Bell Laboratories **RECORD**

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Contents

Cover *Silhouetted against an early-morning desert backdrop, a NIKE-HERCULES missile stands ready at the White Sands Missile Range* *(see article on page 388).*

O. H. Williford

An electronic switching system that operates in microseconds, provides new kinds of telephone service, and is compatible with existing electromechanical systems has been developed at Bell Laboratories.

The No. 101 Electronic Switching System

THE BELL SYSTEM telephone switching network is a flexible and versatile system. Using electromechanical switching techniques, it is responsive to the communications needs of Bell System customers and can be adapted, in most cases, to new services as the need arises. It is characteristic of telephone communications engineering, however, to continually seek more flexible methods that may lead to further extension of telephone services. Over the years, intensive studies made at Bell Laboratories have shown that electronic switching systems are quite feasible and that electronic techniques are readily adaptable to a wide range of new services. Electronic systems also have many other advantages for the customer and the telephone engineer.

A large number of Bell System customers are businesses served by private branch exchanges (PBXs). In many instances, these exchanges have been virtually tailored to the communications needs of the customer and they must be rearranged physically if these needs change. Electronic switching techniques make it possible to easily change services and accommodate new requirements stemming from a customer's growth. Many modern businesses are so complex and change and grow so rapidly that they have created a need that can be filled most effectively by an electronic switching system. The No. 101 Electronic Switching System (ESS), recently developed at Bell Laboratories, fills this need for PBX and Centrex customers.

From the point of view of service to the customer, the No. 101 ESS offers an array of new features in addition to all the traditional ones. Among the important new services are Centrex features (RECORD, *October* 1962), TOUCH-TONE Calling, abbreviated dialing, add-on conference, dial transfer, automatic reroute, and universal attendant consoles (RECORD, *June* 1963), in place of switchboard positions. A compact switch unit which occupies only about one-tenth the floor space of the older PBXs is all that is required on the customer's premises to effect these services.

To provide these services with economy and efficiency, the system embodies a number of new switching techniques. Among the most characteristic are:

Shared Centralized Control. The switching equipment and the control equipment are separated. The control unit, located in a telephone company office, controls simultaneously a number of customer switch units.

Stored Program Control. Highly versatile control of switching and service features is attained by stored program techniques. Switching instructions are stored in plug-in electronic memories and these are consulted and acted upon as dictated by the service demands and the internal system logic. This technique allows features to be changed or added easily at the control unit. It does not require any action at the customers offices.

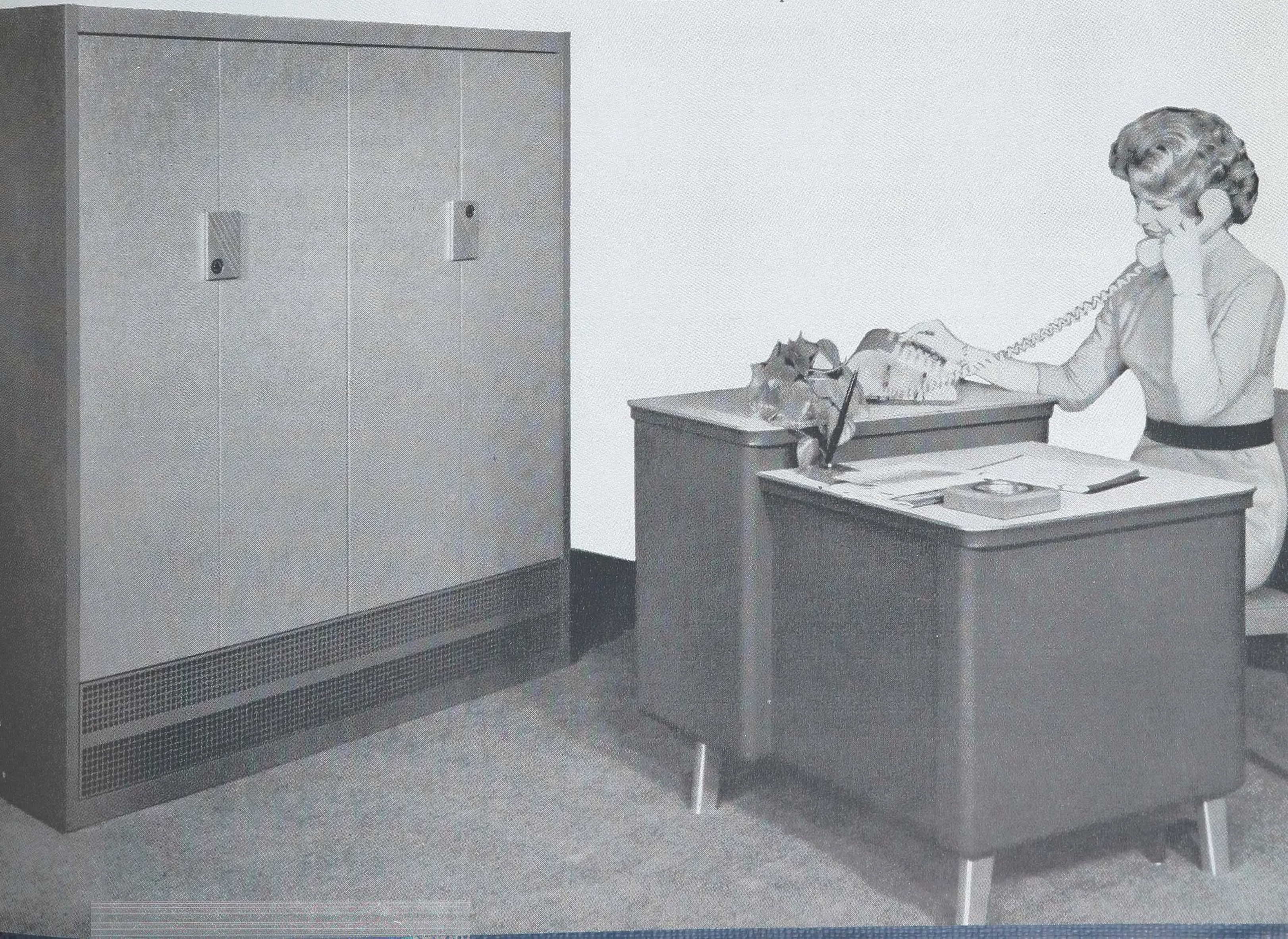
Time Division Switching. The time division networks in the switch units keep to a minimum the space requirements on the customer's premises and enable simple and flexible growth capabilities within the limits of the system.

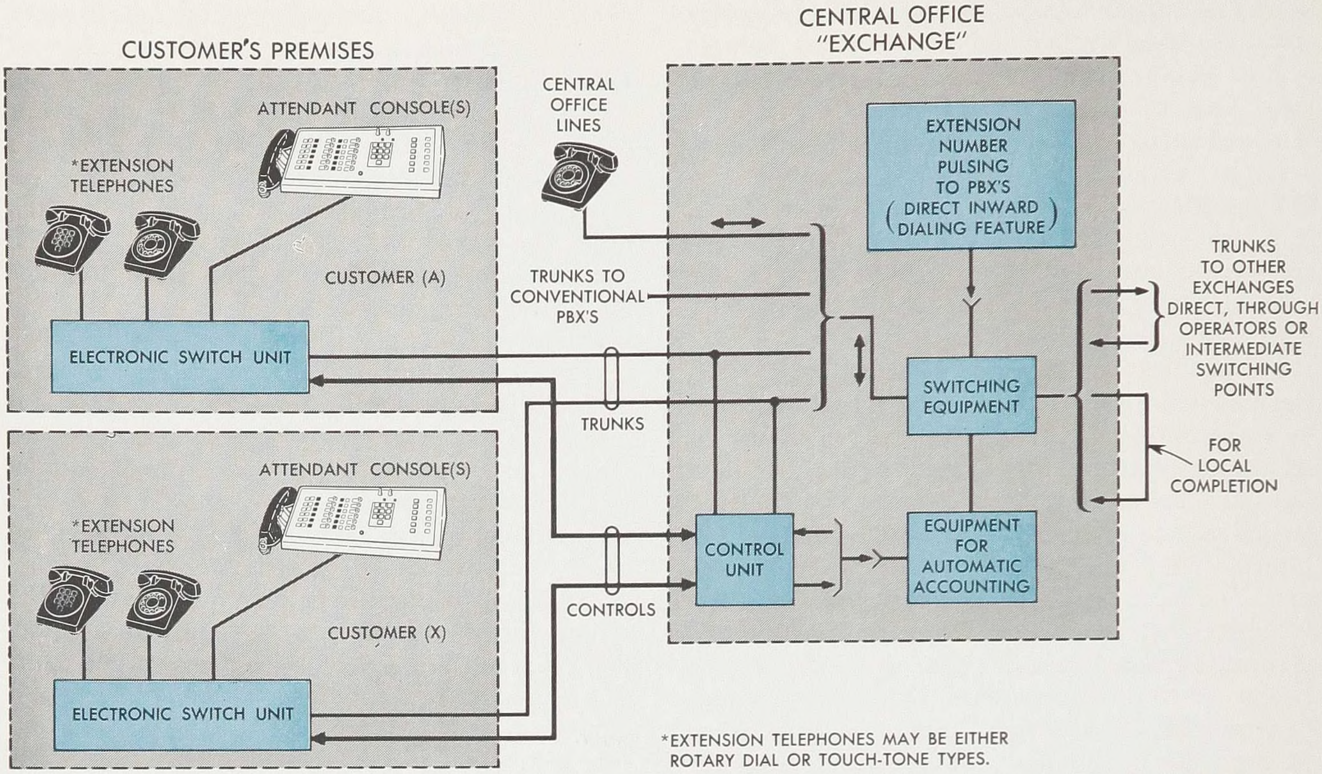
The general system plan is depicted on page 376. Each switch unit is connected to the control unit by two groups of control conductors. One group, consisting of two pairs of conductors called data links, transmits supervisory information from the switch unit to the control unit and switch control information from the control unit to the switch unit. The second group, called digit trunks, is provided as required by the volume of traffic and transmits called numbers from the PBX extension telephones to the control unit. Talking connections between PBX extension lines are established through the switch unit. Calls to and from the central office use trunks to the switch unit in much the same fashion as they do in electromechanical PBX systems.

A switch unit (see the drawing on page 377) can serve up to 200 extension lines. Each line, trunk, and attendant console is individually terminated in a plug-in terminal circuit in the switch unit. The actual switching stages of any talking connection are established by successive joinings of the terminal circuits in the switch unit. For example, a calling line is first connected to a digit trunk for dial tone and dialing, then it is connected to audible ringing tone, and finally it is connected to the called party or to a central office trunk. Three or four terminal circuits can be joined together for conference calls, or, for example, to bridge an attendant's telephone circuit on a connection between an extension line and a trunk.

Time division switching permits all calls in the switch unit to simultaneously share a common transmission path called a common bus. A cycle of time for the bus is divided into discrete, rapidly recurring time positions called time slots. Each time slot serves as a switched-in link over which a

The switch unit cabinet is designed to blend with the decor of any modern office. Universal console is compact and attractive.





General system plan of the No. 101 ESS. The control unit is located on telephone company owned or leased space. It has a capacity of up to 3200 lines which can be distributed over as many as 32 switch units. Each customer can choose whatever features and services benefit his business.

call connection can be established. Thus, when terminal circuits are to be joined in a talking connection, they are assigned the same time slot. Each switch unit has 50 time slots, so that 50 call connections can exist simultaneously.

Supervisory detecting equipment in the switch unit continuously scans the terminal circuits and informs the control unit as to their supervisory states. If the state of a line does not change between scans, the system does not take any action. If there is a change (i.e., from on-hook to off-hook, or vice versa) the nature of the change and the coded identity of the point at which it occurred is transmitted by the switch unit terminal equipment over the data link to the control unit. In the case of an extension starting a call, the output signal is transmitted to the control unit which then returns information to the switch unit. This last message contains the coded identities of a specific time slot and of the line and digit trunk terminal circuits which are to be connected. The data receiver causes this information to be written into the specific time slot position in a memory unit contained in the switch unit. This changeable memory unit has an information position for each time slot.

