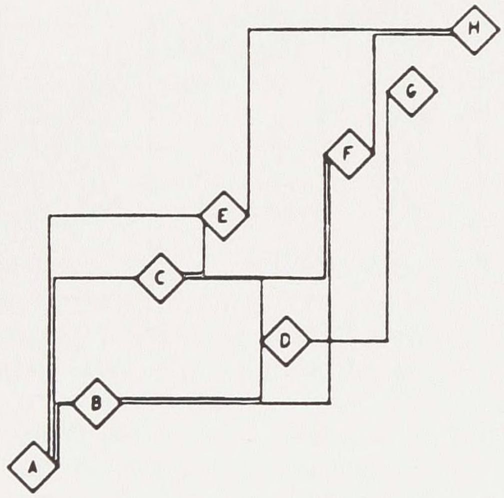
Establishing An Optimum Layout

The process of establishing an optimum layout from a random list of element interconnections is simplified by first organizing the elements into specific categories. Elements with only a single input and output — referred to as "one-to-one elements"—are replaced by a simple run since they have no significance in the topology phase of the program. Reference-input and reference-output elements represent the link from and to other diagrams in the system and are printed as brackets, with appropriate reference statements, at the extreme left and right of the diagram. Elements that originate and terminate signals within the diagram are referred to as "source" and "load" elements, respectively. All elements that receive signals solely from reference elements are called "reference-cluster elements." Similarly, all elements that receive signals solely from source elements are called "source-cluster elements." Each group of source-cluster elements associated with a particular signal is established as a source cluster and is processed separately in the topology phase of the program. The reference cluster, which includes all reference-cluster elements plus a dummy element for each source cluster, is processed as the basic diagram. Common elements—elements that receive both source and reference signals—are included in both the source and reference cluster processing, thus providing a means for combining the clusters after completion of the topology phase.

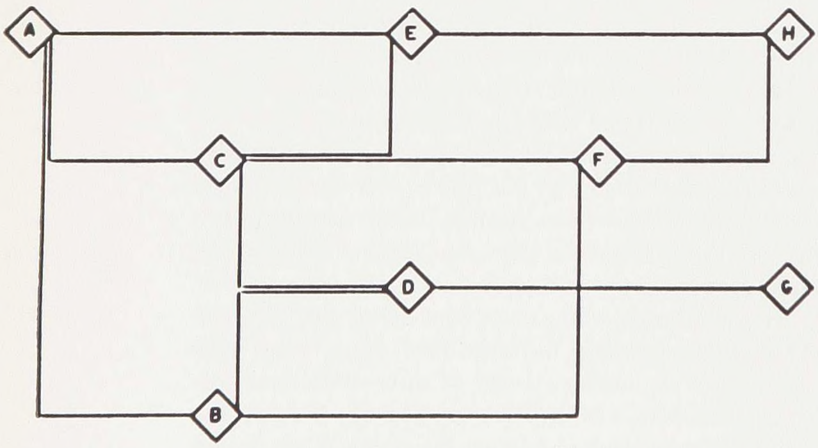
In the topology phase of the program, the criteria of left-to-right flow and minimum crossovers are dealt with consecutively as horizontal and vertical processes. The horizontal process establishes a linear order for all elements in the diagram so that each element is to the right of all of its input



The initial placement of elements and routing of runs form a snake-like pattern.



Fewer crossovers is the result of topological processing.



Rows are combined in the geometric process.

elements. This order, which is maintained throughout the topology phase, may be visualized as a series of columns across the diagram within which the movements of the corresponding elements are restricted. The horizontal process consists of tracing the outputs of each element in turn, starting with the reference input or source elements and terminating at the reference-output or load elements. As each output element is encountered, its number-of-inputs count is tested. When all inputs have been accounted for, the element is placed next in the horizontal order, and *its* outputs are then traced.

The vertical process consists of moving elements vertically within their assigned columns and re-routing input and output runs to reduce the number of cross-overs. Initially, the elements are assigned to rows or Y positions according to the same linear order established in the horizontal process for their columns or X positions. This may be visualized as a single row of elements arranged diagonally across the diagram, as shown on the left. Run routes are restricted to "L" shapes and are designated either vertical-horizontal (VH) or horizontal-vertical (HV).

Snake-Like Pattern

Most of the initial run routes are assigned in a snake-like pattern in order to gain an advanced start toward minimizing crossovers. This is made possible because of the method used in the horizontal process for listing elements. Actually, the linear order is made up of a series of sequence groups, each of which contains elements fed solely from previous groups. By listing the elements of a group in reverse order of the feeding elements in the preceding group, the possibility of adjacent-group runs crossing each other is eliminated. To take advantage of this, runs between consecutive sequence groups are initially assigned alternate VH and HV routes. The routes of remaining runs—those which extend beyond adjacent groups—are assigned after testing each alternative route (VH) or (HV) and choosing the one that results in the fewer crossovers.

With all elements and runs initially placed, the process of minimizing crossovers begins with the first crossover on the crossover list. This list contains the current crossovers in the diagram in terms of the four elements associated with each. As a crossover reaches the top of the list, all crossovers related to its four associated elements are removed for processing. New and unsuccessfully processed crossovers are placed at the bottom of the list and processing continues with the next crossover at the top. The minimization process consists of testing each of the four elements associated with a crossover in all topologically-significant positions. This means that an element is moved above and below all runs which occupy its column. For each position, both routes of all of the element's runs are tested and the net change in number of crossovers is noted. The element, position, and run configurations resulting in the greatest net gain are then chosen, and the appropriate changes in the element's data blocks and the crossover list are made. If no net gain is accomplished, the crossovers are placed at the bottom of the list in hope that subsequent processing will enable a gain when they are considered again. The program pursues this process until a complete pass through the crossover list accomplishes no gain. At this stage the remaining crossovers are assumed "essential" and the topology of the diagram is considered optimum. The position of each element is expressed as a unique row-column designation, and the route of each run is expressed as either VH or HV. The middle diagram on the opposite page illustrates the result of topology processing.

Before the geometry phase is started, those one-to-one and source cluster elements that were removed to simplify the topology process are reinserted into the diagram. Each one-to-one element is placed in a unique column between its input and output elements, and in the same row as the element associated with the horizontal leg of the run. Source clusters are inserted in place of their respective dummy elements. First, a "hole" is made in the diagram for each source cluster by shifting all elements to the right and above the corresponding dummy element. The source clusters, having been processed separately in the topology phase, are then inserted into these areas and connected to their respective common elements.

While the topology phase improves the readability of the diagram through left-to-right flow and crossover reduction, the few simple requirements of good geometry are ignored. The geometry phase shapes the diagram *within the established topology* to further improve its clarity and conventional character. In the vertical process of the geometry phase, elements are moved up or down in their assigned columns to gain straight runs and to minimize the total number of rows. As a result, the signal path from left-to-right is made reasonably direct with a minimum number of jogs. Finally, the row spacing is adjusted for clarity and aesthetics. In the horizontal process, unnecessary horizontal space between elements is eliminated and the over-all length of the diagram is reduced. First, all elements are moved to the left as far as possible. Then, elements with a greater number of outputs than inputs are moved to the right to reduce the number of longer runs.

At the conclusion of the topology and geometry phases, the layout of the diagram is considered to be optimum. As a check on the program at this stage, and possibly as a final product for some applications, an interim graphic printout of the diagram as illustrated by the bottom diagram on the opposite page is provided.

Print-out Phase of MAPID

The print-out phase of MAPID uses the data contained in the element data blocks, together with a library of symbol-drawing routines, to construct a diagram in the format required by the print-out device. First, the original input data specifies the symbol to be "drawn," the orientation of the symbol, its designation, and special characteristics. Second, the layout phase of the program defines the location of each element and the configuration of each run. Finally, the library of symbol routines provides for constructing the specified symbol and orientation at the defined location.

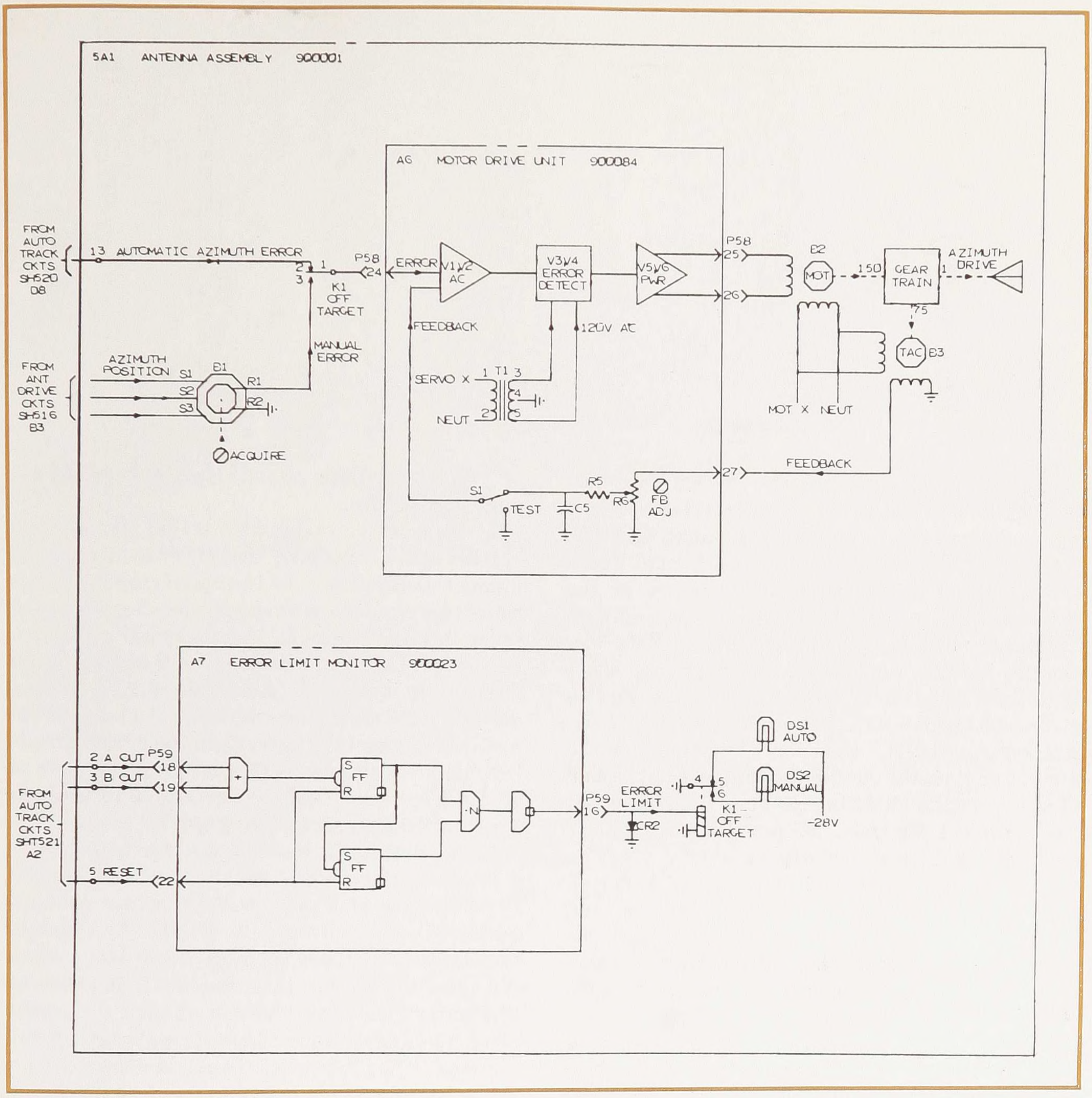
The present symbol library contains routines for drawing most of the commonly-used electrical schematic symbols; however, routines for drawing practically any type of circuit element can be included. The six-character symbol name, taken from the element data block, is used to call the appropriate symbol routine from the library. The routine then uses the X and Y coordinates which define the symbol's location to generate all the coordinates required by the printer to draw the symbol. The symbol routine also provides the appropriate coordinates for terminating the associated runs, placing the four-character designation, and rotating to the proper orientation.

The diagram on page 345 represents the first of many tests on several different machine-oriented printers. Although this diagram was prepared by a crude print-out program which placed symbols, lines, and characters at predetermined coordinates, the result proved the feasibility of preparing conventional electrical diagrams by machine. Automatic layout data will be provided shortly by the layout portion of MAPID, now in the final stage of completion.

An average diagram is processed in approximately one minute on the IBM 7094 computer and one second on the SC 4020 printer. The SC 4020 output is 35 mm "microfilm" which, in turn, is printed using standard blowback facilities. The printed diagram is 10¼ in. high with the equiva-

Evelyn House checks diagram prior to printing.

Miss House inserts aperture card into Xerox 1824 printer (left) and inspects finished diagram.



This sample shows a conventional electrical diagram printed automatically from basic input data.

lent of 0.080 in. lettering, suitable for direct use in standard 8½ x 11 books.

The applications of a completely automatic means for preparing book-size graphic diagrams from basic run data are virtually limitless. In the most sophisticated application, computer-prepared data from an automatic design program may be channeled through MAPID to produce graphic engineering information along with other engineering and manufacturing information. In a simpler application, a draftsman may "consult" the program for its version of the optimum layout of a specific diagram. Among the many inherent advantages of automation, perhaps the single most significant feature is the speed of producing and updating finished drawings. This is based on the continual struggle to prepare documentation and instruction data in time for delivery with developmental models. In addition to the advantage of being able to meet tight schedules, the automatic production of diagrams would permit greater attention to other important and perhaps more challenging aspects of preparing engineering information.

W. O. Turner

Traffic Simulation

For each new switching system designed by Bell Laboratories, the operating telephone companies must have guides for estimating traffic capacity so that they can match equipment quantities to expected traffic volumes. Even in the early stages of systems design, Laboratories engineers must be able to estimate traffic capacities in order to make valid comparisons of alternatives in terms of costs incurred and service given. After some actual experience with a working system, traffic capacity estimates can be checked empirically; but in the critical early period of a new design all estimates have to be based on mathematical analysis, on simulation, or on a combination of these techniques.

An estimate of the traffic capacity of a system, to be useful to a Laboratories engineer, should show the relation between traffic load and the significant service variables of blocking or delay over the full potential range of offered traffic loads —in some cases all the way up to virtual saturation. The relation between quality of service and load is not linear, so that to show this relationship over the entire range of interest a number of examples have to be worked out, no matter whether analysis or simulation is used.

The dividing line between the fields of mathematical analysis and of simulation is not well defined, and, in fact, they may be looked upon as complementary analytical tools. The choice of method in any particular case may always have to be flavored with a good deal of judgment. Both methods start with the creation of a model of the system under study. A traffic input is submitted to the model system, and the resulting grade of service is estimated. The adequacy of the model is the key to the reliability of the traffic estimate. Its realism is limited by the model builder's ability to understand and synthesize the real system, and by the degree of manipulative skill that he has available to him.

If the number of possible traffic states of the system can be explicitly described by a moderate number of equations, or if simplifying aproximations can be made without introducing too much error into the estimate, mathematical analysis is generally faster and more flexible than simulation. Frequently numerical solutions can be reached directly with the aid of the desk calculator. If the model is of general interest and the effect of varying one or more parameters of the model is to be studied, it usually will be preferable to program the solution on a digital computer.