The control unit (see the drawing on page 378), which can serve up to 32 switch units, operates much like a data processing system. Its inputs are indications of changes in the supervisory states of terminal circuits and dialed digits from extension telephones. Its outputs consist of switching orders to the switch units and outpulsed digits to the central office or to tie lines. Both input and output information are assembled in a ferrite sheet type of changeable memory element called the digit and data store. Input information is read out sequentially and processed. Output information is transmitted as switching orders to the switch units or out-pulsed through a sender portion of the control unit.

The stored program that tells the control unit how to operate on the inputs in order to determine the proper outputs is incorporated in a semi-permanent magnetic memory device called a "twistor." Program instructions are embodied in magnetized spots on non-magnetic metallic "cards." To change the program, one card can be substituted for another in the twistor, or a card can be withdrawn and its magnetic patterns changed.

A control unit contains two twistor memories. One, the program control store, records the basic program. This is designed into the system and it determines the routine the system will follow to effect any service feature or carry out any operation. This store is changed only if the system design is changed. The second twistor, the line information store, records those factors of call processing related to telephone company administration. It includes information such as the switch units in service, the number of lines in each unit and the number of attendant consoles associated with it, the number and types of trunks, and the particular service features elected by the customer. Finally, another ferrite sheet changeable memory element, the call status store, keeps an up-to-the-minute record of the status of all lines, trunks, and other terminal circuits which are active in the system.

The actual routine of call processing involves all the memory elements in a continuous interplay. The identity of a line, trunk or other source of input signals is referred to the call status store; the resulting status information influences the output information required to advance the call. Output information may be determined directly in the program store, or after consulting the line information store. For instance, when an extension user lifts his receiver to start a call, the number of the extension is referred to the call status store. Because the extension was idle before starting this call, its identity will not be found in the call status store. Under these conditions the program store will furnish information that the extension is starting a call and output information is generated that causes the line to be connected to a digit trunk in order to give the extension user dial tone. The call status store is also searched to determine the busy or idle state of the called line. If a called line is found busy, the line information store is consulted to see if the line is in a hunt group, and to determine what other lines are in the group. The call status store then is searched to see if a connection can be made to an idle line in the group. If no line is idle, output information is sent to generate busy tone.

These principles of operation, which can take full advantage of the microsecond response speed of the system, are the basis of some new switching techniques that, in turn, are the basis of many new services. For example, during a call a customer can get dial tone without disconnecting merely by flashing his switchhook. Then he can dial, and establish connections to other extensions. A number of new features are built on this technique:

Add-on conference. One customer in a talking connection can add one or two more parties in a conference arrangement merely by dialing; he

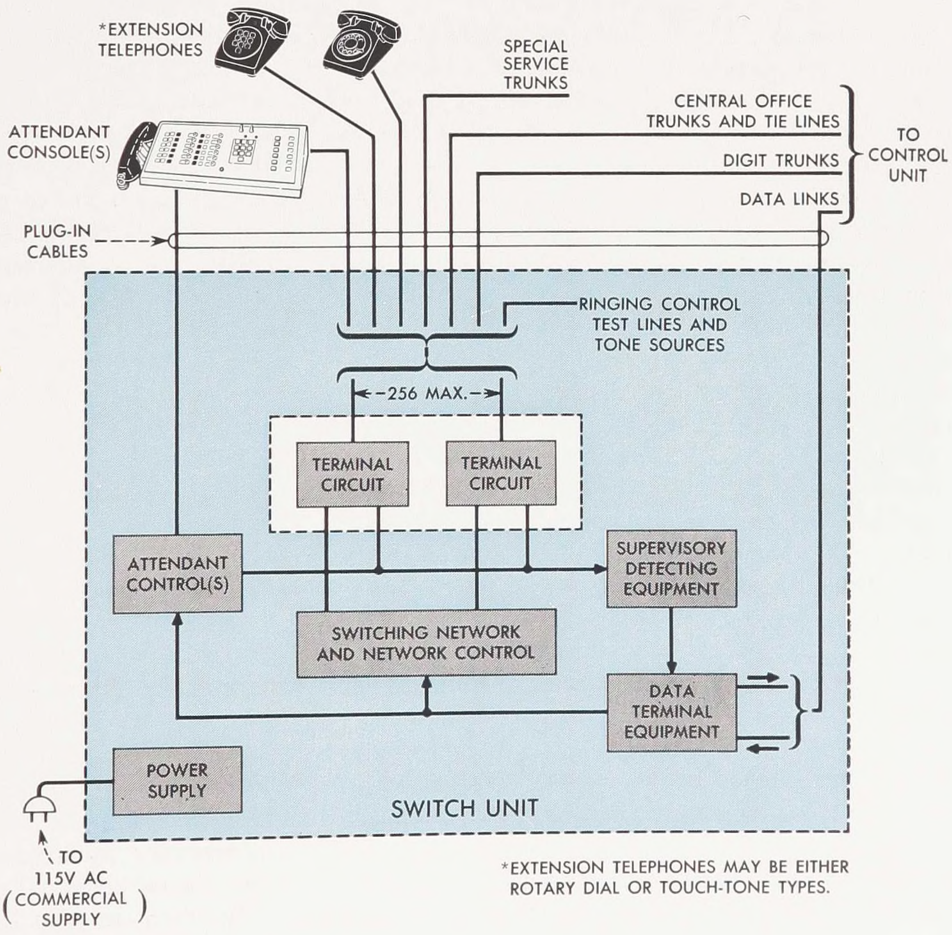
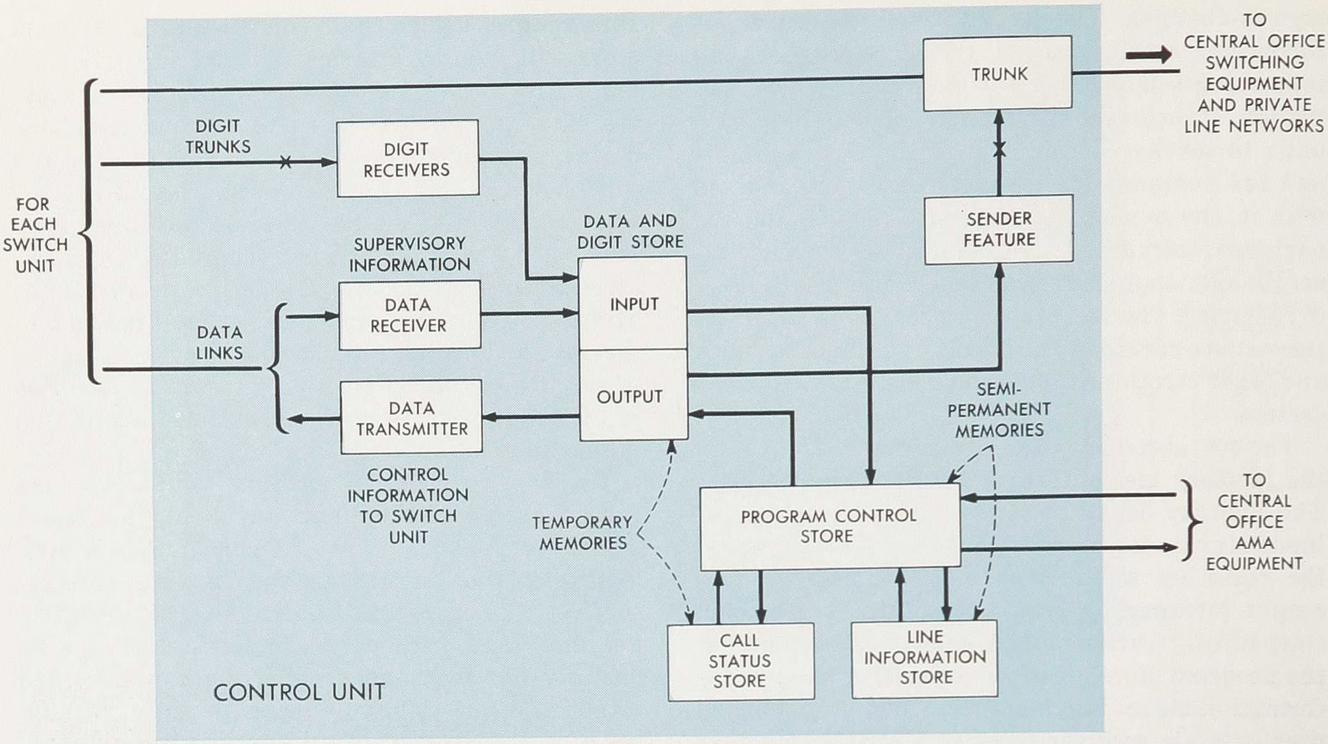


Diagram of a customer switch unit for the No. 101 ESS. The unit can be plugged into a 115-volt wall outlet. Its operating power is only about 600 watts, less than that of a home toaster.



The control unit contains in its memory elements a series of stored programs that detail each step needed to set up a call or direct a special service feature. The control unit sends data messages to the switch unit, telling it what actions it must take in completing a call or in taking down connections.

does not need operator assistance.

Dial transfer. A customer can transfer a call to another extension by dialing the new number.

Dial hold. A customer can put one call in a hold position, dial another customer for consultation, then return to his original call.

Either standard rotary dial or TOUCH-TONE dial telephones can be used with the system. The control unit regenerates all digital information before it is transmitted over tie lines or trunks. TOUCH-TONE signals are converted to dial pulses so that TOUCH-TONE equipment is needed only in the No. 101 ESS and not at the serving central offices.

Abbreviated dialing also makes use of this technique. The calling party simply dials a 3-digit code and the system outpluses the 7 or 10-digit number of a previously specified customer. Before the output digits are sent the input digits are referred to the line information store which may have special instructions to interpret them as a signal to outpulse other number or digit combinations.

Special codes also can be used to temporarily modify established programs of call routing and treatment. For example, a customer can dial a code that will cause his incoming calls to be routed to another extension. This feature is called automatic reroute. Restrictions on particular telephones also can be effected for certain codes. For example, calls from the restricted telephones on which the prefix "9" is dialed may all be routed to the attendant. Other lines can be partially restricted—they can be permitted to place central office calls to up to 15 specific office codes, and denied access to all others. In the same way, some lines can be permitted local calls and denied access to toll points. Yet another pattern of restriction can be applied to abbreviated numbers; access to these numbers can be limited to specified extension lines and to the attendant.

The No. 101 ESS can provide Centrex features such as direct inward dialing (DID) and automatically identified outward dialing (AIOD). Incoming calls can thus be routed directly to the extension without going through the attendant. For outgoing calls, central office Automatic Message Accounting (AMA) equipment can be arranged in direct association with the No. 101 ESS control unit. In this case, the number of the calling extension, and not the number of the PBX, will be recorded for billing.

Although the No. 101 ESS is compatible with all electromechanical central office systems, the Centrex features will be operable only where complementary features are activated in the connecting central offices. For example, DID is effective only when the No. 101 ESS operates in conjunction with No. 5 crossbar, crossbar tandem, and step-by-step systems. AIOD is possible only with No. 5 crossbar, but developments are under way that will make this feature available in other central office systems equipped with AMA or ANI systems.

Up to three Universal consoles can be associated with each switch unit. The number needed depends, of course, on the volume of traffic requiring attendant assistance. A call distribution feature evenly divides the traffic among all consoles associated with a switch unit. The console operates by the "switched loop" method so that it is associated with a call only while the attendants services are needed. When a call is directed to the attendant, the console is "switched in" to the connection through an entry called a "loop." When the calling and called parties begin to converse and the attendant is no longer needed, the console is "switched out" and the loop is free for another call. A console can be equipped with up to six loops which enables it to handle six calls simultaneously.

If a call is placed through the attendant to an extension that is busy, a "Camp-on" feature will allow the calling customer to wait and to be connected automatically when the called customer becomes free. Also, an "Automatic Recall" feature can time the waiting period and recall the attendant if the called customer is still busy when the time is up. The attendant can also use a "Busy Verification" feature to confirm that the line actually is busy, or to override a busy indication in an emergency.

A "Transfer" feature permits the attendant to release a connection on an established call and make a new connection to another extension in the PBX.

M. A. Townsend (standing) and W. F. Means inspect one of the twistor memory stores in an experimental control unit of the No. 101 ESS at Bell Laboratories. Mr. Means holds a program card. H. F. Priebe, in background, checks equipment in the line data frame portion of the unit.

A "Holding" feature permits the attendant to delay the completion of a call while she gets information pertinent to its completion. Also, a "Splitting" feature allows her to separate the calling and called parties so that she may talk to each privately.

The control unit is programmed to continually send test calls—about one a minute—through the system. If a test fails because of a defective unit of equipment, the unit is switched out of service and a duplicate unit is switched in. At the same time, information on what part of the system has failed is printed out on a teletypewriter at the control unit. Thus, the system can continue to service customers while repairs are being made. Control equipment is duplicated. If one program store malfunctions, another can take over immediately. In the switch unit, the common bus is actually not a single element, but two, each with a capacity of 25 calls. If one bus malfunctions, the other will continue to give service at reduced capacity.

A basic tenet in the design of the system was equipment "packaging." In the switch unit, the common switching elements (the switching network and control, the supervisory detecting equipment, and the data terminal equipment) are furnished at maximum capacity. The switch unit requirements for a particular customer are met by plugging in the necessary number and type of terminal circuits and console control equipments. The control unit is similarly packaged. The principal control bays are installed essentially as a package in all cases, with equipment engineered as required to meet the interface and trunk requirements individual to the switch units.

The No. 101 ESS is now being given a field trial in New Brunswick, New Jersey. A control unit in the New Brunswick central office is serving three switch units — two installed in the offices of New Brunswick commercial customers, and one serving a group of Bell Laboratories engineers at the Holmdel Laboratory. The first commercial system, manufactured by the Western Electric Company, is being installed to serve a number of customers at Cape Canaveral. Another will serve the Bell System exhibit at the New York World's Fair in 1964. Meanwhile, Bell Laboratories is continuing with further developments that will make the principles established in the No. 101 ESS more widely applicable to Bell System customers.

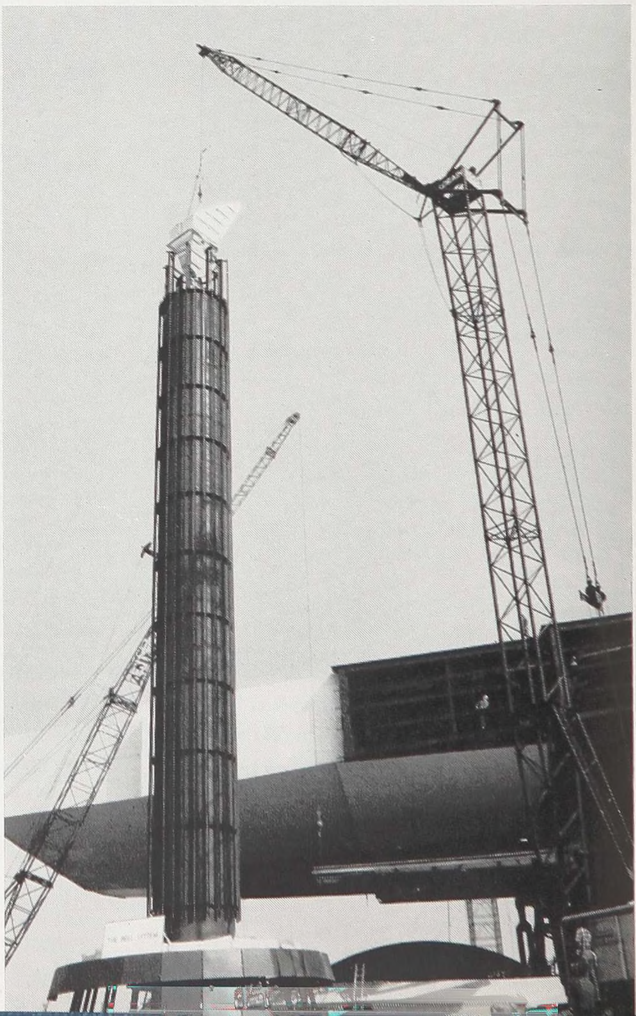
Horn Antenna Tops Bell System Fair Exhibit

A horn antenna that will transmit all television programs originating from the New York World's Fair has been placed atop the Bell System's exhibit building on the fair grounds.

The antenna is part of the exhibit and will serve as the principal entry point to the nation's television network when the fair opens next April. Perched atop a 14-story-high microwave tower, it also will handle incoming and outgoing closed circuit TV as well as data transmission. A second antenna atop a building in midtown Manhattan will complete the first relay leg for nationwide broadcasts.

Installation of transmission equipment will start immediately so that circuits will be ready for use well in advance of the fair's opening. Visitors will be able to see transmission and control equipment as well as programs being televised through the glass-enclosed base of the tower.

The microwave tower is a highlight of the exhibit, the heart of which is a 400-foot long floating-wing pavilion 24 feet above the ground. Though supported at four points, the enclosed pavilion appears to be suspended in mid-air.



G. P. Marki

To prevent interruption of service during periods of routine maintenance or equipment failure, protection switching has been provided for the L3 Carrier System.

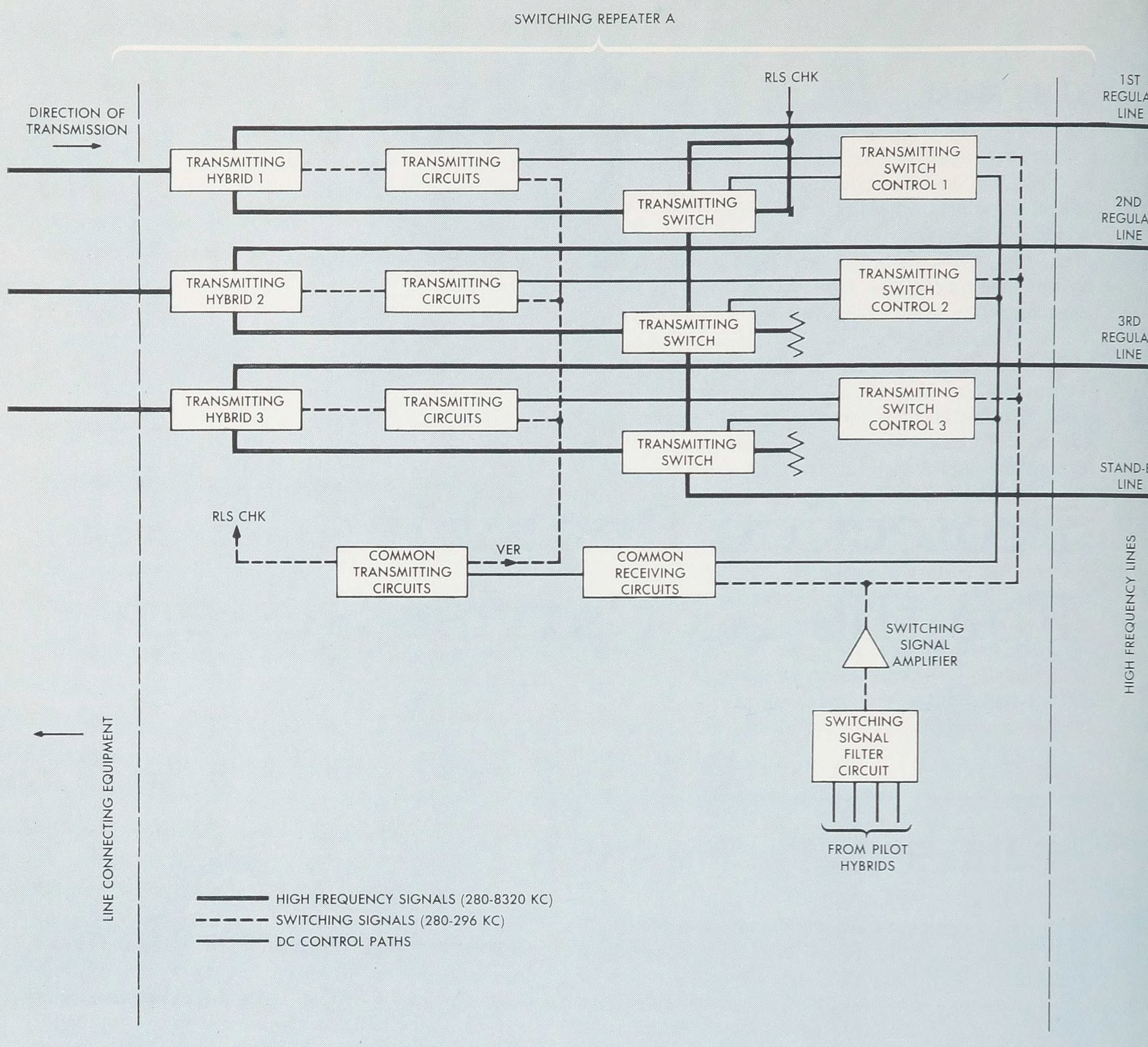
Protection Switching For the L3 Carrier System

THE L3 COAXIAL CARRIER SYSTEM is a long-haul broadband repeatered transmission system capable of carrying 1860 telephone messages or 600 telephone messages and a 4.2 mc television channel in one direction on a single coaxial unit. The cable on an L3 route is composed of several coaxial units within an outer sheath. Each route of the cable is divided into "switching sections" averaging 100 miles in length for purposes of equalization and protection switching. Each includes two repeaters outfitted with switching equipment. Protection switching is provided to prevent interruption of service during periods of routine maintenance or equipment failure.

Before the hardened (blast-resistant) cross-country route was in use, a cable contained no more than eight coaxials within the outer sheath. In a switching section with an equal number of lines working in each direction, there are four lines transmitting each way. Since one line in each direction is used as a protection or stand-by line, the three remaining pairs of lines—called regular lines—carry the services sent over the L3 system. In parts of the country where one-way television is transmitted over L3, an unbalanced arrangement may be used, whereby four regular lines transmit in one direction and only two regular lines transmit in the opposite direction. In either instance, a multiline switching system capable of protecting up to four regular lines with one stand-by line has sufficed.

Most of the new hardened route, however, employs cable containing twelve coaxials. Moreover, two switching sections with heavy traffic have two eight-coaxial cables laid side-by-side. Studies of the service outages due to equipment failure, and maintenance on existing coaxial routes indicate that it is reasonable to plan to use one stand-by line to protect up to seven regular lines. On this basis, when the sections consisting of twin-eight-coaxial cables are fully equipped, the protection switching system must be able to substitute the stand-by line for any one of the seven regular lines. In other sections where 12 coaxials are involved, a switching system capacity of five to one will be required.