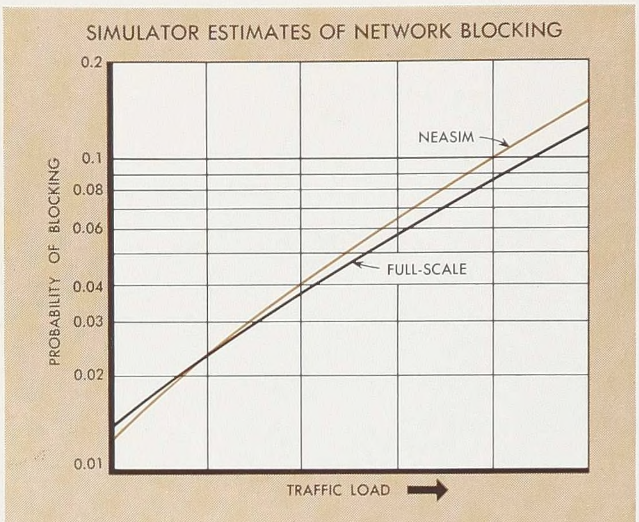
If the system is too complex for a successful analytical attack, simulation is indicated. Almost without exception simulations today are programmed on digital computers. Basically, a simulation consists of three parts: a traffic input whose statistical parameters are specified; an operating program which creates an analogue of the system being simulated and controls the progress of calls through the system; and an accounting program which records the data desired by the experimenter such as the number of calls completed, blocked, or delayed.

There are certain characteristics of a traffic handling system whose existence pretty clearly indicates the desirability of using a simulator. For example, in many cases dependencies will be found between switching stages, as in the case of a tandem queue. Tandem queues exist wherever a call must obtain two switching elements in sequence, if each call occupies one of the first rank of switching elements until one of the second rank becomes available, and if there is competition among first rank elements for an idle second rank element. An illustration is the connector circuit used widely in crossbar systems for interconnect-

At a preliminary conference, engineers and programmers organize a trunk network simulation.

ing senders or registers with decoders or markers. In this model, although the traffic input to the system may be considered random, delays at the first switching stage modify the distribution of the traffic load which reaches the second stage; and delays at the second stage decrease the load-carrying capacity of the first stage. Suitable theories for estimating the traffic capacity of such a system do not exist, but the problem can be solved readily by simulation. In view of the generality of the problem a general-purpose connector simulator has been programmed. This simulator is available at Bell Laboratories for any design problem requiring the determination of the number of inputs and outputs per connector, and for any engineering problem where the equipment parameters are fixed and the permissible offered load for a chosen grade of service is to be determined.

Traffic simulation has played a vital role in determining the blocking performance of internal link matching networks, as used in crossbar systems and in No. 1 ESS. In this case, however, simulation has been used not as a primary engineering tool but as a check on results obtained by analysis. At our present level of programming skill, and with today's generation of computers, a full-scale simulation of the link network of a No. 1 ESS office taxes the capacity of the computer, and computer time per simulator run is a significant expense. The network configuration will vary from office to office depending upon the number of lines and trunks, the traffic load per line, and the percentage of calls completed within the office. To test each of these configurations by simulation would involve reprogramming each time major network parameters were changed, and would require many hours of computer time. Much time and effort has been saved by the creation of a fast and flexible computer program called NEASIM (Network Analytical Simulator). As contrasted with full scale simulations, which are each designed for a particular network configuration, NEASIM is a general-purpose network simulator in the sense that the pattern to be tested is an input specified for each run, along with the traffic occupancy, rather than being built into the operating program itself. The program examines in quick succession a large number of possible states of the system that is specified by the input data. For each state the busy or idle condition of each link is determined by a random number, and the program determines whether a call submitted to the network in this state would be completed or blocked. This is a primary tool for engineering and design studies; but since this program makes only approximate allowances for dependencies between link stages, and ignores the effect of factors such as the order of search for an idle link, the accuracy



THE DIFFERENCE BETWEEN NEASIM AND FULL-SCALE SIMULATOR ESTIMATES ARE WITHIN THE EXPECTED RANGE OF SAMPLING ERROR.

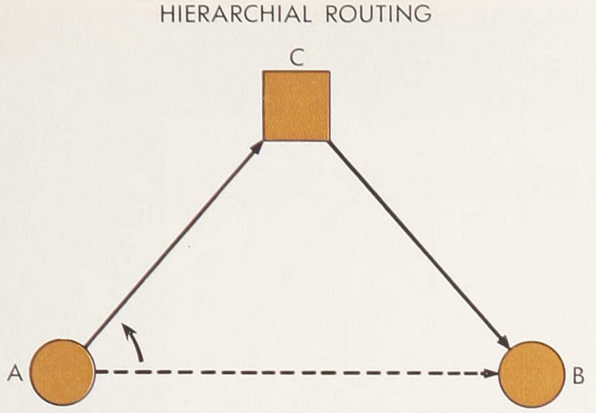
of results had to be checked by full-scale simulations. The graph on this page shows the results of one such check. These checks indicated that such errors as are introduced by the approximations used in NEASIM tend to offset each other, and this fast and flexible program can safely be used as an engineering tool.

Although full-scale traffic simulation has assumed a secondary role in the investigations of the No. 1 ESS link network, it is an essential tool for estimating the traffic capacity of the ESS central control. When a computer is programmed to simulate the call processing functions of the real system, an estimate is obtained of the real time occupancy per call and thus of the traffic capacity of the central control. Simulations are being used to test and refine the operating program of the ESS central control, to estimate its maximum traffic capacity, and to determine at what point in the growth of an office some of its functions should be delegated to auxiliary circuits such as signal processors.

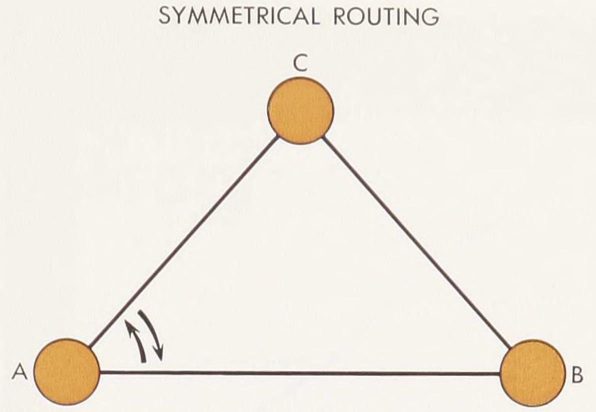
One field in which the technique of traffic simulation is particularly effective is the investigation of the blocking performance of automatic alternate routing trunk networks. The Bell System DDD network has a hierarchical alternate routing pattern, which is particularly suited to the capabilities and limitations of the toll crossbar switching system. A simple two-level hierarchy is illustrated by the left-hand sketch on page 349. The present DDD network consists of four levels of toll offices. Looking ahead to future switching systems with superior logic, many other configurations can be imagined, and it is necessary to test their efficiency against that of the familiar hierarchy. One such competing structure, sometimes called "symmetrical," is shown by the right-hand sketch on page 349. In both structures we encounter dependencies between routes, since the load carried by a given route will depend not only upon the traffic directly offered but also upon the overflow from other routes. The number of equations required to express the possible states is so great that exact mathematical analysis, even on the computer, is not to be contemplated. On the other hand, simulation is straightforward, at least for the networks which do not overtax the storage capacity of the computer.

A by-product of our network simulations is a measure of the effectiveness of the alternate routing process, independent of the particular configuration used. Examination of the lower graph on page 349 shows that alternate routing reduces blocking up to some critical value of offered load, beyond which blocking begins to increase as compared to a non-alternate routing network. This phenomenon is caused by the interplay of two opposing factors. Alternate routing increases the number of trunks accessible to traffic, and this improves network efficiency. On the other hand, alternate routes involve circuitous multi-link connec-

Programmers Judy Trask and Judy Selis study simulation results at the Computation Center.



CALLS OVERFLOWING HIGH USAGE ROUTE AB ARE OFFERED TO FINAL ROUTE ACB. NO ALTERNATES ARE PROVIDED FOR ROUTES AC AND CB.

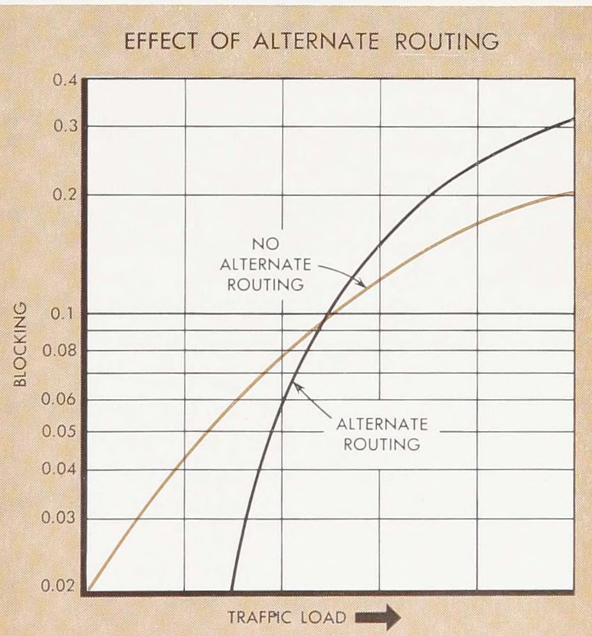


EACH DIRECT ROUTE HAS AN ALTERNATE VIA THE THIRD SWITCHING POINT. FOR EXAMPLE, CALLS WHICH OVERFLOW ROUTE AB ARE OFFERED TO ROUTE ACB, WHILE AT THE SAME TIME CALLS WHICH OVERFLOW ROUTE AC ARE OFFERED TO ROUTE ABC.

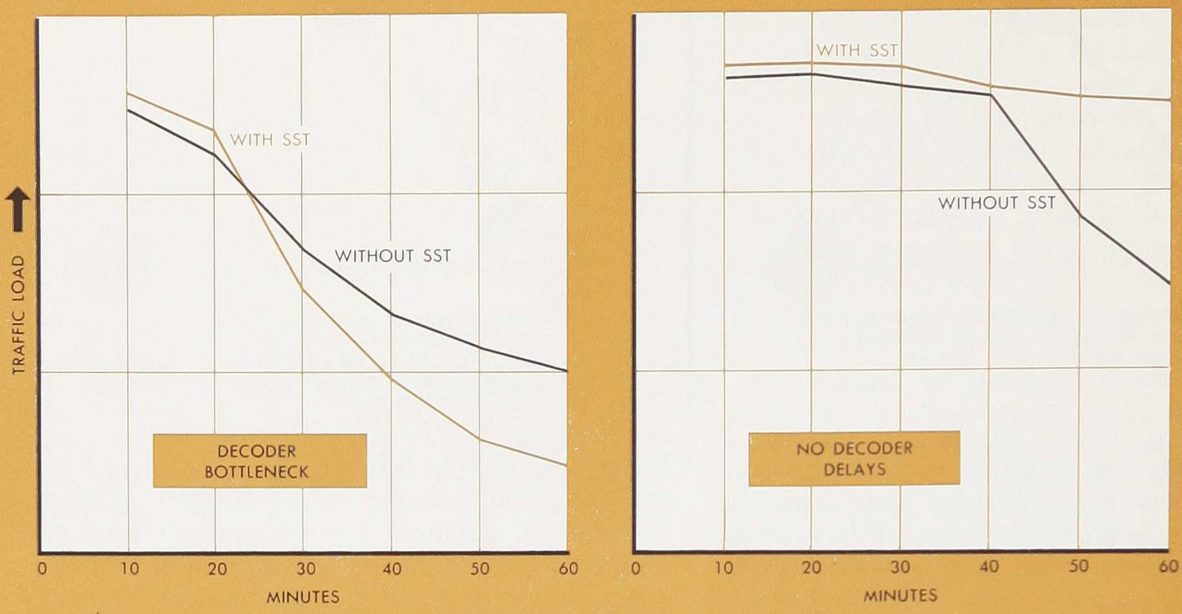
tions and their use tends to decrease network efficiency. Network engineering procedures are designed to strike the proper economic balance between the two factors; but when general network overloads build up, the weight of the unfavorable factor increases much faster than that of the favorable one, and alternate routing eventually turns from an asset into a liability. This knowledge, obtained through simulation, gives us confidence that the practice of canceling alternate routes during DDD overloads is sound, although in the real system it has been impossible to obtain a precise measure of its value.

Perhaps the most ambitious telephone traffic simulation ever attempted anywhere is the Toll Network Simulator (TOLLSIM) now in use at the Laboratories. This simulator is modeled after a part of the existing DDD network. It consists of a hierarchy of switching centers, each equipped with senders and common control circuits, and a number of end offices which originate and terminate the traffic flowing through the network. This is the only network simulator so far constructed that will reproduce switching delays as well as call blocking. Its primary purpose is to permit study of network performance under heavy overloads. Since under these conditions a significant proportion of calls are not completed on the first attempt, provision is made for simulating the action of customers in making subsequent attempts on abandoned or blocked calls. In addition, the simulator can reproduce a number of load-control measures, such as cancellation of alternate routes, reduction of the normal sender time-out interval (known as short sender timing), etc. Some of these measures are presently used in the real system; some are available only in the simulator.

For many years experiments have been conducted to determine the primary causes of traffic congestion in the DDD network, to trace its spread, and to measure the effectiveness of overload control measures. The problem of taking the necessary data for analysis on a coordinated basis throughout a network of continental proportions is formidable enough; but the most significant conditions are those which should be recorded at the peak of the emergency, at a time when all personnel are needed for making and carrying out management decisions rather than for recording data. Hence, adequate data are rarely available. Even if data were available, assessment of the effectiveness of action taken in a particular emergency can be made only qualitatively, since the pattern of each traffic overload is unique and it can never be determined precisely how much bet-



ALTERNATE ROUTING DECREASES THE BLOCKING IN A NETWORK AT MODERATE TRAFFIC LOADS, BUT INCREASES BLOCKING AT HEAVY OVERLOADS.



SIMULATION SHOWS THAT DURING OVERLOADS IN 4A TOLL CROSSBAR SYSTEMS SHORT SENDER TIMING (SST) SHOULD NOT BE USED IF A DECODER BOTTLENECK EXISTS.

ter or worse service would have been had a different kind of action been taken.

The purpose of the simulator is to reproduce, in the quiet of the laboratory, conditions similar to those observed in the real network. The simulator output records the blocking and delay performance of each element of the network and the traffic load being carried, not only for the entire period of simulated time but at frequent intervals during the run so that the origin and spread of congestion can be traced. By reiterating runs with identical offered traffic loads but with different control measures in effect, the relative value of these different measures can be sharply contrasted. For example the left-hand graph on this page shows the effect of introducing short sender timing under extreme overload conditions when decoders constitute the primary traffic bottleneck of the system. Service is sharply degraded because each time a sender times out it must rejoin the decoder queue in order to route the call to reorder, and thus encounters a second delay during which it cannot accept a new call. On the other hand, as demonstrated by the right-hand graph where ample decoder traffic capacity exists, short sender timing greatly minimizes the impact of the overload on system capacity. Experiments like these have helped evaluate load control measures now in existence, and have suggested a number of new measures not previously considered.