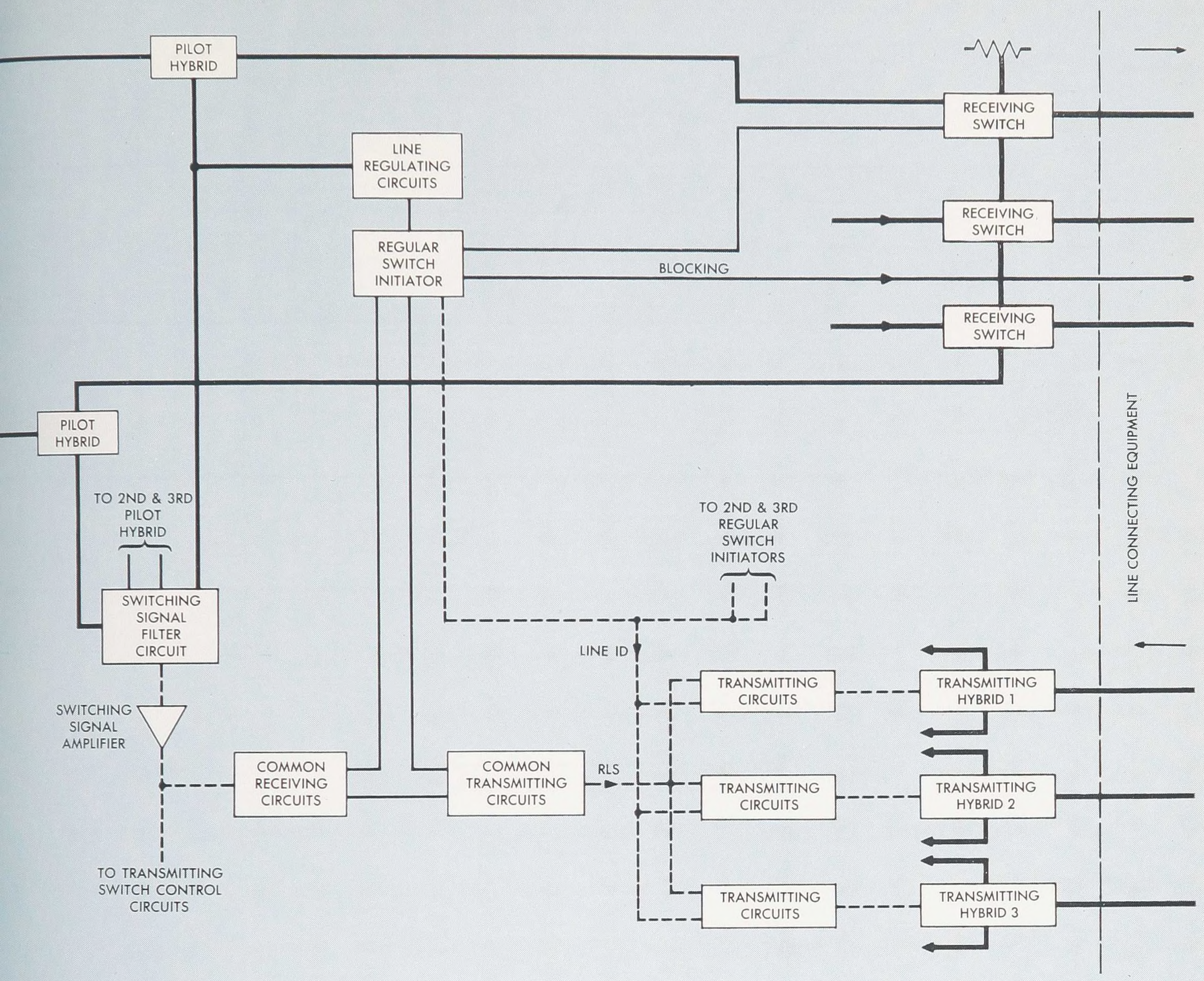
Traffic needs required that the initial working lines for the hardened route be in service before



This simplified schematic shows the multiline switching arrangement. High

work on the expansion of the switching system could be started. The first objective of the expanded design was to permit the reuse of switching equipment associated with the lines equipped initially to keep cutover problems to a minimum. The expected rate of growth of the hardened route imposed a time limit on the development of a suitable switching system since a fifth regular line was scheduled for service in two sections in the latter part of 1963.

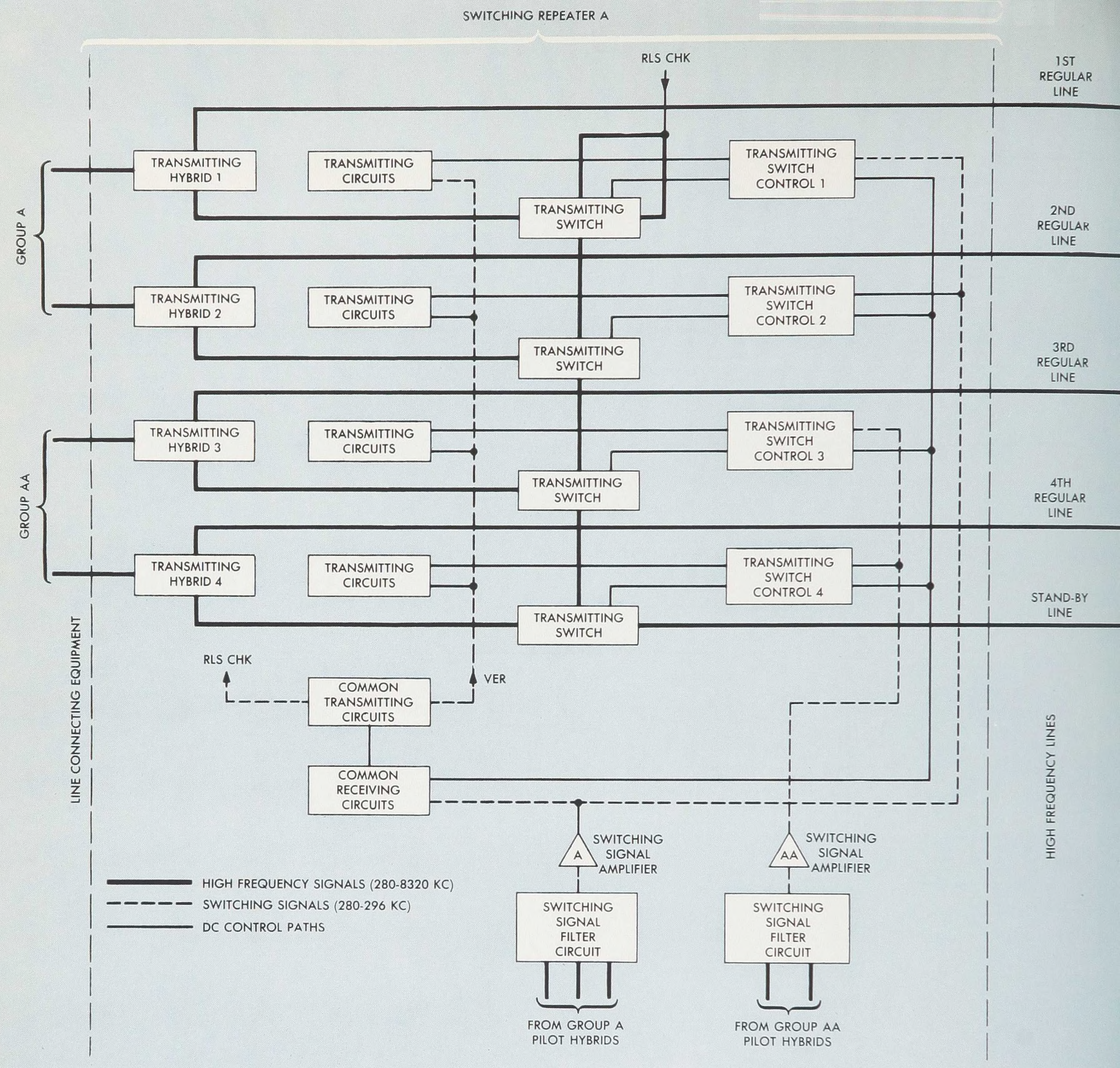
A brief description of the operation of the multiline switching arrangement will serve as an introduction to the expanded switching scheme. Consider an eight-pipe coaxial running between switching repeaters A and B, as shown above. In the balanced arrangement, there are four coaxials transmitting in each direction. Let us examine one direction of transmission more closely, for example, the four coaxials transmitting from A to B. The coaxial designated as the stand-by line must be able to carry the service normally transmitted over any one of the three regular lines. To make the stand-by available to all three regular lines, each regular line is equipped with a trans-



d switching signals are shown for only one direction of transmission.

mitting switch at repeater A and a receiving switch at repeater B. The incoming baseband signal for each regular line is split in the associated transmitting hybrid coil. Half the signal is fed directly to the regular line and half to the transmitting switch. The stand-by line connects to the transmitting switches in tandem and normally is fed from the first regular line in order to obtain the six pilots necessary for line regulation. Operation of a transmitting switch results in the transfer of the stand-by line input from the hybrid coil of the first regular line to the hybrid coil of the regular line associated with the operated switch. At the receiving end of each line the signal is split in the pilot hybrid. This hybrid is so proportioned that most of the incoming signal passes through the nonoperated receiving switch to the line-connecting equipment. The remainder of the signal is divided between the line regulating circuits and the switching circuit. Operation of the receiving switch terminates the regular line and transfers the line-connecting equipment to the stand-by line.

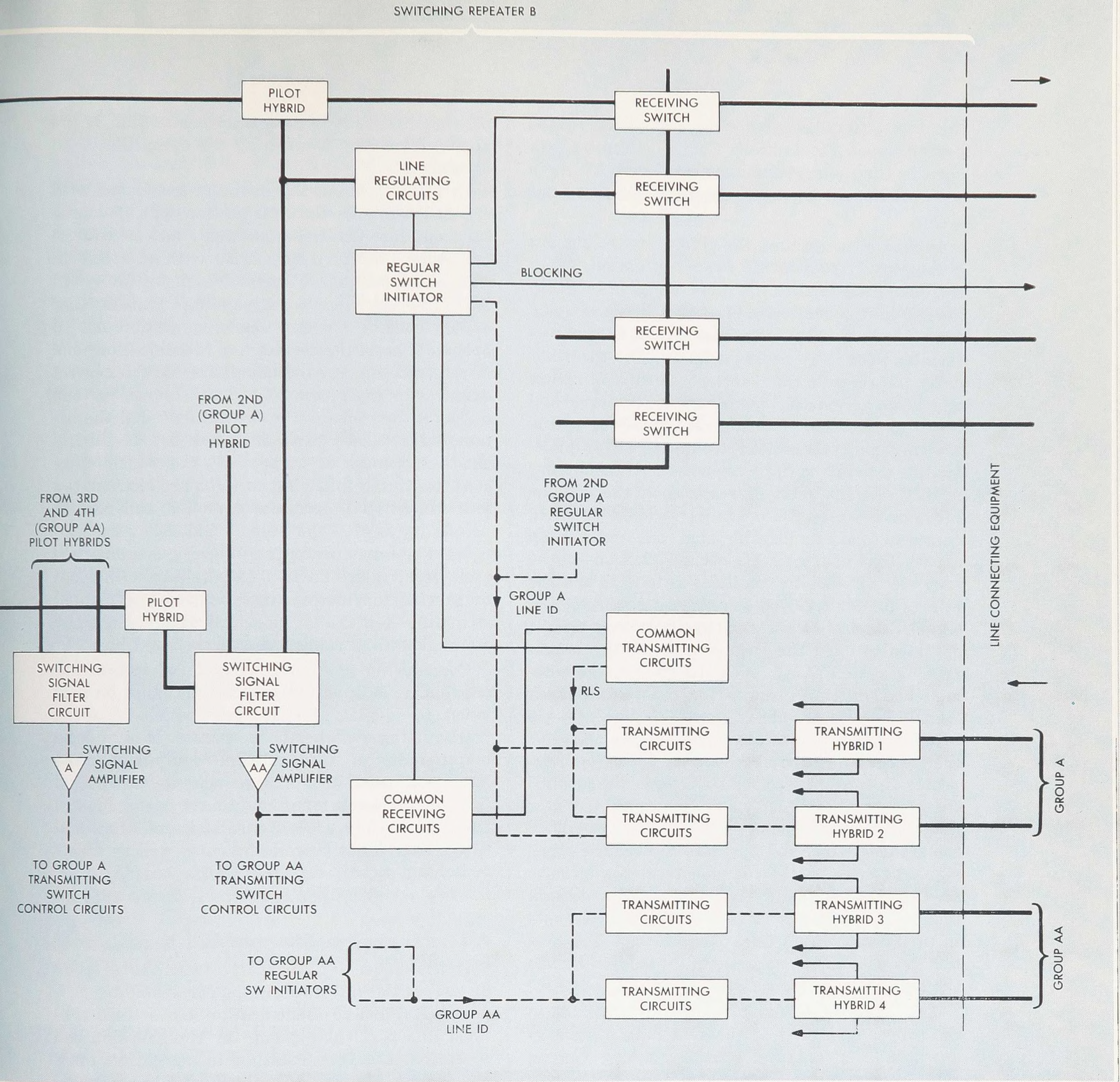
Primary control of the switching system rests



A simplified schematic of the expanded multiline switching arrangement is shown abo

with the switching equipment located at the receiving end of each direction of transmission. Associated with each line is a switch initiator that is activated by the line regulating circuits when transmission of the pilots over the line is impaired. A ±2 db variation in the level of a received pilot results in the closure of limit contacts on a pilot alarm Sensitrol relay. Since the Sensitrol relays require 50-100 milliseconds to operate, a secondary means for reducing the switching time in case of a complete line failure is provided. This last switch is triggered by an electronic gate that responds to a ±3 db deviation of the 7266-kc pilot. The switching operation is normally completed within 15 milliseconds after an electronic gate operation.