Simulation of a complex system may quite unexpectedly bring collateral benefits. Construction of an adequate model requires study of the real system in close detail, and if this study is made critically enough it may disclose ways to re-design the real system along more logical and efficient lines. Two suggestions for improvements of No. 4 toll crossbar office design grew out of the creation of the Toll Network Simulator. Both of these have been adopted, and one has resulted in a patent application.

Thus traffic simulation has become a routine tool used in the design, engineering, and evaluation of communications systems. New programming languages such as SIMSCRIPT are being devised specifically for programming simulations. The power of simulation on the digital computer increases, complementing the increasing scope of mathematical and numerical analysis. New general-purpose subroutines are being created to facilitate computer programming for both simulation and analysis. Laboratories traffic study engineers are working toward the goal of furnishing traffic evaluations of conjectured systems so dependably and so promptly that design decisions can be made in the light of full knowledge of the traffic characteristics of systems which as yet exist only on the drawing board.

Full Sized Replica Of Jansky Antenna Completed

Construction of a full-sized replica of the original Jansky Antenna has been completed at Holmdel and will be erected at the National Radio Astronomy Observatory in Green Bank, West Virginia, later this year.

The Observatory, a 2,500-acre tract located in the remote Deer Creek Valley about 80 miles west of Staunton, Virginia, is financed by the National Science Foundation and administered by Associated Universities, Inc. It is dedicated to the furtherance of studies in radio astronomy.

The late Karl Jansky is recognized as the originator of the science of radio astronomy. When Jansky joined Bell Laboratories in 1928, he was assigned to study static interference on short waves that were to be used for trans-Atlantic telephone communications. While listening for and recording crackling noises from thunderstorms, he discovered radio noises that were determined to be of extra-terrestial origin.

For thousands of years, astronomers could observe the universe only through the "window" of visible light that was radiated by the sun and stars. Jansky had discovered a new "electromagnetic window," through which scientists could gain much new knowledge about the cosmos by tuning in on radio emissions from outer space.

Jansky's discovery was made at Holmdel in 1932. He published his historic findings the following year and they received wide acclaim in the scientific community.

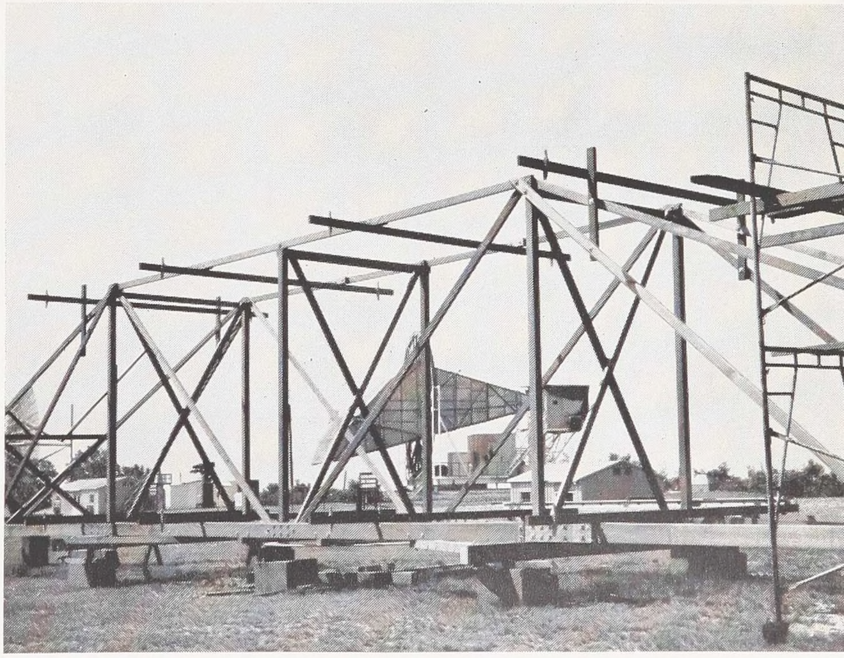
The original Jansky Antenna which received these radio signals from outer space was crude by present-day standards. Based on the design principles of the Bruce Antenna, it was 95 feet long and consisted of a mass of wood support beams which held up a series of metal tubes. The entire structure was mounted on four Ford truck wheels for easy rotation.

Jansky first erected this structure in 1929 in Cliffwood, New Jersey, about ten miles north of the present Holmdel Laboratory. A year later, it was disassembled and moved to Holmdel where it was reassembled just southeast of the new building. In 1944 the structure was completely dismantled. The only part of the original apparatus in existence today is a small gear reducer.

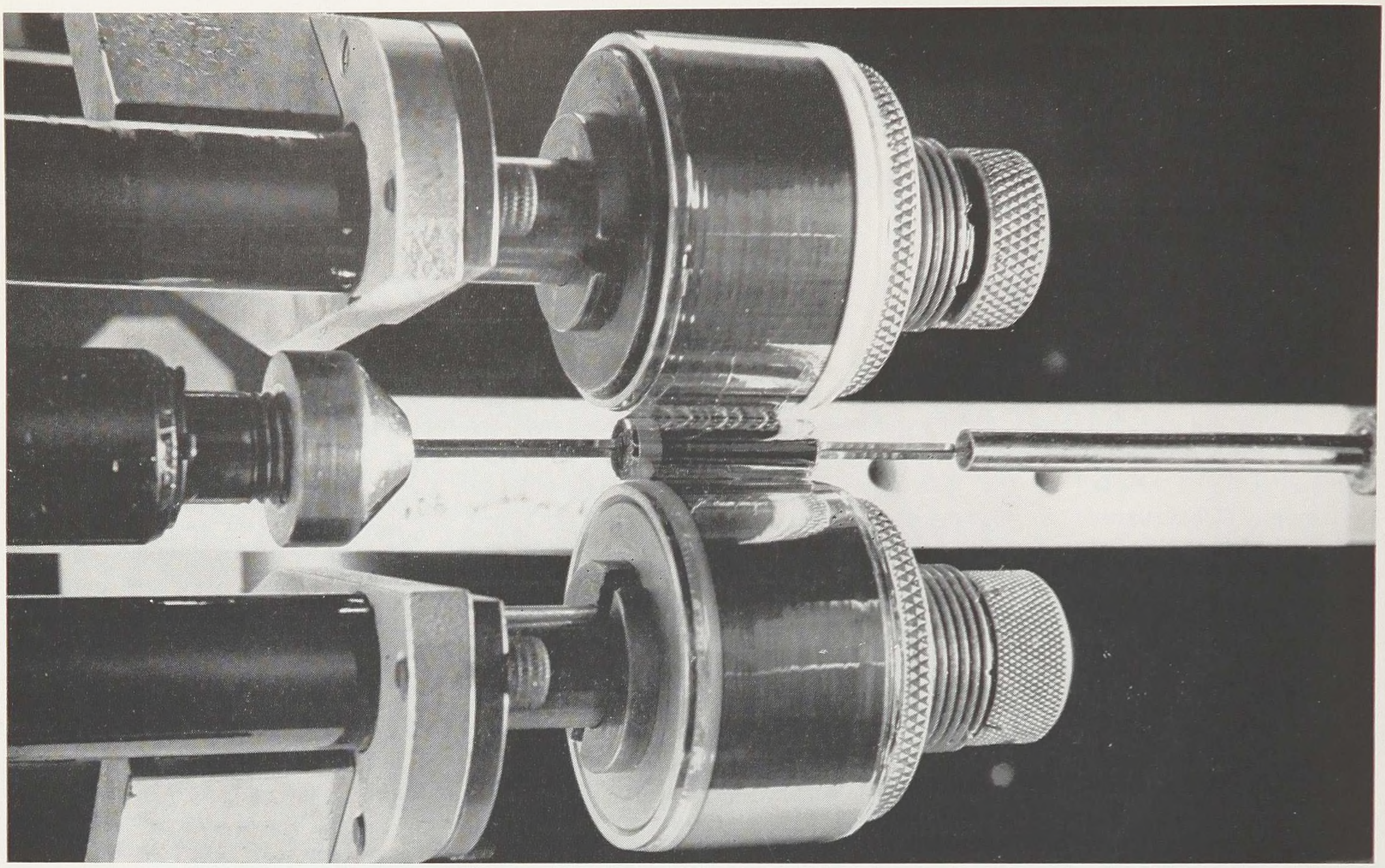
A. C. Beck, a member of the Guided Wave Medium Research Department and a contemporary of Jansky when he was at Holmdel, was chiefly responsible for collecting information needed to construct the replica. The replica was built by members of the Crawford Hill Carpenter Shop who worked from some of Jansky's original notebooks, drawings, and monthly progress reports.

The replica will be shipped in parts to Green Bank where it will be reassembled and erected at the Observatory's entrance gate.

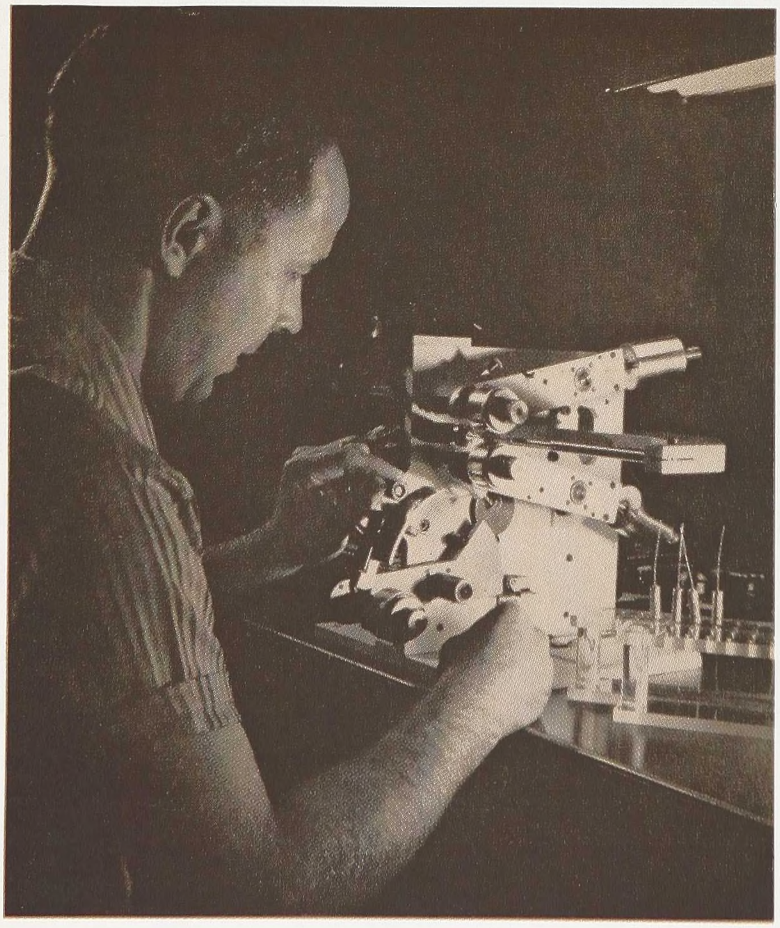
The National Radio Astronomy Observatory already has recognized Jansky's contributions to radio astronomy. One of its buildings is named the "Karl Guthe Jansky Laboratory."

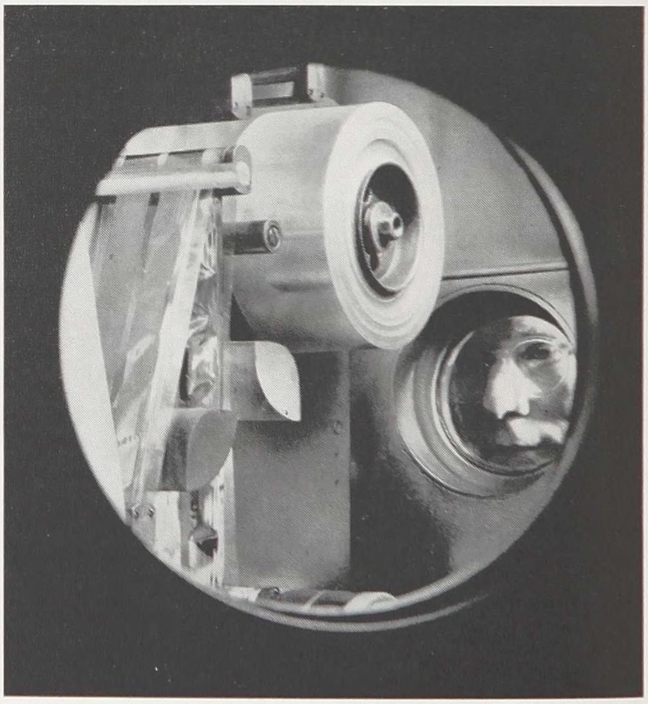


A full-sized replica of the original Jansky Antenna begins to take shape at the top of Crawford Hill at Holmdel.



The new tangential winder keeps the supply rolls of metallized film in contact with the mandrel during winding so that at no time is the film unsupported.





A thin aluminum film coating is deposited on the resin.

Robert Ferchak of the Laboratories operates the new machine.

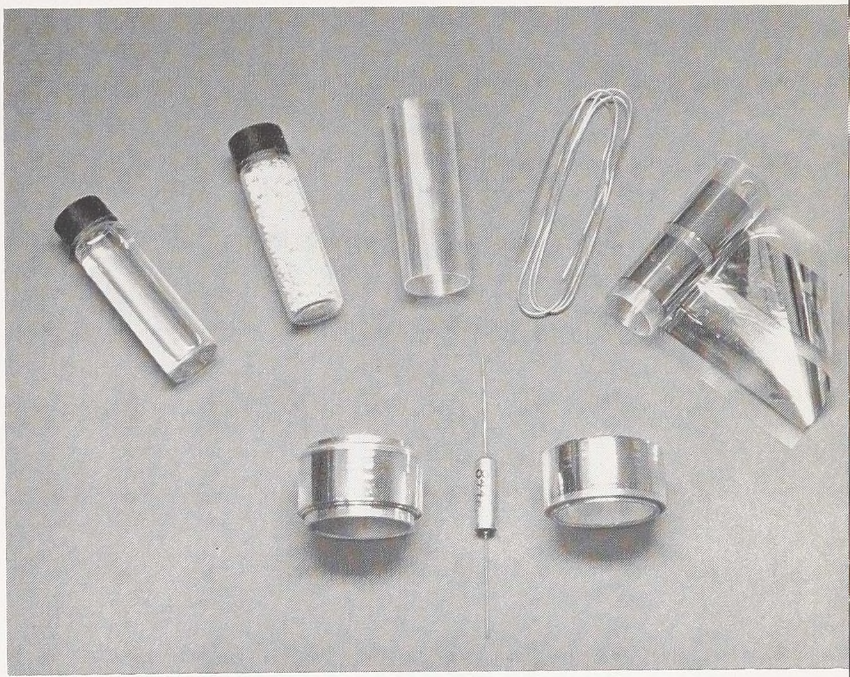
New Metallized Polycarbonate Capacitor Is Small and Self-Healing.