When the need for a switch is detected at repeater B the activated initiator sends a line identification tone to repeater A over all lines transmitting from B to A. The faulty line is also disconnected at repeater B from the input of the switching signal filter circuit to prevent possible



lines and switching signals again are shown for only one direction of transmission.

noise on the line from interfering with the switching circuit. Four line identification tones are provided—290 kc, 288 kc, 286 kc, and 284 kc—although in a balanced section only three are required. At repeater A the signal from each line passes through a 280 to 290 kc switching signal filter circuit where it combines with signals from all other lines. The resultant signal is amplified and fed to all transmitting switch control (TSC) circuits in parallel. The TSC circuits are selective detectors, each of which responds only to its own assigned line identification signal. Operation of the TSC operates and locks up the transmitting switch and releases a 296-kc verifier signal into the associated transmitting hybird. The verifier signal passes through the operated transmitting switch and onto the stand-by line. At repeater B only the stand-by line has a filter that will pass the 296-kc tone to the verifier signal detector in the common receiving circuits. Receipt of the verifier signal indicates the transmitting switch has operated and that the standby line and the line to be switched are being double fed at the beginning of the section. Control circuits then operate the appropriate receiving switch over a path previously set up through the activated initiator.

During a line failure, the pilot alarm relays are automatically reset at 40 second intervals. When this sampling operation finds all pilots within normal limits, the contacts of the Sensitrol relay remain open and the switching circuit begins restoration after a 20 second interval. The resulting delay represents the shortest duration during which an automatic switch can be in force and tends to eliminate repeated switching of a line showing an intermittent trouble. For example, assume a switch is in force on a line transmitting A to B. At the start of restoration the regular initiator releases the operated receiving switch, ceases to send line identification tone and sets up a path that enables release tone—282 kc—to be sent over all lines transmitting B to A. When the release tone is received at repeater A, the release signal detector in the common receiving circuit operates to open the lockup path for the transmitting switch and to open the gate in the common transmitting circuits for the release-check signal. The release-check signal — 280 kc — is bridged directly onto the stand-by line ahead of the transmitting switches. The receiving end, repeater B, continues to send a release signal until the release check tone passes through the now unoperated transmitting switches, travels down the stand-by line, and operates the release-check signal detector in the common receiving circuits at the receiving end. When the release-check tone is received, the release tone is cut off, and in turn discontinues release-check tone. The system is again in its normal state ready to handle the next request for a switch.

The so-called blocking feature is essential to the proper operation of the switching system as a whole. For instance, consider a long coaxial route consisting of several switching sections in tandem. Assume a line failure in the first switching section from the transmitting end in a given direction of transmission. Until the switching operation in the first section is completed, the pilot frequencies traveling through the following sections will appear at reduced levels. At the receiving end of each switching section the initiator associated with the affected line will initiate a switch even though the difficulty lies in a preceding section. Since the signal coming into every section except the first is out of limits, there is no point in switching in the following sections. To prevent unnecessary switching, a provision is made to pass from one section to the next information concerning the operation of an initiator.

In this situation, the initiator associated with the failed line in the first section will of course send out line identification tone; but so will all the other initiators associated with this line in succeeding sections. However, each initiator will also instruct the corresponding transmitting switch control for the following section not to operate even if the correct line identification tone is received. Since no transmitting switch control operates in any of the following sections, verifier signal is not released in the sections and the attempted switches cannot be completed. During the two-second interval in which the transmitting switches in the following sections are blocked, the first section will complete a switch and restore nominal pilots to the second and following sections. The initiators in the following sections will then deactivate. To facilitate taking a line out of service for maintenance purposes, a manual switching feature is provided that essentially simulates a line failure on a preselected line.

Considering again the problem of system expansion, it is apparent that means must be provided to identify distinctively which of seven transmitting switches is to operate. Many of the major units of the multiline equipment could have been used in a scheme whereby additional line identification tones could have been added to the four already used. Additional oscillators and filters could have been designed as well as a new switching signal amplifier with a broader passband.

A Less Expensive Alternative

A less expensive alternative was the division of the coaxial into two groups for switching purposes. If the line identification tones were confined to a particular group for transmission and reception, the four existing identification tones could serve as many as eight lines. This arrangement proved sound and has resulted in an expanded switching system that did not require the development of any new apparatus.

In the expanded multiline system, then, each coaxial is assigned to one of two groups—denoted A and AA—for switching purposes. As an example, consider an expanded multiline section consisting of four regular lines and a stand-by, as shown on Pages 384 and 385. Regular lines one and two in each direction constitute group A and regular lines three and four constitute group AA. Assume regular line two transmitting from repeater A to repeater B fails. The initiator is connected so as to send out the associated line identification tone—say 288 kc—only over the group A lines transmitting B to A. Similarly, at repeater A the incoming signals from the group A lines pass through the group A switching signal filters and amplifier and are applied only to the transmitting switch control circuits associated with group A. If instead, regular line four transmitting A to B had failed, the 288 kc tone from the line four initiator woud have been transmitted only over the AA group from B to A and would have passed only through the group AA filters and amplifier before being applied to the AA transmitting switch control circuits. Line identification tones present on the stand-by are no longer accepted. An ambiguity would result since the stand-by can replace a line in either group. The verifier and release-check signals are handled in exactly the same manner as in the multiline circuit. Release signal is sent over the A group only since the release signal detector in the common receiving circuits is in parallel with group A transmitting switch control circuits. There must be at least two lines in each group to ensure the availability of a transmission path, since a faulty line is automatically disconnected from the switching circuit.

Cutover Is Straightforward

The cutover from multiline to expanded multiline operation is straightforward since the existing multiline equipment can simply be designated the A group. For example, assume that three regular lines are in service in each direction and that the fourth is equipped and ready for service. Equipment for the AA group of lines will have been installed instead of a fourth initiator and transmitting switch control circuit. The first and second regular lines will continue to be served by the original equipment; the third and fourth lines will be connected to the added equipment and will be designated the AA group. The initiator and transmitting switch control circuit that formerly served the third line are then disabled until the fifth line, which will again be in the A group, is added. Since the interconnecting wiring between circuits serving the AA group can be completed at the manufacturing shop, the wiring performed during cutover is but slightly more complicated than that involved in the normal procedure of equipping an additional line in a multiline system. The expanded multiline system has the cost-saving virtues of being able to utilize fully existing equipment and thereby provides for ready conversion from multiline to expanded multiline operation.

Bell Laboratories Conducting Field Tests Of Radio-Telephone Equipment

Bell Laboratories, in cooperation with the Bell Telephone Company of Pennsylvania, is testing new radio-telephone equipment and methods in Pennsylvania which are part of the larger Bell System plan for Improved Mobile Telephone Service (IMTS).

Five IMTS units will operate through the Harrisburg central office, where control terminal switching equipment and three base station transmitters and receivers have been installed. Remote receivers are located at two other central offices, and a test transmitter has been set up at a fourth location.

The initial field test of the new IMTS equipment here will help to indicate the advisability of adopting the program throughout the Bell System.

Based on intensive market research, and designed to remove some of the technical limitations of present systems, IMTS will present a favorable contrast with past mobile telephone service. The old "push-to-talk" operation has given way to "full duplex", which allows for normal two-way conversations with no manual operation required —much like desk telephone service.

When a mobile caller takes the receiver off the hook, his set will automatically pulse its own distinctive signal through the central office, and dial tone will be returned. Mobile units have central office line assignments and terminals much the same as regular telephones.

The mobile subscriber can dial all numbers that can be reached by any land telephone in the exchange. Calls to an IMTS subscriber in his home area from any wire line telephone or other IMTS mobile unit also may be dialed directly.

In multi-channel areas, calls to or from any set within range will be completed without operator assistance if there is one channel—any channel—open. When an IMTS-equipped vehicle roams into another IMTS area, the driver will be able to align his set with the radio channels available in that area and operate with automatic channel selection, just as in his home area. This capability will increase the flexibility of mobile unit operations.

The automatic channel selection feature also means that a mobile subscriber will no longer have to hunt over available channels, monitoring each one to find a channel on which he can originate a call.

R. D. Johnson

Simulation:

Key to NIKE-HERCULES System Testing

NIKE-HERCULES—a command guidance air defense missile system developed by Bell Telephone Laboratories and produced by Western Electric and Douglas Aircraft Co.—is emplaced in tactical positions throughout the free world. It is a system which, through proven effectiveness and reliability plus the flexibility of delivering a conventional or nuclear warhead, constitutes a main bulwark of our air defense.

To meet the ever-changing threat — faster, higher flying, more maneuverable, manned and unmanned aircraft and missiles—a continuing developmental test program is being pursued at the White Sands Laboratory, New Mexico. This test program is designed to explore fringe areas of system capability against new targets and to evaluate improvements in the radar computer and the HERCULES missile itself.