A metallized polycarbonate, stripped lacquer film capacitor has been developed by a group of engineers at Murray Hill. The new capacitor has low-loss characteristics approaching those of present polystyrene or mica capacitors, is many times smaller, and can be operated over a wider temperature range. Recent results of experiments on polycarbonate resins used as a capacitor dielectric were disclosed last month at the Fifth National Insulation Conference in Chicago by H. G. Wehe and W. McMahon in their paper entitled "Developments in Metallized Polycarbonate Lacquer Film Capacitors."

The new capacitor was made possible because of (1) a new polycarbonate resin developed by the Tennessee Eastman Company, and (2) improvements in the method of laboratory fabrication developed at Bell Telephone Laboratories. The polycarbonate resin, which is a polymerized carbonic acid ester of a bisphenol, was found to possess outstanding dielectric characteristics. The resin, in a chloroform solution, is applied to a support of polyethylene terephthalate, and dried by passing it near a set of infrared lamps. A thin aluminum film coating is deposited on the resin by vacuum metallizing. Then the material is slit to the desired width, and the 0.12 mil metallized polycarbonate lacquer film is stripped (or mechanically separated) from the backing. A new tangential winding machine developed by the Western Electric Company is used for winding the metallized film into capacitors. To support the fragile film during winding, the supply rolls are kept in contact with the mandrel. The terminals are "sprayed" to the ends and leads are attached. Finally, the capacitor is hermetically sealed in a metal container (5/16 in. dia. x 1⅛ in. long for a one-microfarad capacitor) and electrically "cleared" of internal short circuits and tested.

These new 50-volt, low-loss capacitors are suitable for use with transistors and where small size and high capacitance-to-volume ratio are essential. They can be operated over a temperature range from −78°C. to 125°C. They have a low temperature coefficient of capacitance (±50 ppm/deg. C.), and are self-healing; that is, they have the ability to isolate faults in the lacquer film or areas damaged by excess voltage. Since the capacitors retain only a small residual charge (0.005 per cent to 0.009 per cent), they are suitable for use in analog computers. It is also likely that they will be useful in aero-space fields, including missiles and satellites.

At present, the Western Electric Company is developing methods of production under a Signal Corps Industrial Preparedness Contract.



The new, low-loss, miniature capacitor is made possible by a number of new materials and processes. The first vial, in the upper left, contains the solvent chloroform, which is mixed with the contents of the second vial, a new polycarbonate resin. Next in line are the polyester support, the aluminum used for coating, and the aluminized polycarbonate on the polyester support. On each side of the capacitor, in the lower portion of the picture, is a roll of stripped aluminized polycarbonate lacquer film.

T. A. Schmader

Touch-Tone telephone sets require more detailed testing than conventional sets. A special frequency test circuit has been developed for these tests.

Testing the TOUCH-TONE Telephone Set

A STANDARD PART of telephone installation is testing the newly installed telephone set to make certain it functions satisfactorily. This testing has been fairly simple in the past—usually involving little more than a check on the telephone set ringer by means of a station ringer test circuit located in the central office. However, for the newly developed TOUCH-TONE telephone sets, a more detailed procedure is necessary. In addition to the "ring" test, the TOUCH-TONE set requires a test on the pushbuttons and transistor oscillator to determine if satisfactory frequencies and tone levels are being generated for each digit.

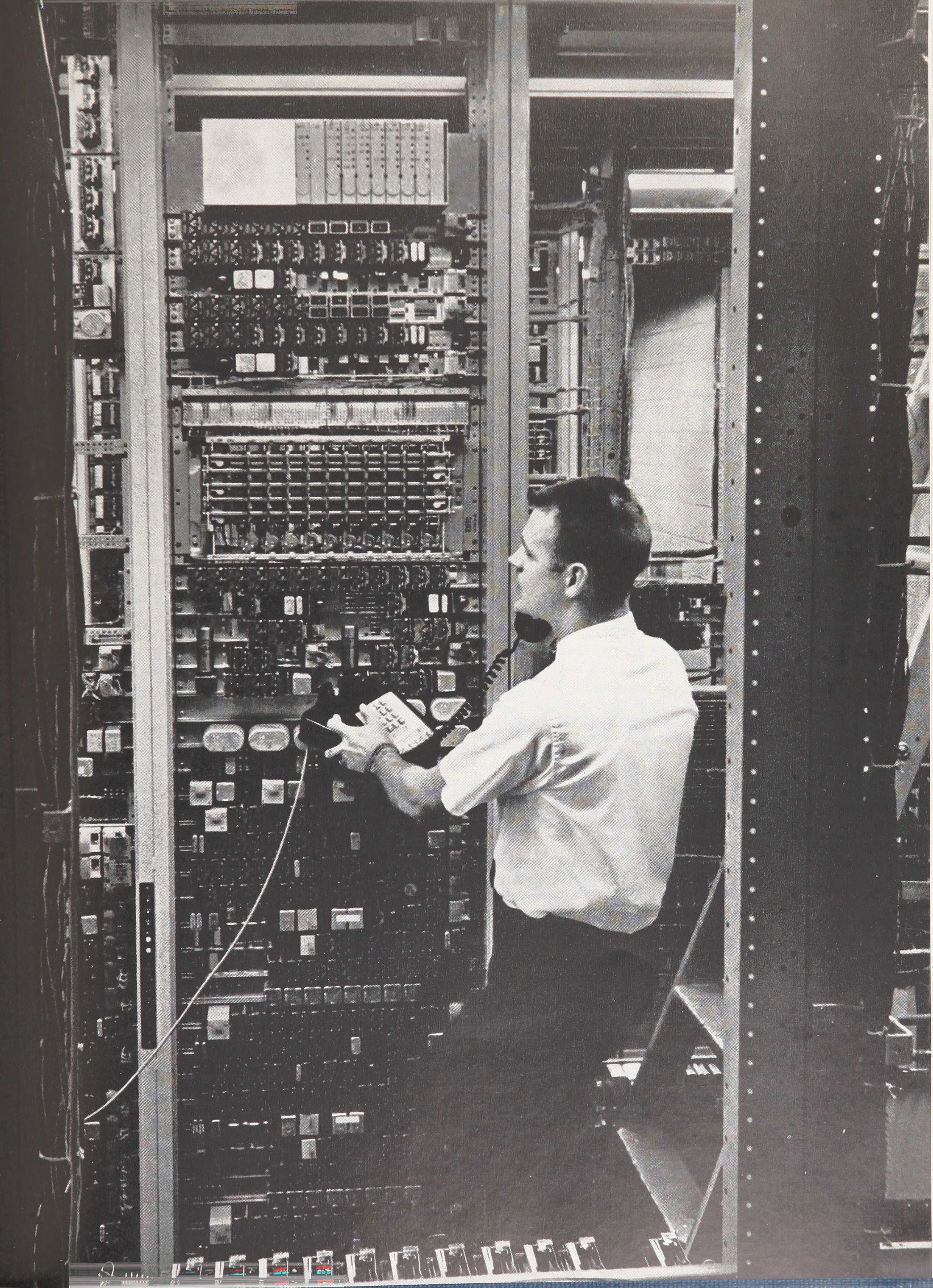
To accomplish this, a common systems TOUCH-TONE frequency test circuit has been developed that will connect into and work with the station ringer test circuits of the various telephone systems. These tests can be made by the installer from the customer station without aid from the central office.

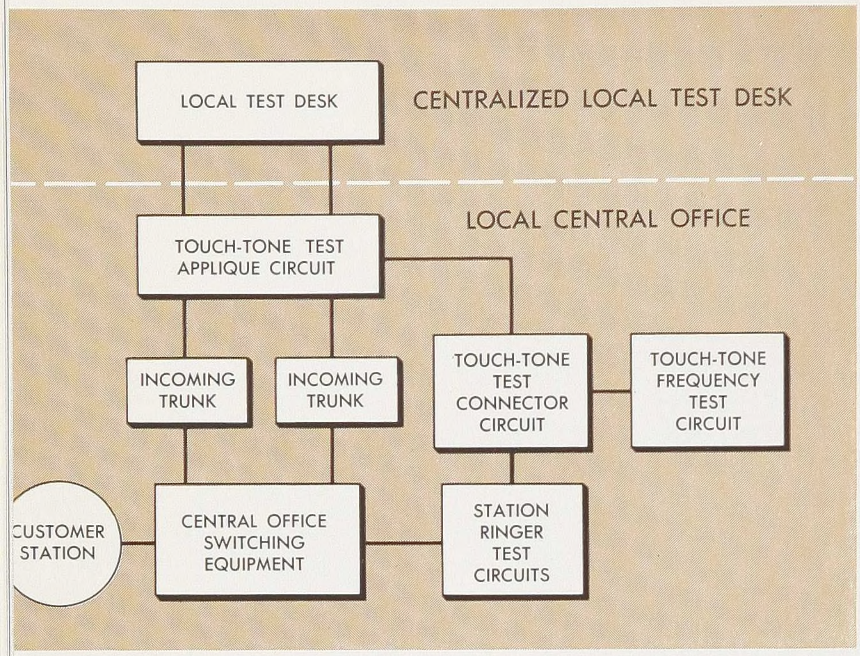
If trouble is suspected after the initial installation, the TOUCH-TONE test circuits can be connected to a customer line under control of the local test desk. The test man can then instruct the customer to key his TOUCH-TONE set to test the digits. By eliminating the telephone set as a cause of the trouble, unnecessary service trips to the customer will be avoided.

The TOUCH-TONE test equipment consists of a connector and a frequency test circuit as shown on page 356. The station ringer test circuits for each system are modified to connect to the TOUCH-TONE test connector circuit. The TOUCH-TONE test connector circuit is composed of a single 100 point crossbar switch and associated control relays. It provides for connecting a maximum of ten inputs to a maximum of four TOUCH-TONE frequency test circuits. The inputs may be either station ringer test circuits or TOUCH-TONE test applique circuits.

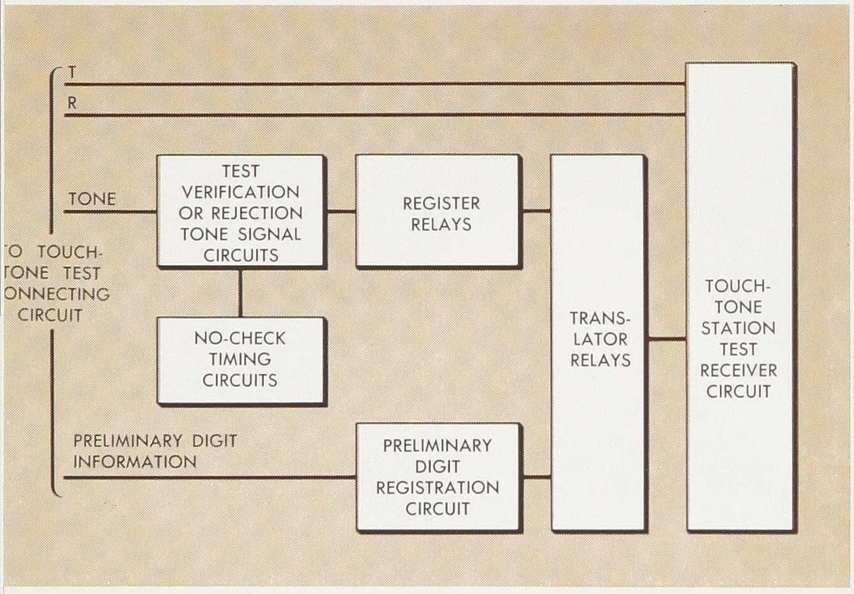
The TOUCH-TONE frequency test circuit employs a special test receiver associated with it. The receiver is less sensitive and has a narrower bandwidth than the TOUCH-TONE receivers used in service. With this feature the telephone TOUCH-TONE dial will fail in the test before it fails in service. The output of the test receiver operates translator relays that control register relays for

J. L. Buckingham observes operation of the Touch-Tone test equipment in the Columbus, Ohio Laboratory as he "dials" a test call.





The diagram above shows interconnection of the Touch-Tone test units with existing central office equipment.



Functional Touch-Tone test circuits parts are shown above.

each "good" digit dialed. At the conclusion of the test either a verification or a rejection tone signal is sent to the calling station indicating the condition of the TOUCH-TONE set.

The amplitude of the TOUCH-TONE signals delivered to the receiver depends on the impedance termination across which the receiver is bridged. Therefore, the impedance presented to the test receiver in the TOUCH-TONE test circuit is the same as the impedance encountered by a regular receiver on a service call.

The impedance presented to a TOUCH-TONE receiver on a service call is determined by the apparatus across the line at the digit receiving circuit (Originating Register in No. 5 crossbar, for example). This apparatus is different, and therefore the impedance is different for each type of system and is also affected by the amount of current flowing in the station loop.

Since the station ringer test circuit terminates the station loop on a test call, the supervisory apparatus across the line in that circuit is identical to that provided in the standard digit receiving circuit employed in the particular switching system involved.

On a service call, dial tone is present when the first digit is dialed into a TOUCH-TONE receiver. Therefore, all digits are tested with the dial tone present. The dial tone used with the test circuit is identical to that used for regular TOUCH-TONE service in the office.

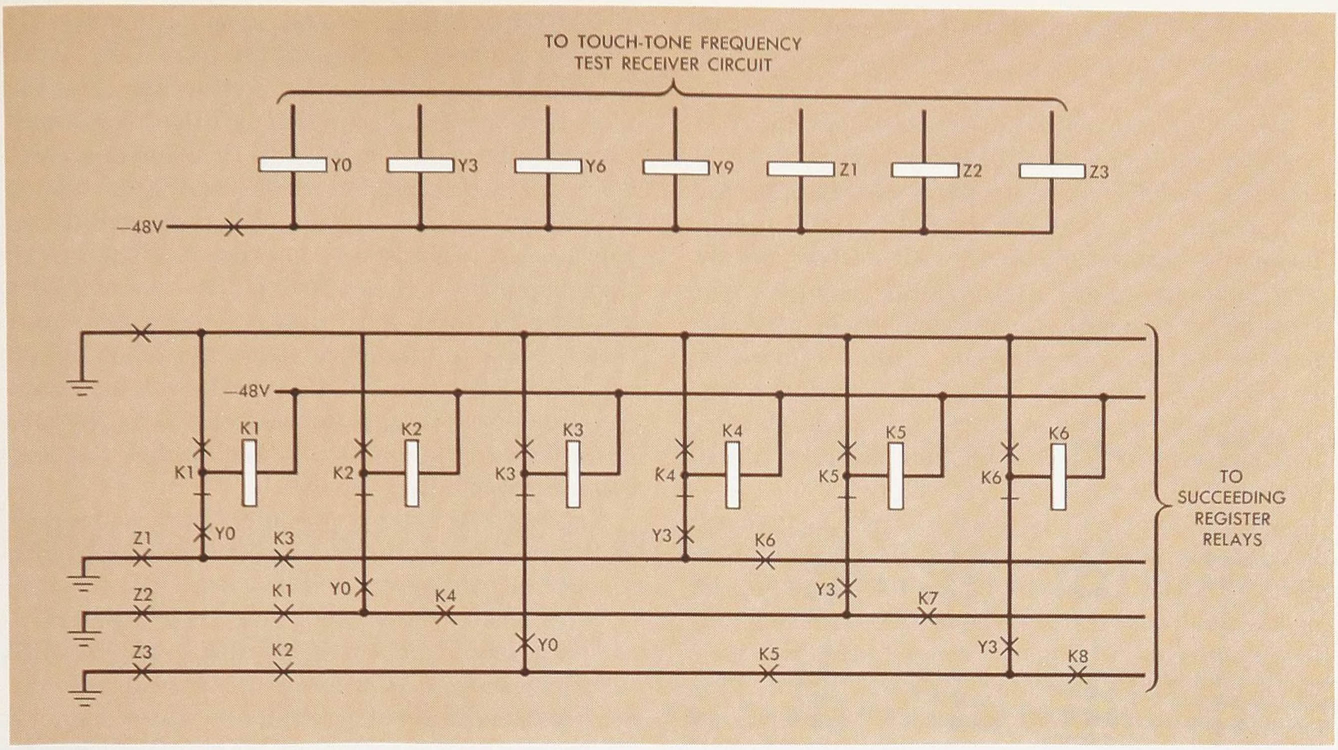
Special code connects test circuit

When an installer wishes to check the dial or ringer of the telephone set he has just installed, he dials a special code that causes the central office switching equipment to connect his set or line to a station ringer test circuit. Upon seizure, the station ringer test circuit connects to an idle TOUCH-TONE frequency test circuit through the TOUCH-TONE connector circuit. Dial tone from the TOUCH-TONE test circuit is then sent to the calling station as an indication that the test circuit is ready to receive the dial test. If all of the TOUCH-TONE test circuits are busy, no tone will be heard by the installer until one becomes idle and is connected to the ringer test circuit he has seized.