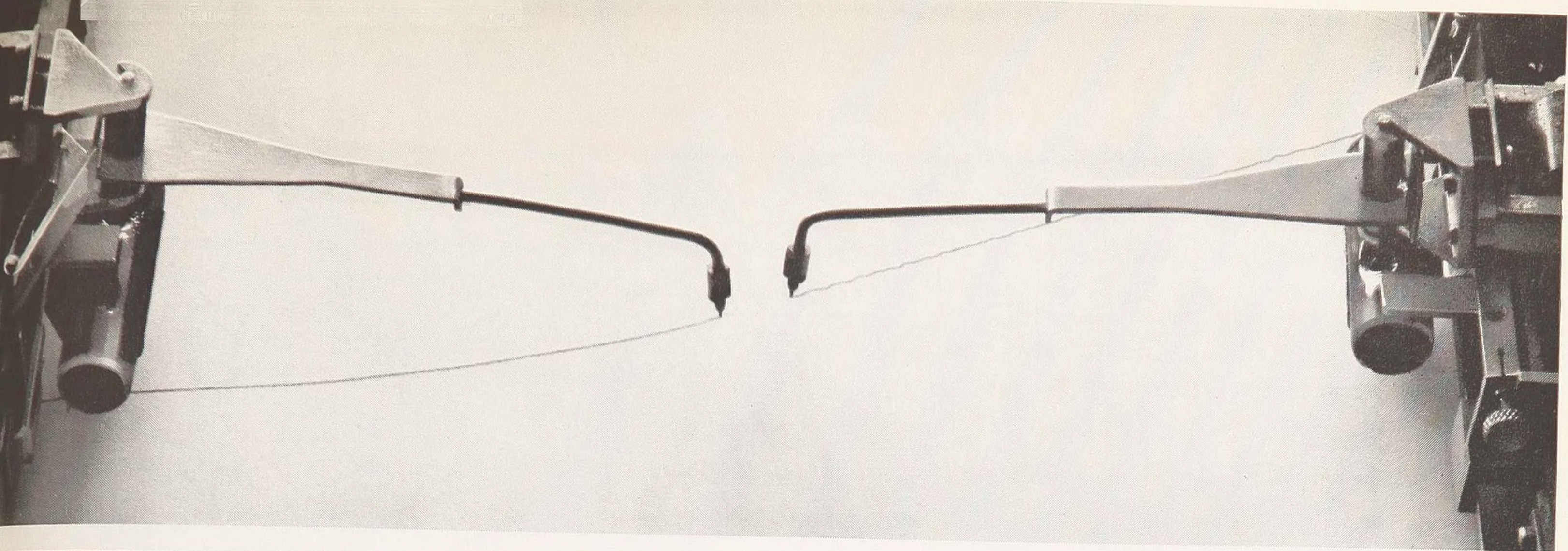
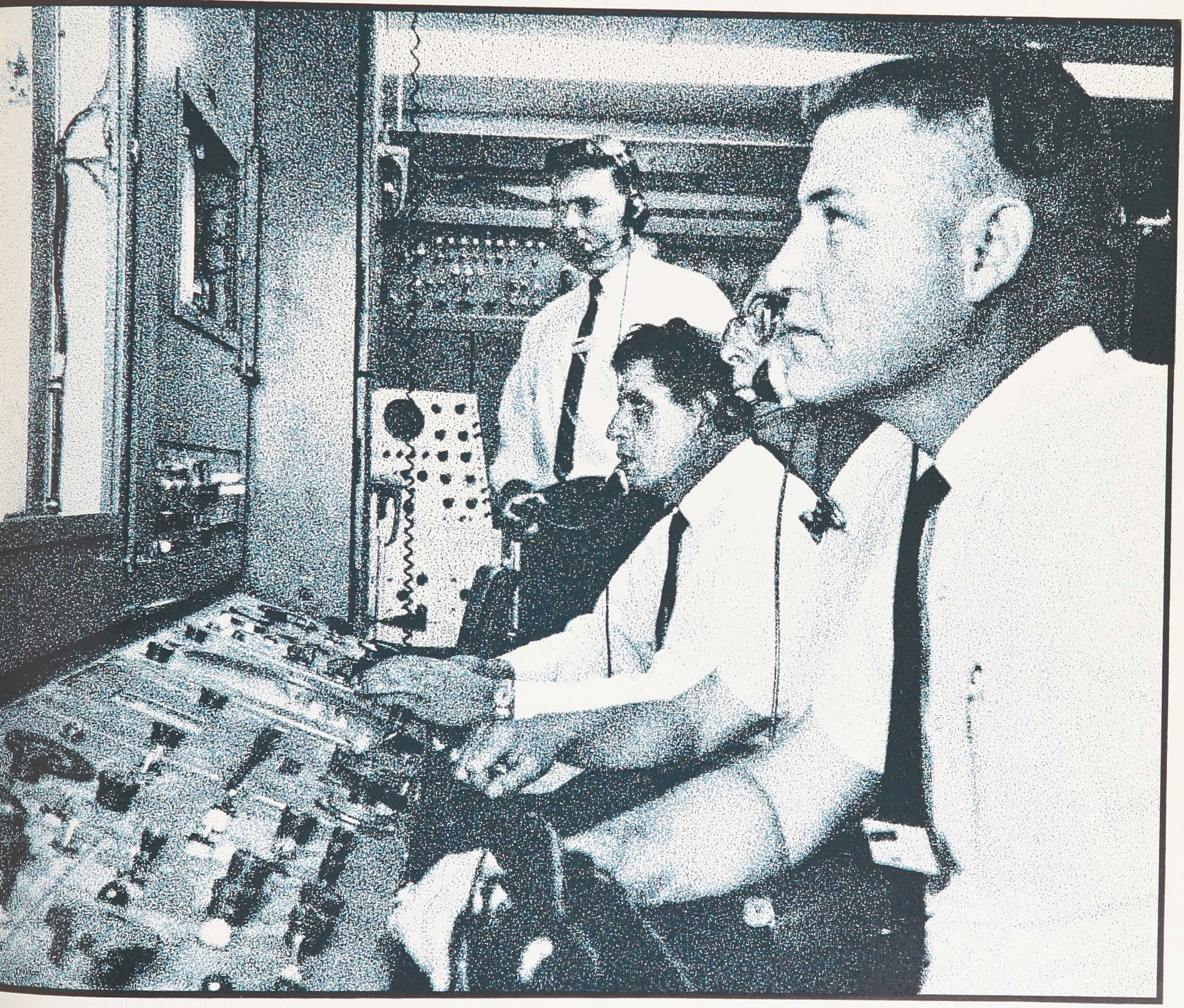
Since 1955, when the HERCULES research and development program began, a total of over 300 HERCULES firings have been conducted at the White Sands Missile Range to ultimately perfect this weapon system. During this same period, more than 25,000 simulations have been performed in support of these firings to investigate and solve a variety of system problems.

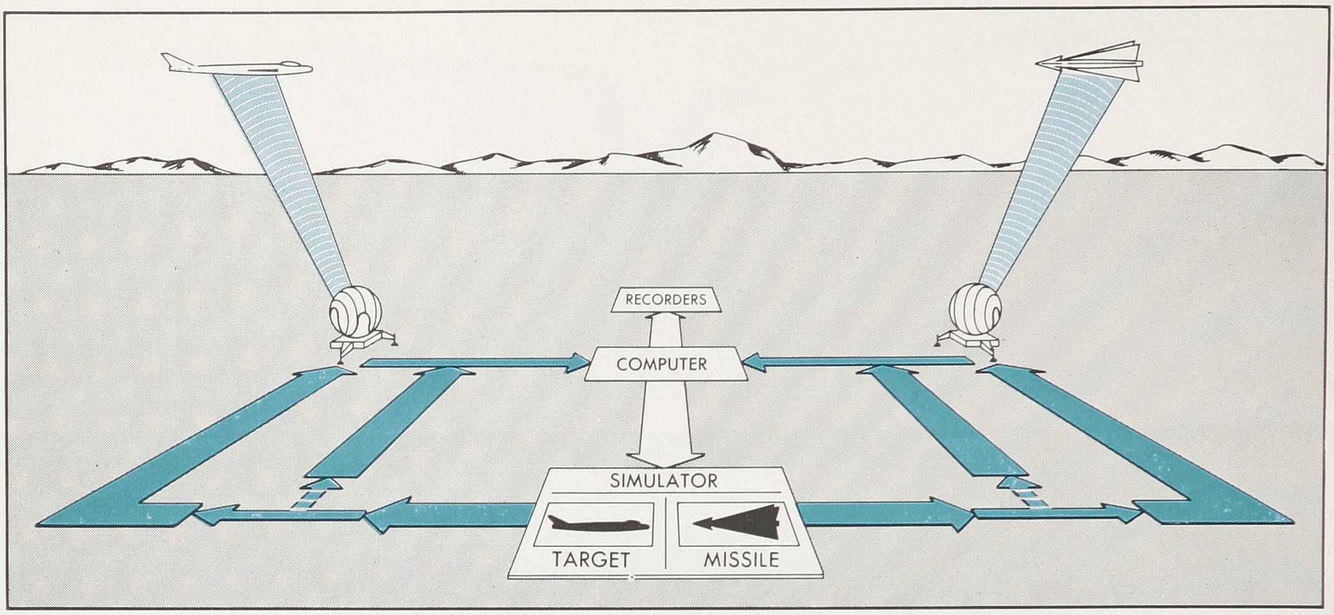
The HERCULES System is one which readily lends itself to analog simulation technology. That is, the nature of command guidance (where most of the system "brain" is located on the ground) is such that only an aerodynamic entity—missile or target—need be replaced to duplicate real conditions. Because of this, the system can be almost wholly evaluated through a well planned series of simulations. Hence, only a minimum number of live firings is required to proof-test system capabilities—a benefit manifested by the rapid, low-cost development of the NIKE-HERCULES System.

The desirability of conducting simulations right at the "firing line"—to complement the missile firing program—was foreseen at the outset of the NIKE testing program. Simulation had proved to be an indispensable tool in design studies at Whippany, and many techniques were developed for use in the R&D program. Simulation equipment was therefore made an integral part of the system installation at the White Sands Missile Range.

The simulation facilities at the White Sands

The command station battery control console is the nerve center of both live and simulated firing missions. Here, engineers monitor the progress of a missile-to-missile encounter.



Basic block diagram of the HERCULES research and development facility. This system is used interchangeably for both simulations and live firings. Any desired combination of real or simulated missiles and targets can be used with the option to bypass the radars in the simulation loop.

Laboratory are located in the Range Control Building (colloquially known as "C" station) at the south end of WSMR. "C" station is the ground guidance center for HERCULES test firings and has all of the ground control components of a Basic HERCULES System: Missile Tracking Radar, Target Tracking Radar, Acquisition Radar, Guidance Computer, and Battery Control Equipment. This configuration is typical of a tactical system except that the control equipment is housed in a single, permanent building instead of two mobile vans.

As depicted diagrammatically, the ground control equipment is used interchangeably for simulations and real firings with the analog guidance computer serving as the heart of both systems. Flexibility of operation is afforded in that any desired combination of real or simulated missiles and targets may be used. Moreover, as shown, the Missile and Target Tracking Radars can be included in the simulation loop if evaluation of true radar noise and the response of the antenna mounts is required.

To be underscored is the fact that the ground control system (minus the RF link) used in simulation is actually that which is used to track a target and control a missile in a physical engagement. This has the inherent advantage of reducing to an absolute minimum the pseudo components (missile and target) in the simulation loop.

In live firings, the Missile Tracking Radar continuously tracks the missile and feeds the computer with data on missile azimuth, elevation, and range position. The computer resolves this polar coordinate information into dc voltage analogs of the equivalent X, Y, and Z rectangulor coordinates for ease in equation solving. For purposes of simulation, then, the Missile Tracking Radar need only be replaced by equipment which generates three analog voltages representing the position data history of a synthetic missile. The target is simulated in like fashion by generating voltages which effectively replace those normally received from the Target Tracking Radar. To yield meaningful results, these voltages must duplicate the true radar outputs on a "real-time" basis—on the same time schedule that the data is developed in an actual engagement. The target and missile simulator is a two-part dc analog machine of such design.

Target Simulator Equipment

The target simulator equipment is capable of reproducing a wide range of high-performance targets with speeds and accelerations beyond the capabilities of actual aircraft and with flight characteristics of various air-supported vehicles. Dynamic operation can be synthesized throughout typical altitude and range operating regimes. Target maneuvers such as might be expected in attempting to escape can be applied automatically or by joy-stick control. Special networks are also included which duplicate pilot and aircraft response time, thus adding to the realism of the simulation. A typical use of the simulator is the creation of targets for live missile engagements where currently available targets lack the performance capability of various present-day advanced planes and missiles.