If the station being tested is a rotary dial type telephone set, use of the TOUCH-TONE test equipment will not be required. In this case, the installer flashes the switchhook or dials a digit immediately after receiving the test circuit tone so the TOUCH-TONE test circuit will be disconnected and available for other test calls. This action also advances the station ringer test circuit to prepare it for the ringing test.

For a TOUCH-TONE telephone set a preliminary digit is first dialed (if required by the particular system involved) to indicate the type of ringing to be sent to the station on the ringing test. (Different types of ringing signals are used for selective ringing on party lines.) This information is transferred to the station ringer test circuit and stored there for later use in the ringing test.

A preliminary digit is also required if the station is a 4-wire telephone set to inform the frequency test circuit that 12 digits instead of 10 will be checked on the keyset test. (Four wire tele-



This partial schematic of the test circuit shows digit translation, registration, and check circuits.

phone sets have two extra keys—priority and special grade.)

Following the preliminary digit, the installer dials all the digits in numerical sequence. The frequencies generated by a TOUCH-TONE station consist of four in a low band and three in a high band. Each digit consists of one frequency from each band. As each digit is keyed, the pair of frequencies corresponding to that digit is sent over the customer line and picked up by the receiver in the test circuit. For each digit that satisfies the test receiver as to frequencies and levels, the receiver supplies output current from one transistor in its high band frequency group and one transistor in its low band frequency group to operate translator relays in the test circuit.

The illustration on this page shows a simplified diagram of the translator and register relays. The translator relays are designated to form an additive code arrangement. For example, when digit "5" is keyed, translator relays Z2 and Y3 operate. The translator relays operate register relays for each digit. A register relay, on operation, locks operated and prepares a path for the operation of the next register relay. Thus, all register relays must operate in sequence. If all the register relays operate, a verification tone signal is sent to the calling station immediately following the last digit dialed. If one of the digits fails to meet the requirements of the test receiver, the translator relay for that digit will not be operated and the chain of operation for the register relays will be broken and none of the succeeding register relays will operate. In this case, a test rejection tone signal will be sent to the calling station following a no-check timing interval. The verification or rejection tone signals also serve as an indication that the test circuit has reset itself so the dial test may be repeated, if desired.

When the installer is satisfied with the dial test, he flashes the switchhook or merely hangs up to release the TOUCH-TONE test circuit and to prepare the station ringer test circuit for the ringing test. In either event the telephone handset going "on-hook" causes a current from the ringer test circuit to test the telephone set's ringer. Ringing continues until it is tripped by lifting the handset from the switchhook. With the ringing test completed, placing the handset on-hook concludes the call.

Local test desk checks dial

As previously stated, the TOUCH-TONE dial may be checked by the local test desk man with the cooperation of the customer. The local test desk may be located in another central office. A centralized local test desk may serve many local central offices of different types (i.e. Crossbar No. 1, Crossbar No. 5, SXS or Panel). In order to gain access to the TOUCH-TONE test equipment from the local test desk, the incoming trunks from the local test desk for each switching system are modified to connect to the TOUCH-TONE test *connector* circuit through an applique circuit, as noted on page 356.

The applique circuit has access to one input of the test connector circuit. It terminates the station loop during the test—arranged like the station ringer test circuits—to present the proper impedance termination to the test receiver circuit. The applique circuit also contains a high input impedance transistor amplifier that is used for monitoring the customer-test circuit connection from the local test desk. This high impedance connection is necessary so it will not affect the impedance termination that the applique circuit presents to the TOUCH-TONE test receiver.

When a complaint is received from a customer having trouble placing calls and the test man suspects that the trouble is in the telephone set, he places a call to the station to be tested through an incoming trunk in the local central office to which the station to be tested is connected. He then instructs the customer to operate all the digits on his telephone set dial in numerical sequence when the customer hears dial tone. With instructions to the customer completed, the test man operates a key that causes an idle TOUCH-TONE test circuit to be connected to the incoming trunk through the TOUCH-TONE connector and applique circuits.

Upon connection, the TOUCH-TONE test circuit transmits dial tone to the station set. The test man also hears the tone through the high impedance monitoring connection in the incoming trunk circuit. The test man hears the tones generated by the subset as the customer keys them and listens for the test verification tone from the test circuit upon completion of the keying. The test man then releases his test key, causing the TOUCH-TONE test circuits to disconnect from the trunk circuit and return the trunk circuit to the talking condition between test man and customer. The test may be repeated if necessary, or the parties may disconnect, concluding the call.

TOUCH-TONE calling provides more convenient and faster service for customers. The average customer can TOUCH-TONE call in about half the time it takes with a rotary dial. These test features insure top operating condition for newly installed telephone sets. In addition, continued high quality service is maintained through procedures supplied for rechecking the telephone set with customer cooperation without visiting the customer premises.

Testing in this manner provides a minimum of inconvenience to the customer and a minimum of expense to the telephone company.

New Bell System Book On Satellite Communications Physics For High School Students

How do you calculate a satellite's orbit? What color should a satellite be? These questions and others like them are answered in a book titled *Satellite Communications Physics,* prepared by some of the scientists and engineers who designed and developed the Telstar satellite. The 88-page illustrated book is Bell Laboratories' most recent aid to high school science education. Teachers and students may obtain copies, without charge, from local Bell telephone companies.

Part 1 explains some of the reasons for communicating by means of man-made satellite, describes the progress made in space communications, and points out some of the problems that had to be solved. It was written by the editor, Ronald M. Foster, Jr. Part 2 contains six case histories about the problem-solving techniques involved in designing a communications satellite, keeping it working in outer space, and repairing it even after it has been placed in orbit. The authors are Franz T. Geyling, Peter Hrycak, Joefry S. Courtney-Pratt, Kenneth D. Smith, Peter D. Bricker, and E. Jared Reid, all of Bell Laboratories.

Satellite Communications Physics is written to give science students an idea of "what it feels like" to confront some of the actual problems encountered by scientists and engineers who worked on the Telstar project. Each problem is taken from a somewhat different technological area: aerospace mechanics, mechanical engineering, optics, electronics, psychology, and electrical engineering. In each case the solution of the problem is based on fundamentals—on basic principles of classical physics taught in high school.

The book is challenging and satisfying to teachers and students seeking some understanding of the physics of satellite communications.

W. H. Newton

As the demand for the TOUCH-TONE Calling receiver increased, Bell Laboratories was asked for a new design that would be more economical to produce and that would use central office space more efficiently.

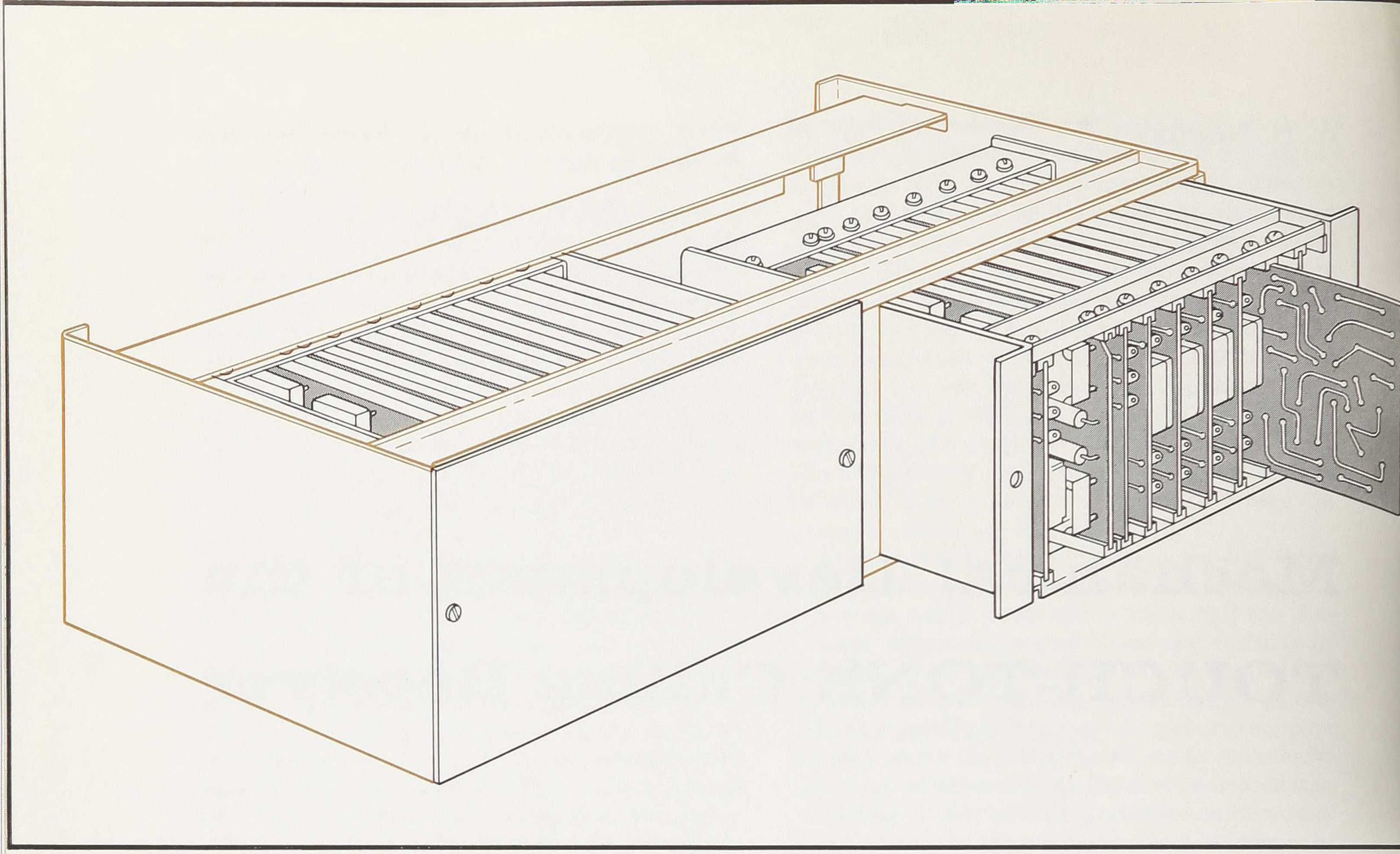
Mechanical Development of the TOUCH-TONE Calling Receiver

TOUCH-TONE signaling, or pushbutton dialing, has required the design and testing of a variety of new equipment. TOUCH-TONE signaling enables a customer to set up a call more rapidly that by using the conventional rotary dial. The central office receives voice frequency tones instead of dc pulses. Part of the job of translating these tones into the language of established switching equipment is handled by a special receiver. Once the circuit problems had been resolved, the mechanical design of this TOUCH-TONE calling receiver had to be developed. Considerations such as physical size and strength, adaptation to existing equipment, installation and maintenance procedures, and especially manufacturing costs had to be met before the design of the receiver could be regarded as successful.

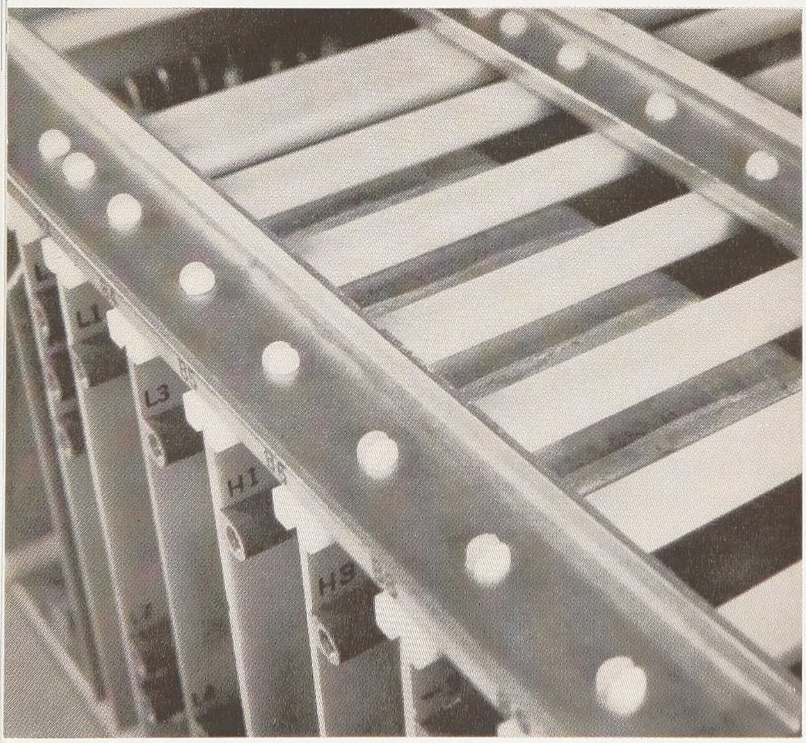
The TOUCH-TONE calling receiver accepts signals at the central office from customers who are equipped with pushbutton telephone sets. It is bridged across the input terminals of a dial pulse subscriber sender, an originating register, or equivalent common dial impulse equipment. The receiver responds to voice frequency tones but sends dc pulse signals on to the remaining switching equipment in the central office.