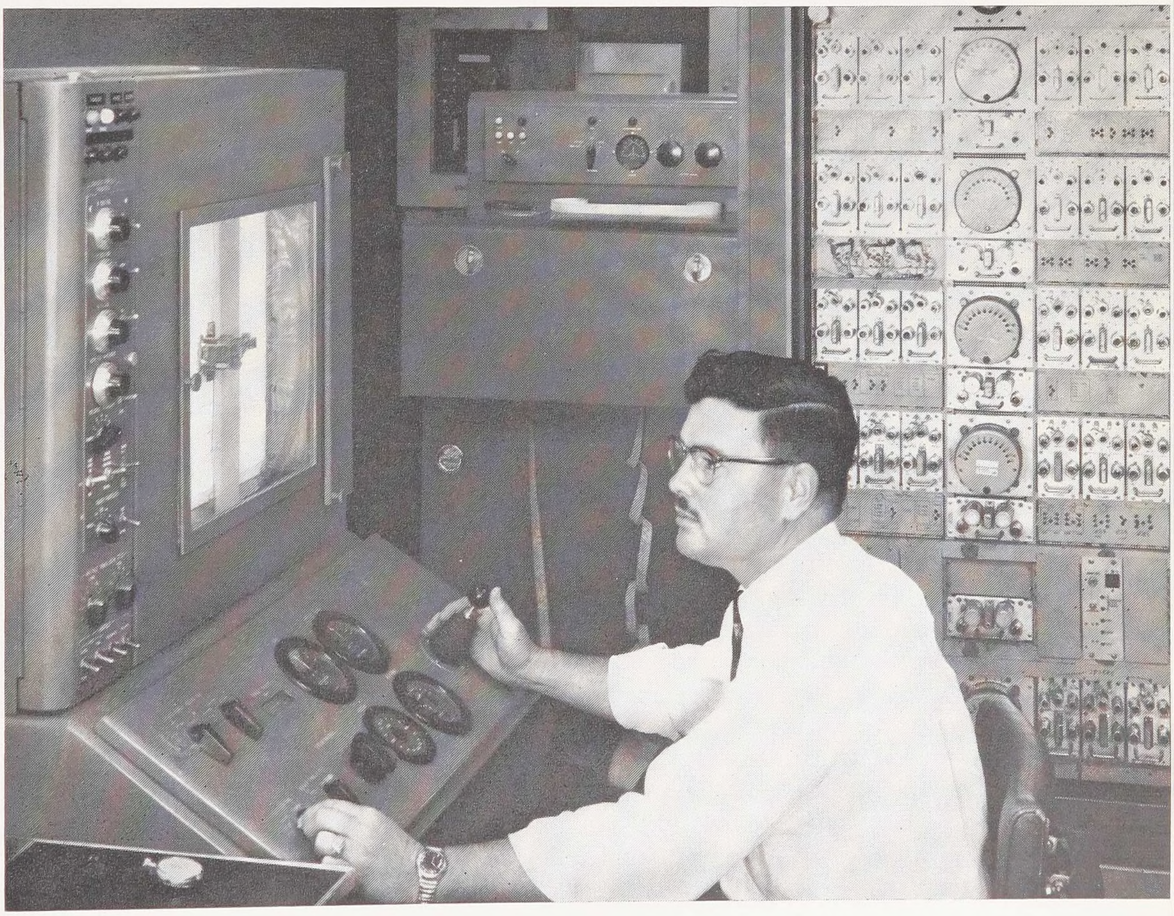
The counterpart missile simulator equipment contains circuits that match the characteristics of a NIKE-HERCULES missile. Factors such as missile weight, propellant temperature, aerodynamic drag, and acceleration response time are all properly taken into account to insure accurate simulation of missile performance throughout the chosen trajectory. Aerodynamic drag, for example, is computed as a function of atmospheric and dynamic pressure together with missile angle-of-attack and is inserted into the over-all computation to reproduce the proper position and velocity history. The simulated missile is steered by the guidance computer just as in an actual firing except that the steering orders are not transmitted via the Missile Tracking Radar, but are fed directly into the simulator. The received steering orders, which are shaped by special networks within the simulator to duplicate the characteristic response of a physical missile, cause the "missile" to climb or turn as required to intercept the target.

In addition to these basic components, special purpose equipment is included to facilitate the simulation task. One such piece of equipment is needed to duplicate the imperfections of tracking reality. That is, the RF elements of the Missile and Target Tracking Radars, and hence the radar perturbations or noise which normally accompanies the tracking of real objects, are lacking in the simulation loop. As a substitute, equivalent noise as produced by a random noise generator is superimposed on the simulated position information. Through appropriate amplification and filtering, tracking noise with the required amplitude and frequency spectrum is available by this method.

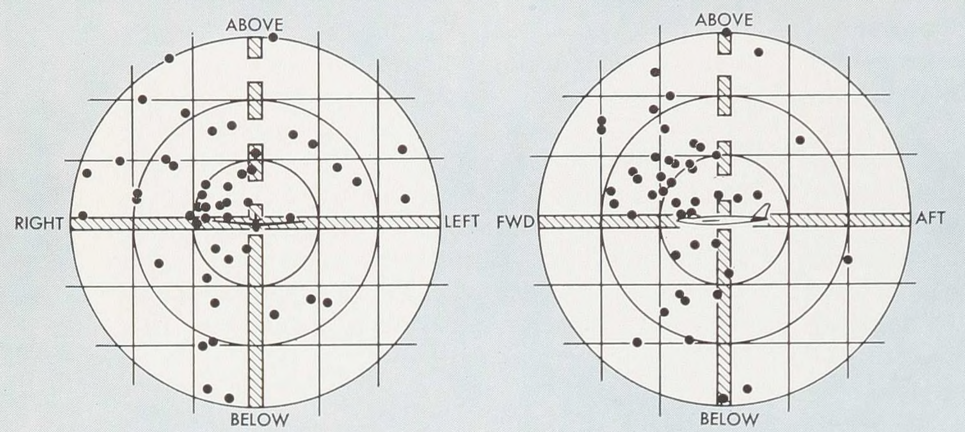
Punched-Tape Programmer

Another special device, a punched-tape programmer, can be used to issue a predetermined set of orders to a missile under test. A tape is prepared with the desired series of commands which are then inserted in place of those generated by the computer. This allows measurement of missile response to prescribed inputs to verify control system performance.

A general purpose analog facility, GENAFAC, is provided as a supplementary source of basic ana-



By joy-stick control evasive maneuvers are imparted to a simulated target to tax system intercept capability. Target course is plotted on the vertical display board.



Simulations were conducted in lieu of large numbers of missile firings to predetermine the intercept accuracy and kill probability of the NIKE-HERCULES system. These charts show typical miss-distance distribution as compiled for pre-set target characteristics and intercept parameters.

log components (e.g. dc amplifiers, integrators, servos) to extend over-all simulation capabilities. The many analog elements included are readily adaptable for this purpose; signal inputs and outputs can be programmed into the simulation loop as desired. Among its many uses, GENAFAC affords a means for generating special missile trajectories, instrumentation scale factoring, and miss-distance measurements in extreme intercept regions. It also serves as a function generator, time reference generator, or other such device for circuit design improvement studies. The most recent application of GENAFAC has been in the generation of targets in the tactical ballistic missile class for advanced system studies.

Augmenting the normal complement of system readouts and displays is an extensive instrumentation system designed to accomplish the data-gathering task. Included are various analog recorders, oscillographs, plotting boards, and photographic recording facilities for the presentation and recording of the many test functions.

The simulation system at "C" station has logged far more "flight" time than any other HERCULES System; it has been in almost continual operation from the inception of the HERCULES testing program. It has been utilized for such purposes as prefiring simulations, system statistical studies, missile and target behavior studies, plus the investigation of various special engineering and design problems. A few examples of these studies will illustrate the vital role simulation has played in the HERCULES R&D program.

The most extensive simulation study—one which would have been impracticable by any other means—was that devoted to statistical evaluation of the intercept accuracy of the NIKE-HERCULES System. This was a study program aimed specifically at determining expected miss distances for the wide gamut of possible intercept situations. To this end, intercept conditions including target range, altitude, speed, maneuverability, and heading were systematically varied in such a way as to tax system counterability to the fullest. In determining missile and target displacement at intercept, each intercept was repeated over an over again until sufficient statistical confidence could be attached to miss-distance distribution. These data were in turn examined with respect to warhead capabilities to affix a kill-probability for each intercept situation.

Miss-distance measurements in a simulated engagement are obtained by special circuits within the guidance computer. These circuits "freeze" the target and missile coordinates at the instant the warhead burst order is generated, subtract one set of coordinates from the other, and record the individual differences via a recording instrument. A three-dimensional measure of miss distance is obtained by computing the radial distance and plotting a frequency distribution curve.

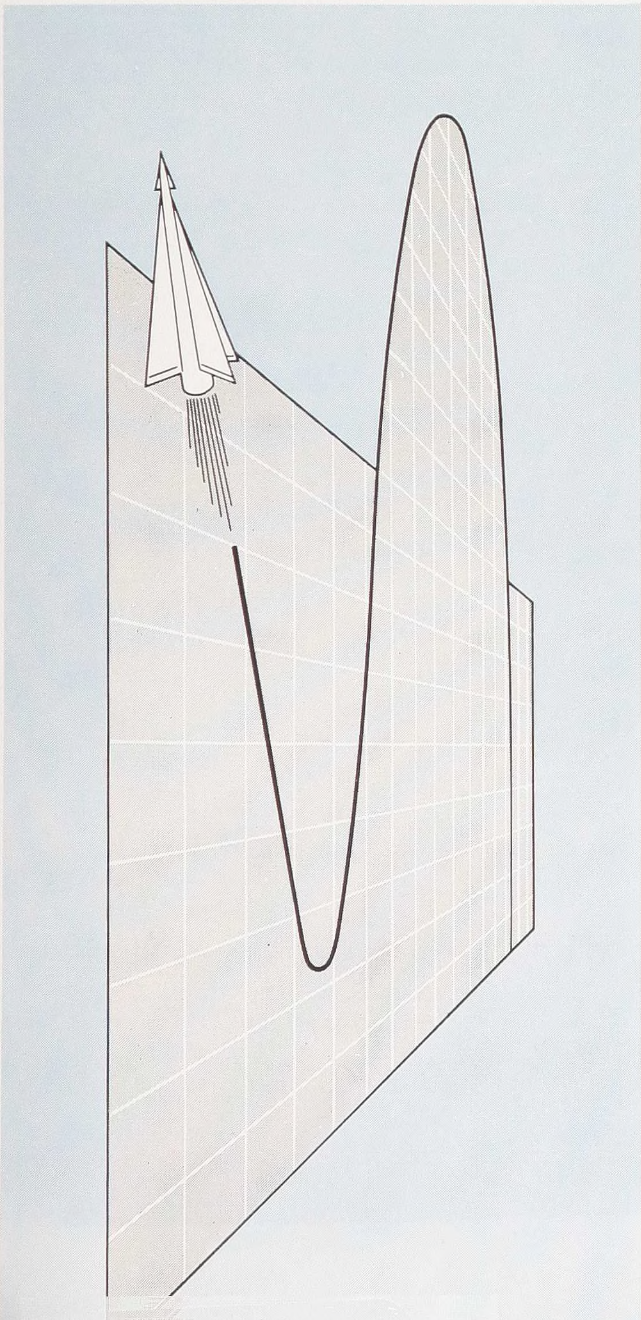
It is noteworthy here that, in addition to range and altitude, the principal factor affecting miss distance magnitude is radar tracking noise. For proper evaluation, then, radar noise matched to the tracking data recorded in previous line missions was superimposed on the simulated position data by means of the noise generator.

These simulations, conducted under conditions as nearly realistic as possible, provided a complete catalog of intercept accuracy. The data categorically define the basic accuracy of the NIKE-

HERCULES System—a determination we hope will never be challenged by data from real (wartime) engagements.

Development of a "roller coaster" trajectory exemplifies how simulation is employed to resolve special test problems. The particular problem in this case was how to flight-test new missile-steering circuit components under both high and low extremes of dynamic pressure. To do this required a unique trajectory—one which would impose a severe initial dive (to get to a very low altitude at high velocity and thereby subject the missile to high dynamic pressure) followed by a high-altitude climb and stall (a condition of virtually no dynamic pressure). Such a trajectory presented a certain amount of risk that during the dive and pull-out maneuver the missile might plunge into the ground or incur a structural failure.

This roller coaster trajectory was developed by simulation for purposes of flight testing new missile components under extremely high and low dynamic pressure environments.



To avert this possibility, a simulation study was undertaken to develop a suitably shaped trajectory. This was done using the simulator to arrive experimentally at the exact steering orders to be sent to the missile over the entire trajectory. By virtue of this approach, two fully successful missile flights were subsequently conducted which subjected the new components to the required environmental conditions.