There have been two previous mechanical designs of the TOUCH-TONE calling receiver; Model-I, which was the earliest design from both a circuit and mechanical standpoint, has been discontinued and Model-II has been introduced in its place. The Model-II TOUCH-TONE receiver, which is still in production, incorporates many circuit refinements but is essentially the same mechanical design as its predecessor. It was recognized that a lower cost equipment design would ultimately be necessary, but in the interest of meeting early production schedules the Model-I approach was retained. Generally the equipment arrangement consists of modular-type cards mounted in aluminum die-cast card holders. The card holders slide into a cabinet-type framework utilizing the shelf die castings developed for the TASI project. Phenol fabric boards are used for the modular-type cards and all components are mounted on stand-off terminals, or wedge-lock terminals. Test points are brought out through the front face of the aluminum card holders so that the test points must be wired to the stand-off terminals mounted on the cards.

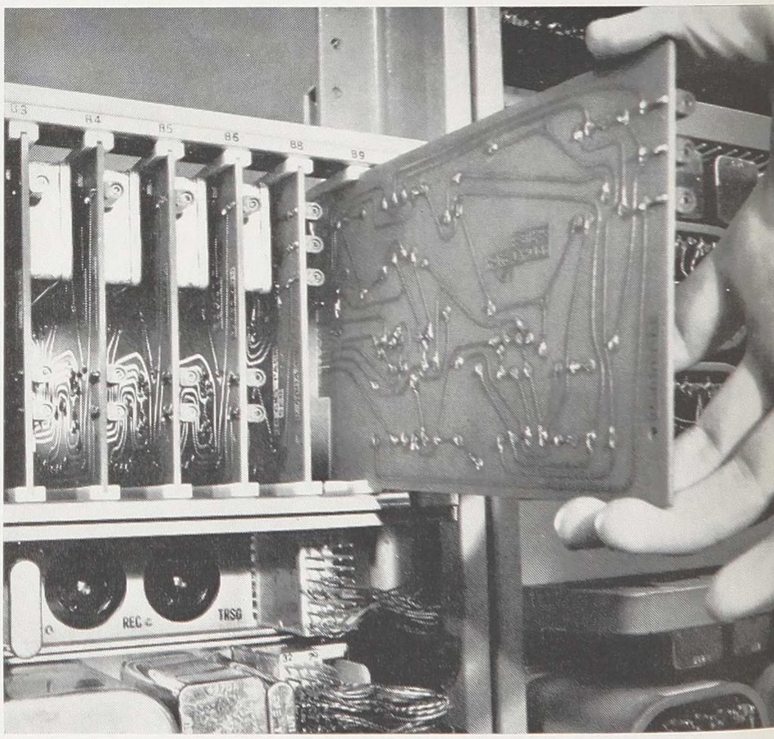
As the demand for the TOUCH-TONE receivers increased for application to various projects, the



The Model-III TOUCH-TONE calling receiver contains two receiving units in space formerly occupied by one. Each unit can be removed separately either for inspection or for repair.



Nylon runners snapped into chassis holes offer the designer selective spacing of circuit boards.



Craftsmen can also insert individual circuit packs by the simple plug-in process shown here.

At a typical central office installation, the author replaces a receiver in the Model-III chassis.

Western Electric Company requested that the Model-II unit be redesigned for easier manufacture. Cost considerations took on much greater importance as more general use of the receiver was anticipated. In addition, space savings in central offices also entered the picture, since it appeared that two receivers might fit into the space now occupied by one Model-II receiver.

One of the first features to receive attention was the expensive wiring approach utilizing stand-off terminals. The stand-off terminal is attached to the board in much the same manner as a rivet and projects perpendicularly from the surface. Components and wiring are then soldered between these terminals. This arrangement is time-consuming to assemble and bulky when component density is high. An alternative was therefore sought among three possible solutions.

The first was the use of AMPLAS (*A*pparatus *M*ounted in *Plas*tic) where components are cast in epoxy and then wired. This type of circuit package is used in the E-7 repeater and in the N-2 carrier system. The second alternative was printed wiring, which would cost about the same as AMPLAS (at the present time) but offers one distinct advantage: the boards do not have to be fitted with separate plugs. The savings thus effected are considerable. A final alternative was the molded grid package in which components are welded to a wire grid that has been molded in plastic. The rigidity of the plastic supports the wire grid, eliminating the need for a separate, die-cast card holder. A disadvantage to this arrangement is the limited component density permissible and the heavy tooling costs its adoption would necessitate.

Printed Wiring Boards Selected

Of the three alternatives, printed wiring boards were finally selected as offering the most advantages at the least expense for this application. Another development program at the Laboratories reinforced the decision, for it had recently developed a highly reliable printed wiring board connector (RECORD, *March*, 1963). This connector employs bifurcated contact springs and citrate gold contacts which are pressed against the lands of the circuit board. Using a contact lubricant with this arrangement yields a service life quite comparable with that of the older and much more costly pin-and-socket connectors.

Additional savings were sought through the elimination of the die-cast card holders. Without card holders, boards lose rigidity and have some tendency to warp and bow. This problem was met by a combination of improved materials and redesigned cabinetry. Boards of thicker material (3/32-in. phenol fibre) were specified with pre-designated grain direction. Each board is prepared with the grain parallel to the shorter, 4-in. axis. This, along with support from the connector, limits warpage in that direction. The longer, 8-in. axis is supported by a plastic runner attached to the cabinet. The resulting board and runner arrangement has more than adequate strength and offers a 90 per cent cost saving over the previous design.

The use of plastic runners also has eliminated the need for shelf die-castings with guide channels. The new design, unlike most modern communications systems, thus does not require that all circuit packs be mounted in modules of fixed uniform size. In the fixed-channel design, if a particular circuit pack uses a component that extends slightly into an adjacent module, then two full modules are required. The present design allows for varying the separation of boards by attaching plastic sliders at whatever intervals the designer desires.

An important advantage to this successful elimination of die-castings reflects the anticipated demand for the TOUCH-TONE calling system. At least for present day usage, the demand for TOUCH-TONE receivers is expected to be relatively low. While the use of die-castings is economical in cases of high volume production, it is not so for less usage. Larger volume allows the manufacturer to absorb the heavier tooling costs required for die-castings. Smaller volume usually means adapting a die-casting from another piece of equipment, with subsequent sacrifice of features that might be of value in a new design. Thus the elimination of die-castings provided for economy and flexibility that otherwise would have been impossible.

The cabinet design at this point consisted of steel channels and angles welded to side plates. Should the cabinet be used for other equipment that does not require ventilation, the channels could be replaced with sheet metal shelves. The plastic (or metal) runners snap into holes in the shelf or channels; the holes can be spaced for optimum space utilization. At the rear of the cabinet, multicontact connectors are mounted between steel angles and engage the boards when inserted. Because of the considerable space savings of this new arrangement, two receivers now fit in the shelf space formerly occupied by one.

With present maintenance procedures in central offices, the removability of circuit packs alone is inadequate. To avoid interruption of service, current practice sometimes requires removing a malfunctioning unit entirely, replacing it with another, and sending the defective unit to a repair center. For this reason, the new design provides that each receiver can also be removed separately, as illustrated on page 360. Additional nylon runners for the receiver package guarantee that the unit will smoothly engage its connector when inserted.

The over-all cabinet with its two inner cabinets (one for each receiver) mounts on a standard 23-in. relay rack bay. Each receiver unit is six inches high and is fitted with a single front cover. The innovation of plastic runners which guide and support circuit boards makes an extremely flexible combination that can be adapted to a variety of designs.

Preliminary cost studies by the Engineer of Manufacture at Western Electric indicate that the Model-III TOUCH-TONE receiver can be produced at a cost reduction of approximately 50 per cent in relation to the previous design. This, plus the savings arising from more efficient use of space and increased ease of maintenance, helps the Bell System meet the constant challenge of providing improved communication service at the lowest possible cost.

Bell System Ground Station Receives TV Via Syncom II

The horn antenna at the Bell System's ground station in Andover, Maine, was used last month to receive the first television signals transmitted via the National Aeronautics and Space Administration's Syncom satellite.

On Monday night, Sept. 23, test pattern signals were sent, followed Tuesday and Wednesday evening by TV pictures. Because of bandwidth limitations, no audio was sent during the test.

Despite Syncom's narrow bandwidth and the satellite's great distance from the earth, the horn antenna and its ultra-sensitive receiving equipment picked up the faint signals and amplified them to produce a TV picture of reasonably satisfactory quality.

In modifying the ground station at Andover to receive Syncom's signals, engineers from Bell Laboratories installed a traveling-wave maser amplifier specially designed for operation at Syncom's frequencies and the waveguides necessary to couple this equipment to the antenna.

The basic problem that confronted the engineers was: "How to obtain a satisfactory TV picture from a satellite 22,300 miles above the earth and which transmits very weak signals with a bandwidth of only four megacycles?" Part of the answer was inherent in the horn antenna itself. Because of the antenna's unique shape, received signals are shielded from earth noise—natural radiation interference from such objects as rocks. However, even if incoming signals are shielded from earth noise, the problem is to amplify those signals and introduce almost no additional noise generated by the amplification equipment itself. The answer to this was the use of the traveling wave ruby maser cooled by liquid helium to a temperature close to absolute zero (—457 degrees F.). At this temperature, the noise generated by the receiver is infinitesimally small. A third factor involved in receiving Syncom's signals was narrow-band frequency modulation techniques used because of the satellite's four megacycle bandwidth.

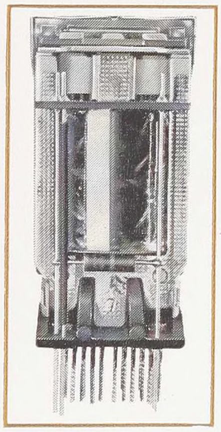
At the transmitting end at Fort Dix, N. J., Laboratories engineers supplied "pre-emphasizing" equipment for the TV transmitter. This step significantly improved the signal-to-noise ratio.

Many of the details and potential problem areas involved in the equipment were ironed out in the laboratory before the transmission occurred.

F. P. Balacek

'Ruggedizing' The Wire Spring Relay

New features are now increasing wire spring relay shock resistance



Bell System wire spring relays now being made are tougher than ever. These relays—long considered the best in the Bell System—have been a vital part of telephone switching systems and those now being placed in service can withstand surprisingly rough handling and shocks.

Experience with wire spring relays in many applications indicated that improvements were desirable to make the relays withstand certain rough conditions. Tests were carried out at the Columbus Laboratory with "drop test" equipment to determine their resistance to shock. Sample relays—about 60 in all—were exposed to shocks, vibrations and general rough handling. Measurements under these various conditions were made and a Fastax camera, taking pictures at 4500 frames per second, was used to record the experiments so the tests could be observed in slow motion.

After extensive testing, representing severe conditions, the relays were found to have the following faults: contact covers fell off permitting the twin wires to be crossed or misplaced, core plates slipped, and mounting blocks were broken in some cases. It should be pointed out that earlier tests of shock and vibration, representing the degree likely to be encountered in normal handling and shipping, were made before the design was released for production. These tests showed the design to be satisfactory for general use in central offices. At that time, it was not anticipated that the relays would be abused to the extent they are in small equipment units.

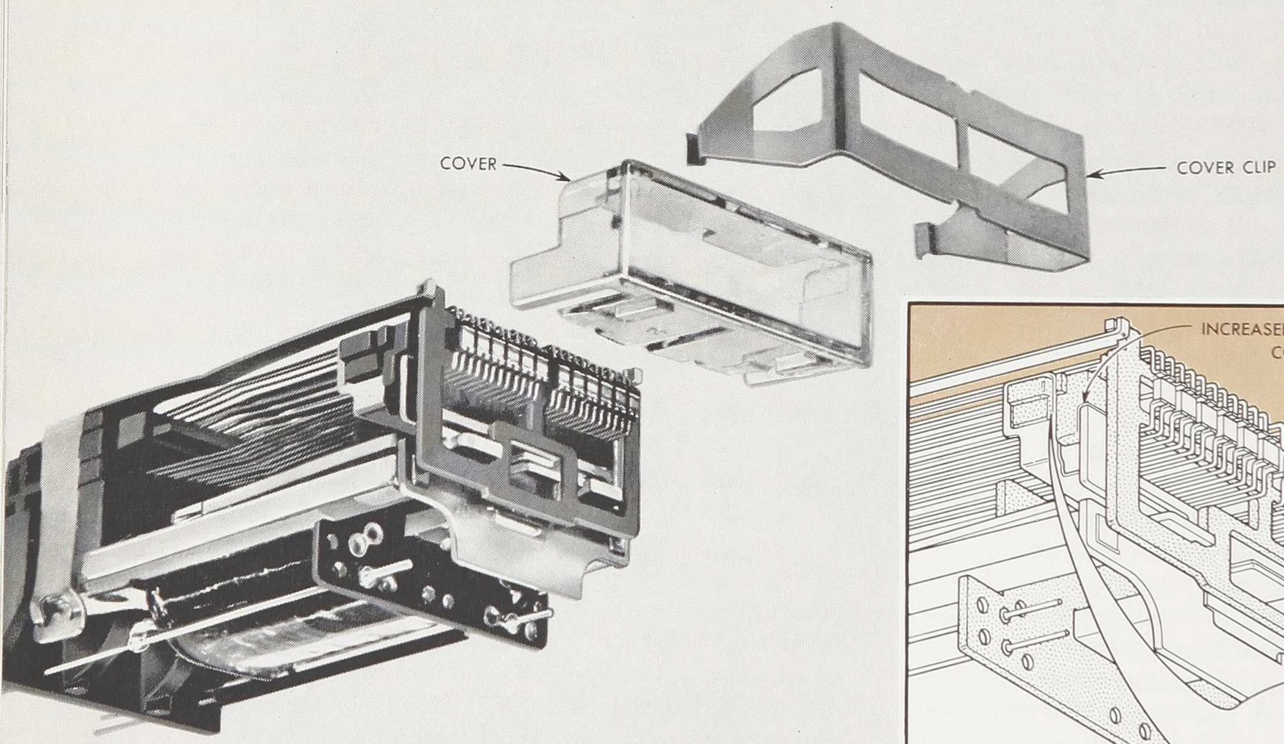
Several modifications were then made, keeping in mind the continuing objective of reasonable cost and good design. The most important objective was to keep the cover and core plate in place so the associated contacts would remain engaged in the "comb"—the normal position for the contacts. Achieving this objective involved several design changes. For example, a different cover material was introduced. The new material, styrene acrilonitrile (the old cover was methacrylate), is tougher, less brittle, has the necessary transparency, and costs less. These new covers are tinted blue for easy identification.

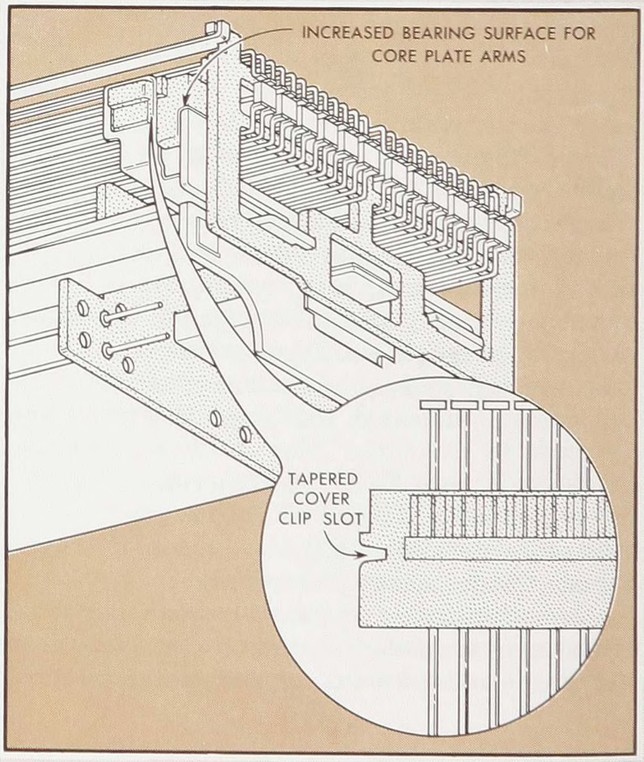
In addition, molding dimensions were changed to provide a wider ledge on which the core plate would rest; this enabled the relay to withstand much greater shocks without disengaging at the front end.

Changing to a tapered cross section in the slot that holds the cover clip insured better engagement of the clip with the ramp on the cover. With this configuration, greater pull-off forces can be tolerated before the cover is disengaged.

Up to this point, the design modifications were general for all wire spring relays manufactured, including those used in central office equipment. However, a special auxiliary clip was also designed for relays used in small telephone equipment, likely to receive excessive rough handling. This clip, coded 4B, is intended to be used in Key Telephone Units, Data-Phone Sets and other portable applications, as well as in mechanized TWX equipment. The clip has a toe-in feature—the legs of the clip "toe-in" as the front end moves outward, precisely the action required to prevent disengagement of the clip and cover when attached to a wire spring relay. It is easily removed with a standard screwdriver and will withstand decelerations of 175 g's when dropped in various planes.

The new improved wire spring relays are now going on the job to add years of service to Bell System equipment. If the relays get to their destination in perfect order—by any means of transportation and any kind of handling—they are set for at least 40 years of service.





New features now being incorporated into the wire spring relay to increase shock resistance are shown in the exploded view above. An enlarged drawing of the new tapered cover clip slot and increased bearing surface is shown on the right.

news in brief

Honorary Degree Given To Fisk By Akron Univ.

James B. Fisk, Laboratories President, was awarded an honorary degree by the University of Akron in Akron, Ohio, earlier this month.

Following the award, Mr. Fisk was the featured speaker at the 16th annual banquet of the Akron Council of Engineering and Scientific Societies (ACESS). The banquet was held in conjunction with the 50th anniversary observance of the founding of the University of Akron's College of Engineering.

Telstar II Continues To Show Capabilities

Telstar II, the Bell System's communications satellite, which has now made over 1,000 passes since its launching last spring, continues to successfully demonstrate its communications capabilities. Recent significant demonstrations include: September 29, television pictures of the opening of the second Ecumenical Council in Rome; September 27, television address by Pope Paul VI from Rome to Georgetown University in the United States; and September 20, transmission to Europe of President Kennedy's television address to the United Nations in New York.

101 ESS Installation Underway In Florida

Installation of the first 101 Electronic Switching System for commercial application has started at Cocoa Beach, Florida. The Laboratories-developed system is expected to be operational by the end of the year.

The 101 ESS will provide improved communications service for several corporations working with the National Aeronautics and Space Administration at Cape Canaveral.

Installation of the system is being carried out by the Western Electric Company for the Southern Bell Telephone and Telegraph Company. A five-man team from the Laboratories is acting in an advisory capacity during the installation.

Williams At Dedication

Dedication ceremonies were held recently in Philadelphia, Pa. for the erection of a new $3 million headquarters building for the American Society for Testing and Materials.

Participating in the cornerstone dedication was I. Vernon Williams, head of the Metallurgical Engineering Department at the Laboratories and president of the Society.

Three Men Honored By Franklin Institute

Three Bell Laboratories men, one of them retired, have been awarded John Price Wetherill Medals by the Franklin Institute in Philadelphia for their invention of the Bell Solar Battery.

Medals were awarded to Daryl M. Chapin, Calvin S. Fuller and Gerald L. Pearson. Mr. Pearson retired from the Laboratories in 1960 and is presently a member of the faculty at Stanford University in Palo Alto, Calif.

Established in 1925, the Wetherill Medal is awarded for discovery or invention in the physical sciences or for new and important combinations of principles or methods.

The three men were awarded John Scott Medals for the same work in 1957. The John Scott Medal is named for a chemist whose will established the award in 1816 and entrusted its administration to the city of Philadelphia.

Increase In Research And Development Shown

About two per cent of the nation's working population and almost one-third of the country's scientists and engineers are engaged in research and development, according to a study by the National Industrial Conference Board.

The NICB study shows that total expenditures in this area have increased nearly 25 times since the beginning of the '40's, and the number of workers in this field has grown almost ten times.

Research conducted by private industry represents about three-fourths of all resources invested in the field. While industry performs about 76 per cent of the work, it finances less than one-third, according to latest official data.

In recent years, the proportion of self-financed research and development work has declined in all private sectors of the economy for both basic research and applied research and development.

The NICB study points out that research is centered in several key areas: defense, space, machinery and equipment products, health, and agriculture. Some 57 per cent of all resources devoted to research and development in 1960 went for defense, atomic energy, and space. Privately financed research in manufacturing and communications companies represented almost one-third of the national total. About five per cent was devoted to health and three per cent to agriculture.

The bulk of industrial research work in this country is conducted by relatively few firms, the study reported. Research and development work contracted by the Federal government was more concentrated among specific industries and individual companies than the privately financed projects.

Permanent electrical connections are at the heart of most Bell System equipment. Here's a rundown on four major types and how they hold up under different environmental conditions.

Comparing Permanent Electrical Connectio

G. W. Mills

ELECTRICAL CONNECTIONS—over a billion made each year—are an important part of Bell System equipment. In fact, these connections are so important that the operation of all the switching systems now used—as well as those to be used in the future—are dependent on their reliability.

The Bell System uses many types of electrical connections. Although many of these are temporary, such as the switchboard jack and plug, the majority of them are permanent in the form of wires attached to apparatus terminals.

Most of these permanent connections are made during the manufacture and installation of central office equipment. The four main types now being made are (in order of decreasing quantity): solderless wrapped, soldered, percussive welded, and resistance welded connections. Many billions of these connections are now in use all over the country.

When designing new equipment it is necessary to decide which type of connection will be used. The choice of the best connection for a specific application is based on the relative merits of the connections in the following three areas: adaptability of each connection for the application under consideration, reliability or life required from the connections under the environmental conditions in which the new equipment must operate, and the relative cost of each connection.

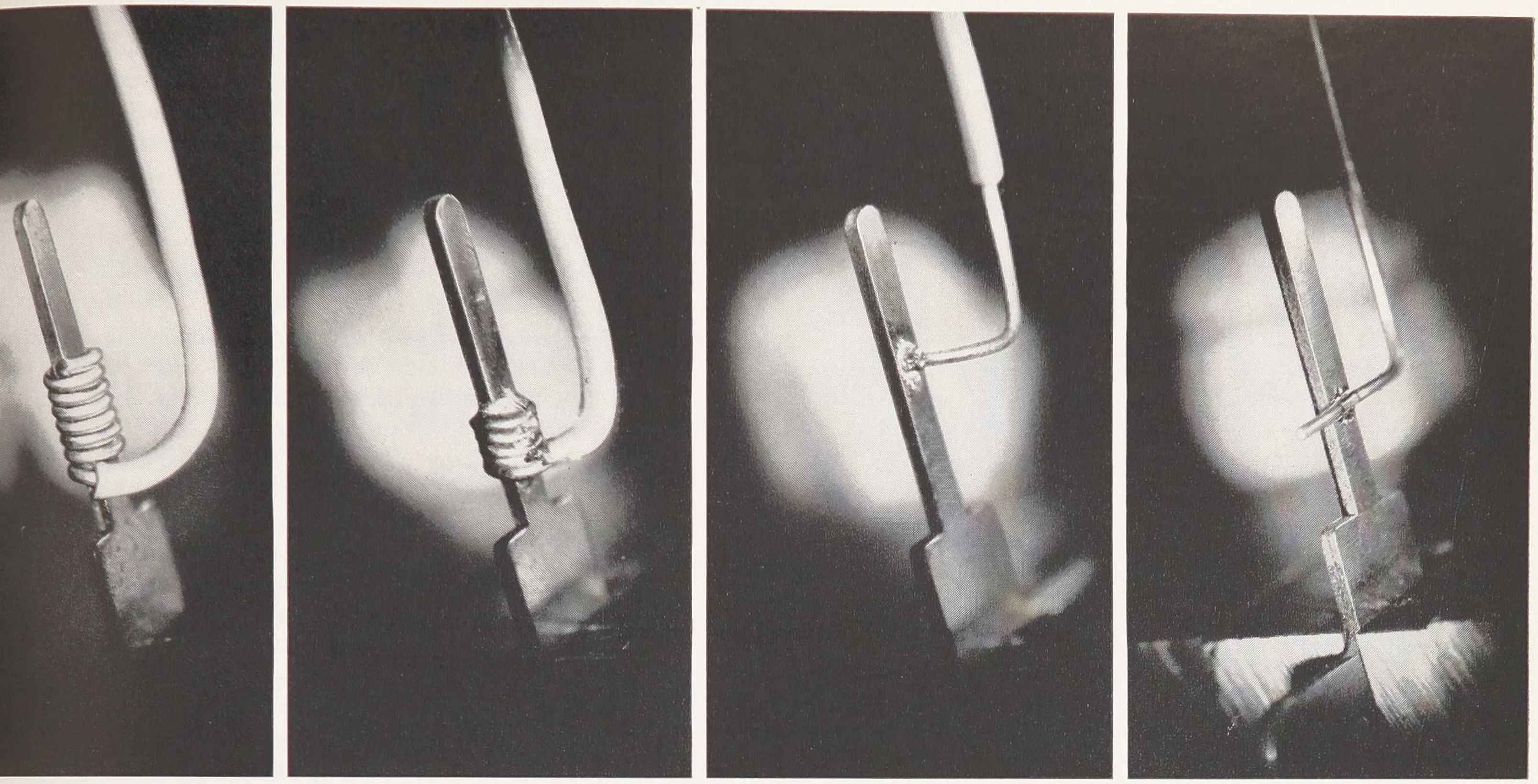
The criterion for judging whether a given connection is better than another is basically whether its life is longer under identical environmental conditions. By definition, a connection "life" has ended when, for any reason, it fails to provide an adequate path for conduction of electrical current.

A connection may fail in two ways: electrically or mechanically. An electrical failure occurs when the connection develops electrical characteristics such as a large resistance—constant or variable—that is incompatible with the equipment it connects. Electrical failure generally becomes a problem only if the connections are not made properly.

On the other hand, a mechanical connection failure occurs when the conducting path is physically broken. Almost all permanent connection failures fall into this group. These mechanical failures can be further divided into two groups: excessive force failures and fatigue failures.

An excessive force failure occurs when a force is applied that is greater than that which an average new connection is able to withstand. The probability of such a failure is directly related to the way the connections are treated and is generally very low.

A mechanical fatigue failure results when a connection is repeatedly stressed to values below



Typical examples of the four most commonly used permanent electrical connections now in use in the Bell System are (l. to r.) solderless wrap, soldered, percussive weld and resistance weld. (Enlarged views)

its breaking point. Actual connection failure depends not only on the stress level but also on the environmental conditions and fatigue history of the connection. Conditions such as temperature extremes, corrosion, and humidity will not, in general, cause connection failure but will reduce the fatigue life and thus hasten ultimate failure of the connection. Two severe environmental conditions encountered in a typical central office are the small amplitude vibrations due to equipment operation and the occasional bending of the connections during testing and wiring changes. These are both of a fatigue nature and can cause connection failure.

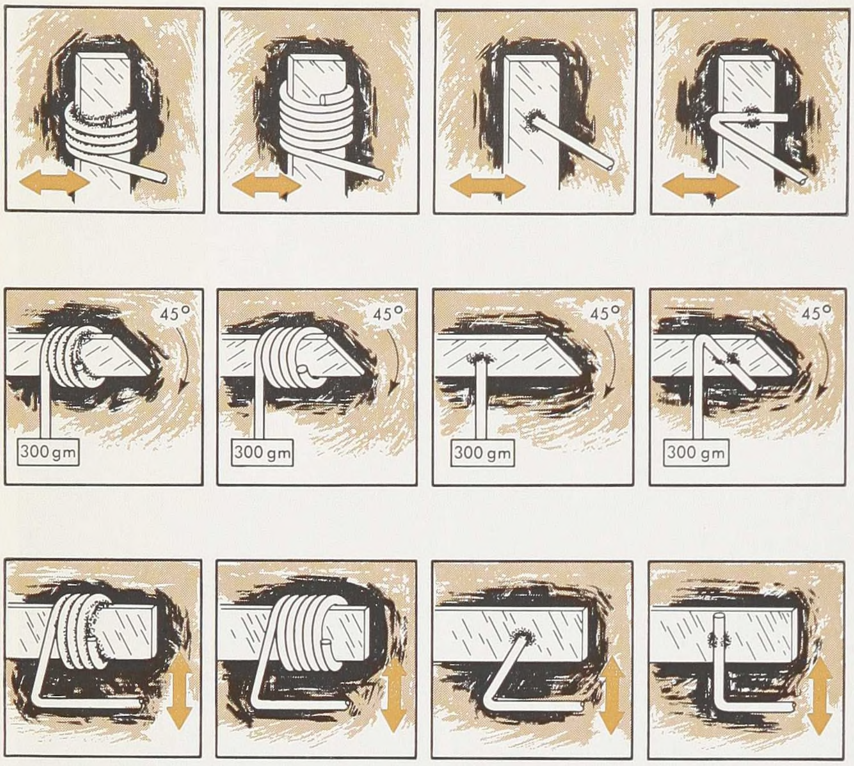
Since many connection failures are due to fatigue, fatigue life was selected as the most meaningful method of comparing different types of connections in this study. To provide comparative information, extensive testing of the four main types of electrical connections was performed at the Columbus Laboratory. The connections were exposed to various environmental conditions such as vibration, shock, temperature extremes, corrosion, humidity, and bending.

Vibration fatigue life was measured by the number of hours the connections survived a standard vibration schedule. The vibration was sinusoidal in wave shape with the frequency varying between 5 and 500 cps in a two minute period. Displacement was increased by 0.1 in. every two hours (from 0.1 in. to 0.5 in.) with the addition of 5 g's per 0.1 in. displacement up to 25 g's.

A direct comparison of all "fatigue" measurements yielded an "order of merit" for the four connections in each of the specific test conditions mentioned earlier. The connection with the longest life expectancy in a specific environmental condition was placed at the top of the order of merit list and the connection with the shortest life was placed at the bottom. In addition, estimates of deterioriation of each type connection were obtained by comparing fatigue life measurements after the tests to a control group that had not been subjected to any environmental stress.

All normal manufacturing standards were followed in making test connections so each connection represented the present "state of the art" for each type. Connections were made with one size terminal (0.025 in. x 0.062 in. nickel-silver) and one wire size (24-gauge solid copper). Therefore the conclusions of this study will not necessarily hold true for every terminal and wire size.

The percussive welds used were made according to the monitoring criteria developed by J. C. Coyne (BELL SYSTEM TECHNICAL JOURNAL, *January,* 1963). The welds were also made under



Bending fatigue life was measured in both the lightly-loaded configuration (top) and the heavily-loaded configuration (middle). A 90-degree bend in the leadoff wire improved fatigue life (bottom).

conditions which produced an increased diameter of the wire in the region of the weld. This increased wire diameter plus the monitoring greatly improves the quality of percussively welded connections. This should be kept in mind when interpreting the comparative results given in this article.

The table on page 369 lists the environmental conditions to which the connections were subjected and the order of merit for each of the four types for each condition. An over-all order of merit was obtained from these data by combining results of all tests using the number of test connections in each test as a weighting factor.

For the conditions which existed during this study the best over-all connection based on fatigue life was the percussive welded connection. Soldered and solderless-wrapped connections were next best and the resistance-welded connection was the poorest. However, soldered and solderless wrapped connections, which are in wide scale use in the telephone plant, meet the severe criteria for acceptable quality with a minimum amount of inspection. The test connections used in this study were of this same quality.

On the other hand the percussive welded connections used in this study were of higher quality than those that have been used in special applications. This higher quality results from the use of the monitoring technique described in Mr. J. C. Coyne's Bell System Technical Journal article and which is recommended for all applications of percussive welded connections.

The presence of insulation on the lead-off wire of a solderless wrapped connection improved fatigue life characteristics. The use of a modified wrap—one in which a turn of insulated wire is placed around the terminal—would therefore improve the fatigue life of these connections. However, the need for this in normal field application appears unnecessary since billions of solderless wrapped connections are in use in the telephone plant today and they have given excellent service since their introduction 10 years ago. Furthermore, extensive laboratory testing indicates that conventional solderless wrapped connections have the required 40-year life.

Another important factor affecting fatigue life of a permanent connection is its configuration—the way the wire is "brought off" the terminal. The configuration used on most of the tests is shown on this page. A bend in the wire in the vicinity of the connection partially isolates it from external wire movements and was found to improve fatigue life. When the 90-degree bend was omitted, all four types of connections showed a significantly lower fatigue life.

An important result of the comparison study on good connections just described was the recognition of fatigue life as one of the most important connection characteristics when measuring the effects of various environments. Thus, if the fatigue life of a connection is known for the various fatigue methods and the effect of adverse environmental conditions is determined on these fatigue lives, the mechanical quality of the connection is established.

Another important result of the study was that percussive welded connections, when each weld is properly monitored, are a very reliable form of connection in the various environments and treatments likely to be encountered in the telephone plant.

The results of this study should materially facilitate selection of the best electrical connection for each application and thus contribute to the high reliability and good service that characterize the Bell System today.

Orders of merit for the four permanent connections under different environmental condition are shown in the table on the right.

ORDERS OF MERIT

Environmental Conditions	Connections Tested	Order of Merit			
		Best	Second	Third	Poorest
VIBRATION (90° bend)	320	P	S	SW	R
VIBRATION (Omitting 90° bend)	160	SW	P	S	R
LABORATORY SHOCK Using the standard vibration configuration, the fatigue life of the connections was compared after being subjected to 90 half sine wave shocks (30 in each of three mutually perpendicular directions) of 500 to 600 g's amplitude and 2 to 3 milliseconds duration.	160	S	SW	P	R
RAILROAD SHOCK Using the standard vibration configuration, the fatigue life of the connections was compared after being subjected to 10 round trips between Columbus, Ohio and New York City via railway express.	160	S	P	SW	R
TEMPERATURE Using the standard vibration configuration, the fatigue life of the connections was compared after being subjected to a temperature of 105° C for 154 days with mechanical disturbance every two weeks.	320	S	P	SW	R
CORROSION Using the standard vibration configuration, the fatigue life of the connections was compared after being subjected to the corrosive atmosphere of New York City (BTL at West St.) for 3 & 6 months (2 exposure groups).	160	P	S	SW	R
HUMIDITY Using the standard vibration configuration, the fatigue life of the connections was compared after being subjected to 90% relative humidity and 85° F dry bulb temperature for a total of 64 days.	160	P	S	SW	R
LIGHTLY LOADED BENDING Using the lightly loaded bending configuration, the fatigue life of the connections was compared. This bending fatigue method moved the wire 30° in each direction from its equilibrium position with a load that varied from zero to 4 grams.	160	P	SW	S	R
HEAVILY LOADED BENDING Using the heavily loaded bending configuration, the fatigue life of the connections was compared. This bending fatigue method moved the wire through an angle of 45° with a constant load of 300 grams applied.	160	SW	P	S	R

NOTE: S—Soldered SW—Solderless Wrap P—Percussive weld R—Resistance weld

Magnetic Hysteresis Damping—

Key element of passive system to keep satellite's antennas earth-pointing

Engineers at the Laboratories have proposed a method of keeping a satellite's antennas pointing toward the earth without using power, active controls, or attitude sensors. The system is based on the gravity-gradient effect—the same effect that keeps the heavy side of the moon always facing toward the earth. A key element in the system is a magnetic hysteresis damper which dissipates the energy caused by a satellite librating, or swinging back and forth, in space.

In an article in the September issue of the Bell System Technical Journal, Messrs. B. Paul, J. W. West, and E. Y. Yu describe the over-all aspects and the hardware of this system. A companion article by Messrs. H. J. Fletcher, L. Rongved, and E. Y. Yu gives an analysis of the motion of gravitationally-oriented satellites.

Designated as passive gravitational attitude control (PGAC), the system consists of two bodies: a satellite at one end of a 60-foot mast and an auxiliary body, made of two crossed rods with tip weights, at the other end. The auxiliary body is connected to the mast by a universal joint, or hinge unit, which permits the auxiliary body to move in two directions relative to the mast. A mechanism inside the universal joint damps out librations by dissipating the resultant energy in hysteresis losses in magnets.

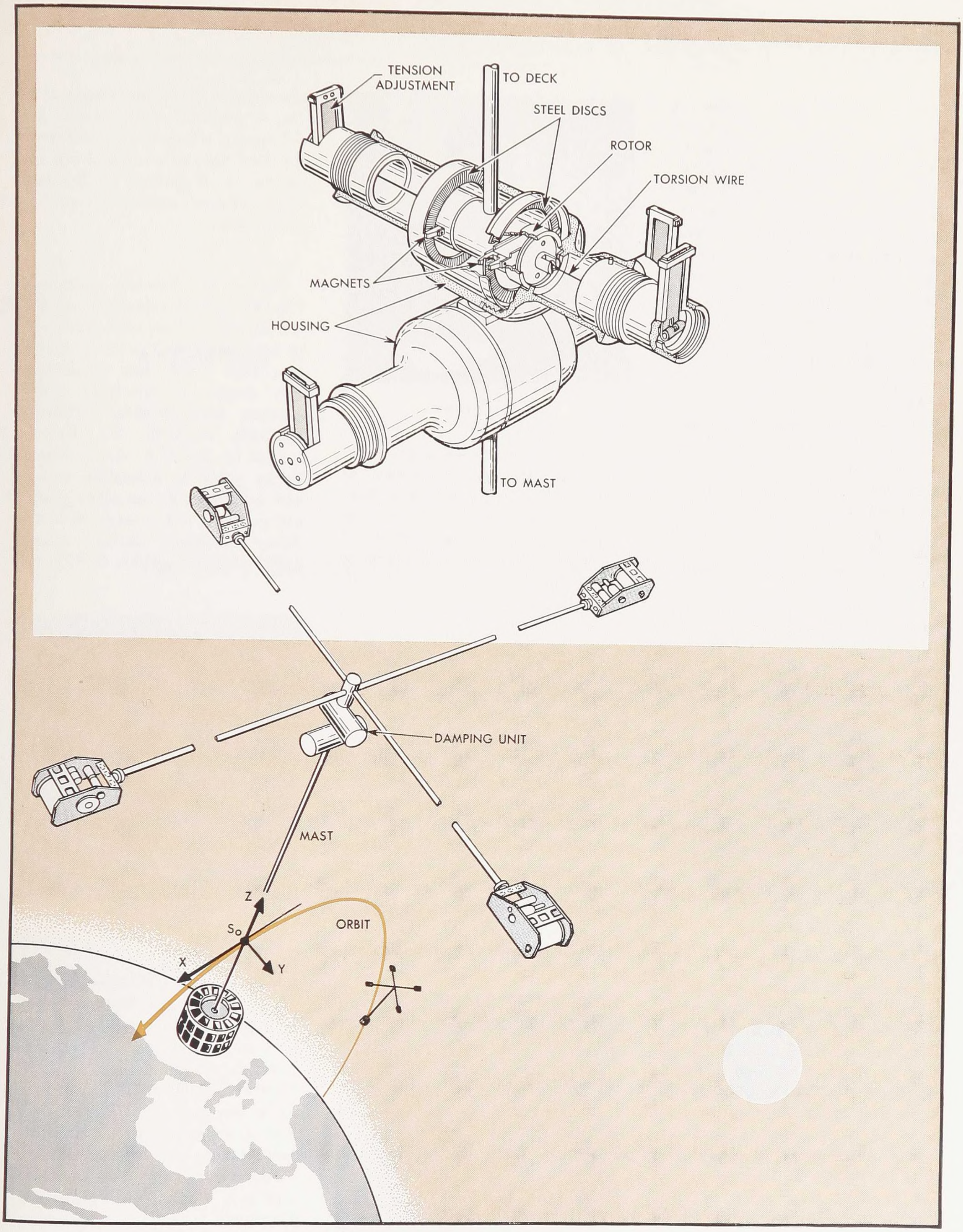
The chief advantage of this type of damping is that it depends on the extent, or amplitude, of the satellite's libration in space rather than on the velocity of the libration. This is important because the rate of the satellite's libration is too low to make velocity-dependent damping effective. Also, magnetic hysteresis damping is insensitive to temperature variation, involves no sliding parts, and requires little weight. Computer analysis predicts that the proposed PGAC system should stop a satellite from tumbling within four orbits after launch, and limit librations to less than 10 degrees after six orbits.

A low-orbiting satellite using a gravity-gradient system developed by the Applied Physics Laboratory at Johns Hopkins University was placed in a 400-mile orbit in July 1963. The Bell Laboratories system, however, uses a different damping unit designed to operate at significantly higher altitudes. The PGAC system, like the one developed by APL, is completely passive. It not only operates throughout the useful life of a satellite but also eliminates the need for active devices and thus permits a considerable reduction in a satellite's size and weight. With the antennas of a satellite constantly earth-pointing, the power radiated by the transmitter of a satellite at an altitude of, say, 6000 nautical miles, need be only about one-tenth that required with an isotropic antenna, which radiates signals in all directions.

Laboratories engineers based their proposal on the fact that an elongated body in orbit around the earth tends to line up with the local vertical. The local vertical is an imaginary line drawn from the center of the earth to the satellite. A satellite at one end and the deck structure at the other end of a 60-foot mast constitutes such an elongated body. The gravitational torque will dominate other disturbing torques in space.

Without a damping mechanism, such a satellite would swing back and forth, or librate, in space like a huge pendulum. Since there is no atmosphere in outer space to slow down these librations by friction, the satellite would swing indefinitely. Thus a damping mechanism to decrease librational motion is of prime importance.

The magnetic hysteresis damper for the PGAC system is inside a universal joint. It consists of a rotor suspended by wires which are attached to the ends of the housing. Rings of permeable material, such as steel, are fitted inside the housing. Associated with each ring is a bar magnet fixed across the diameter of the rotor. Each magnet has its north and south poles hollowed out so that the ring of permeable material passes through each pole. The magnetic fluxes from the north pole of each magnet pass through both halves of the permeable material back to the south pole. This forms a closed circuit. When the satellite librates, the magnets rotate relative to the rings, thereby creating magnetic hysteresis losses which dissipate the libration energy. Thus, the rotor is inhibited from turning and the libration energy is given off as heat.



In the magnetic hysteresis damper unit (shown above), the rotor is suspended inside the housing by two torsion wires connected by springs to the end of the housing. The poles of the magnets are hollowed out in a horse-shoe shape so they enclose the steel discs. Below is an over-all view of the passive gravitational attitude control system.

THE AUTHORS

Harry M. Kalish, author of "Machine-Aided Preparation of Electrical Diagrams," is a native of Yonkers, New York. He graduated from RCA Institutes and completed specialized courses in electronics and teaching at New York University. After teaching communications in New York private schools for five years, Mr. Kalish started technical writing for Laboratories military projects in 1952. His work concerned the preparation of technical manual information for such systems as K5, TITAN and NIKE. Mr. Kalish is presently engaged in studying the feasibility of using machine aids in the preparation of instruction data as described in this issue. He is a member of the IEEE. Mr. Kalish and his wife live in Parsippany, New Jersey.

H. M. Kalish

Warren O. Turner, author of "Traffic Simulation" in this issue, was born in Acworth, New Hampshire, and received his AB degree from Dartmouth College in 1920. He joined the New England Telephone and Telegraph Company in that year and served in various Traffic Department assignments until 1927 when he transferred to the headquarters staff of the American Telephone and Telegraph Company. There he worked on the development of traffic engineering methods, and was appointed head of the Traffic Dial Equipment Engineering group in 1941. In 1951 he transferred to Bell Laboratories where he organized and became Director of the Traffic Studies Center. Most of the work described in his article is done there. Mr. Turner is a resident of Rumson, New Jersey.

W. O. Turner

T. A. Schmader is a graduate of the Central Technical Institute, Kansas City, Mo., where he specialized in radio and television. During the Korean War he served in the Army Signal Corps as a Radio Teletype Technician. Mr. Schmader joined the Laboratories in 1955 and was associated with the Electronic Switching Systems Department until his transfer to the No. 5 Crossbar System Department at the Columbus, Ohio location in 1959. For the past four years he has been engaged in various aspects of the development of No. 5 crossbar test circuits. Mr. Schmader, whose outside interests are Boy Scouts, woodworking and sports, is a native of Lucinda, Penn., and now resides in Reynoldsburg, Ohio.

T. A. Schmader

Walter H. Newton, author of "Mechanical Development of The TOUCH-TONE Calling Receiver" in this issue, was born in Brooklyn, New York, and received a B.S. degree in Electrical Engineering from Virginia Military Institute in 1953. Mr. Newton served in the U.S. Army Signal Corps prior to attending college and served in Korea after graduating. He is now a captain in the Army Reserve. After release from military service in 1957, he joined the Western Electric Company, Merrimack Valley Works, as a planning engineer and acted as a project engineer on the first four TASI systems. In 1961 Mr. Newton joined Bell Laboratories as a Member of Technical Staff and has been engaged in equipment design and development. Mr. Newton is a member of the IEEE and is a Registered Professional Engineer.

W. H. Newton

F. P. Balacek is a graduate of Cooper Union in New York City from which he holds a B.S. and