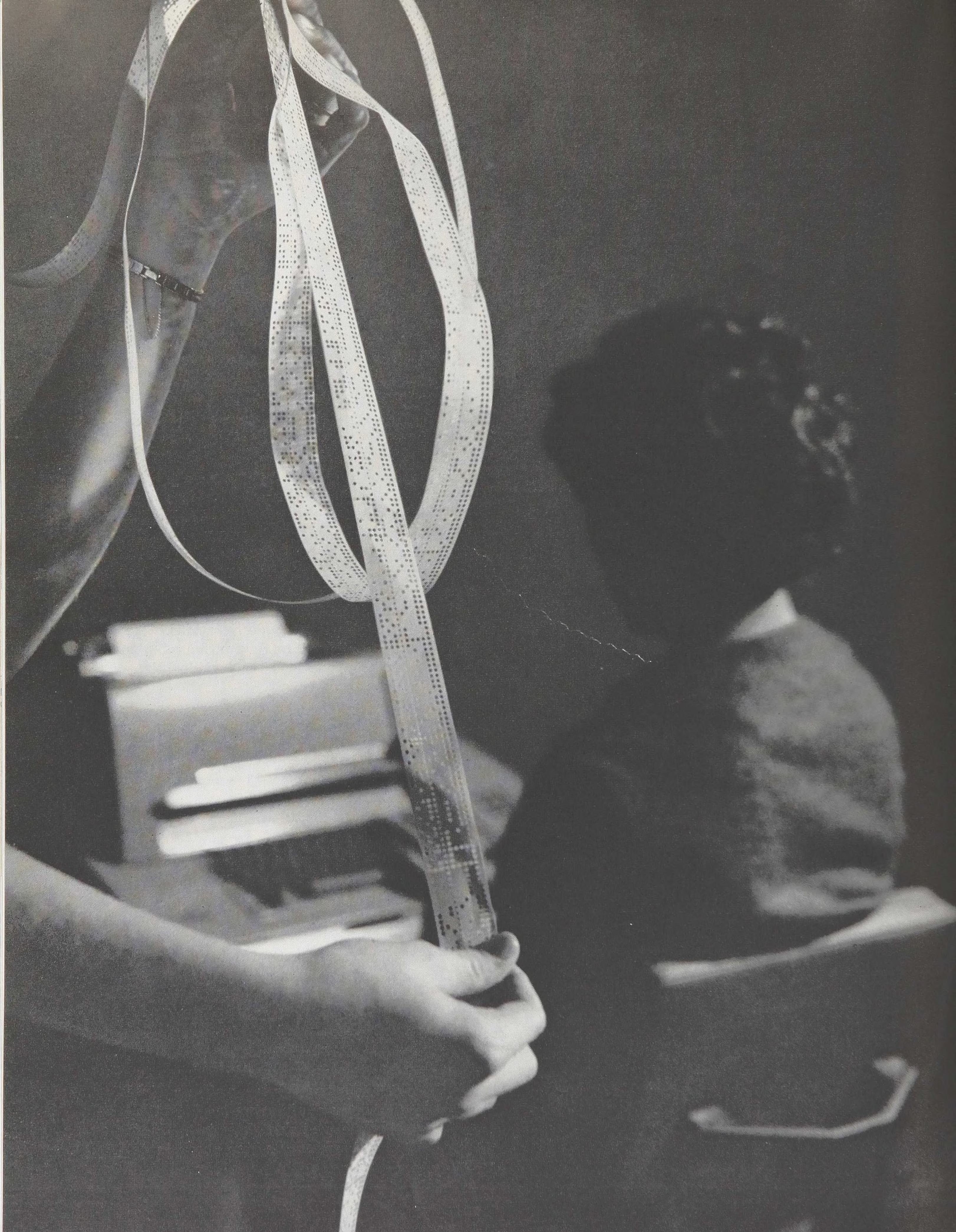
The most recent example of how simulation directly aids in system development is offered by the current NIKE-HERCULES ATBM (Anti-Tactical Ballistic Missile) System evaluation program. Simulated intercepts are presently being carried out to determine system field-of-fire and accuracy against tactical ballistic missiles.

Reproduction of the flight characteristics of ballistic targets is a relatively sophisticated problem considering re-entry factors such as altitude, velocity, approach angle, and weight-to-drag ratio. As mentioned previously, an effective means of synthesizing these targets was devised using the multipurpose analog computer, GENAFAC. In the ATBM program to date, ballistic targets have been simulated which range from low-altitude Mach-1 performance vehicles that exhibit no appreciable "slowdown," to high velocity, long range tactical missiles with high re-entry decelerations. The simulations have allowed an evaluation of the intercept guidance equations, achievable otherwise only in live engagements.

Simulation Role Essential

Simulation's role in the HERCULES R&D program is thus a most essential one. Studies on the scale necessary to fully examine and define system capabilities simply could not be done otherwise. For example, the system-accuracy study described earlier involved a total of some 5,000 simulation runs against targets "attacking" at various altitudes, ranges, and approach angles. Missile firings in like number would be inconceivable, not only from the standpoint of direct missile cost, but because of the prohibitive expenditure of range time and support effort as well. Of further economic benefit, simulation provides a method for optimizing the data yield from each live test, a feature that has paid continuous dividends during the course of the R&D program.

The importance of simulation cannot, however, be measured by economic values alone. Simulation is a proven method of testing the system against new and improved targets in advance of the time such targets become available. This is a benefit that is helping to keep NIKE a step ahead in defensive weapon design.



Just as the many human languages make communication difficult between men, many machine languages have created a problem in data communications. A uniform code has now been developed to work between many kinds of data processing systems.

A New Standard Code For Teletypewriters

J. F. Auwaerter

EARLY THIS YEAR a new and unusual teletypewriter was introduced into Bell System service. Instead of the traditional three rows of keys on the keyboard this machine had four rows, making it look quite like a standard office typewriter. Important as this new look will be to the teletypewriter user, its significance could be dwarfed by an underlying but hidden difference which makes this keyboard change possible. The new sets operate on a new seven element code alphabet based upon the American Standard Code for Information Interchange (ASCII) which was approved June 17, 1963, by the American Standards Association.

The new code alphabet promises not only to simplify communication by providing the typewriter-like keyboard, but also to benefit the information processing industry by providing a uniform machine alphabet for interchanging data. The code looks to the future, not the past; its structure is based on the binary logic of the modern computer. Because it is thus useful in both digital communications and data manipulation, the code will encourage the interworking of these two fields.

At left is shown the eight-level tape and the new four-row teletypewriter. A drawing of the keyboard showing the placement of all characters is depicted on page 399.

The vast bulk of the communication common carrier's telegraph business has been man-to-man communication, either of messages such as telegrams, or of data such as purchase orders and weather reports. Human operators have "delivered" messages to teletypewriter keyboards, and the telegraphic system has delivered page copy to another human at a distant teletypewriter. In between the information is cast in a five bit code, the so-called "Baudot" alphabet. Since five binary digits provide only thirty-two (2^5) permutations, the code's character capacity was doubled by use of a pair of mode shift characters. The alphabet was placed in one case (LETTERS), the numbers and symbols in the other (FIGURES). The limited number of characters in each case made the three row, 32 key, keyboard a natural choice.

But there were difficulties. Typists trained to the four-row standard typewriter keyboard found the three-row teletypewriter keyboard somewhat confusing. Both the quality and quantity of operator output of the mixed alpha-numeric text typical of "data" applications were unsatisfactory on three-row keyboards. On-line, the case shift characters introduced problems of continuing errors where one of two intercommunicating machines failed to receive the proper shift information, and the limited number of special symbols and controls available in the FIGURES case has frequently caused the same code combination to be assigned two or more alternative meanings. This in turn led to difficulties as systems tended to merge. These problems stimulated consideration of a new code both domestically and internationally, but they were not sufficiently serious to warrant a break with the past and all the expenses such a break would entail.

Data Processing

The data processing industry on the other hand was rapidly outgrowing the period where its work was primarily of local concern. In most early applications of data processing, information was converted from documents into machine readable form on the site. There was no problem of connecting machines on a compatible language basis over any significant distance, nor was there much need to interchange data off-line through use of media such as punched tapes, magnetic tapes and punched cards. Under these circumstances equipment manufacturers made independent choices of character sets and code alphabets. Translators took care of boundary conditions.

In recent years a new trend has appeared. Intercommunication between data processors and between processing centers and related equipment is increasing. The Internal Revenue Service will accept income tax forms on magnetic tape—but whose tape and in what code? The Social Security Administration is best served by receiving its data in machine readable form as a by-product of the employer's data processing. Large commercial operations need to transfer data not only within their own operations but also frequently must converse on a machine basis with their suppliers and customers. A standard coded set of characters is the heart of any such interchange of records.

Equipment And Incompatibility

The lack of standards in the data processing industry had another equally restrictive effect on the user of these services. New equipment or replacement equipment was frequently not compatible with his system. Thus he tended to be locked in to his initial system supplier or he would be burdened with the cost of conversion operations when he had to deal with a new supplier whose equipment, although it might be less expensive and more efficient, was incompatible with the original system.

By the end of the 1950s, the data processing industry was very much in need of standardization. Hundreds of different codes were in use. The communication industry, though using essentially only one code, was also beginning to feel the need for better things. It thus became apparent that if a single new code could serve not only the traditional communication market but also the data interchange needs of the information processing market, not only would each class of user benefit in his own area, but also large message communications networks would form an important new facility—a widespread net of compatible and low cost input/output devices for the larger, programmed machines. Further, should such a movement gain international acceptance, the new code alphabet would become a sort of machine Esperanto, reducing the barriers within our multi-lingual human world. It was with this background generally in mind that a group of experts from the data processing and communication industries set to work in 1960 to establish a standard code for information interchange.

Standardization Studies

Working under the guidance of the American Standards Association Sectional Committee X3, this group examined all the codes currently in common use, but none were considered satisfactory. The universally used five-level communications code was obviously unsuited to data manipulation. The most popular code in information processing, the 48 character, 6-bit so-called BCD (binary coded decimal) code, offered the advantage of a simple relationship to the Hollerith punched card code used by tabulating machines, but was not well structured for use in either central processors or other peripheral equipment. The Department of Defense FIELDATA code developed in the mid-

BIT NUMBER

Bits 7 6 → / Bits 5 4 3 2 1 ↓	0 0	0 1	1 0	1 1
0 0 0 0 0	NULL	SPACE	@	UNASSIGNED
0 0 0 0 1	SOM	!	A	
0 0 0 1 0	EOA	"	B	
0 0 0 1 1	EOM	#	C	
0 0 1 0 0	EOT	$	D	
0 0 1 0 1	WRU	%	E	
0 0 1 1 0	RU	&	F	
0 0 1 1 1	BELL	'	G	
0 1 0 0 0	FE_0	(	H	
0 1 0 0 1	HT/SK	)	I	
0 1 0 1 0	LF	*	J	
0 1 0 1 1	V_{TAB}	+	K	
0 1 1 0 0	FF	,	L	
0 1 1 0 1	CR	–	M	
0 1 1 1 0	SO	.	N	
0 1 1 1 1	SI	/	O	
1 0 0 0 0	DC_0	0	P	
1 0 0 0 1	DC_1	1	Q	
1 0 0 1 0	DC_2	2	R	
1 0 0 1 1	DC_3	3	S	
1 0 1 0 0	DC_4	4	T	
1 0 1 0 1	ERR	5	U	
1 0 1 1 0	SYNC	6	V	
1 0 1 1 1	LEM	7	W	
1 1 0 0 0	S_0	8	X	
1 1 0 0 1	S_1	9	Y	
1 1 0 1 0	S_2	:	Z	
1 1 0 1 1	S_3	;	[	
1 1 1 0 0	S_4	<	\	ACK
1 1 1 0 1	S_5	=	]	
1 1 1 1 0	S_6	>	↑	ESC
1 1 1 1 1	S_7	?	←	DEL

A 4-BIT SUBSET (0 1 0 1 0 through 1 1 0 0 1, columns 0 1: * through 9)

GRAPHICS SYMBOLS, DIGITS, AND ALPHABET (columns 0 1 and 1 0)

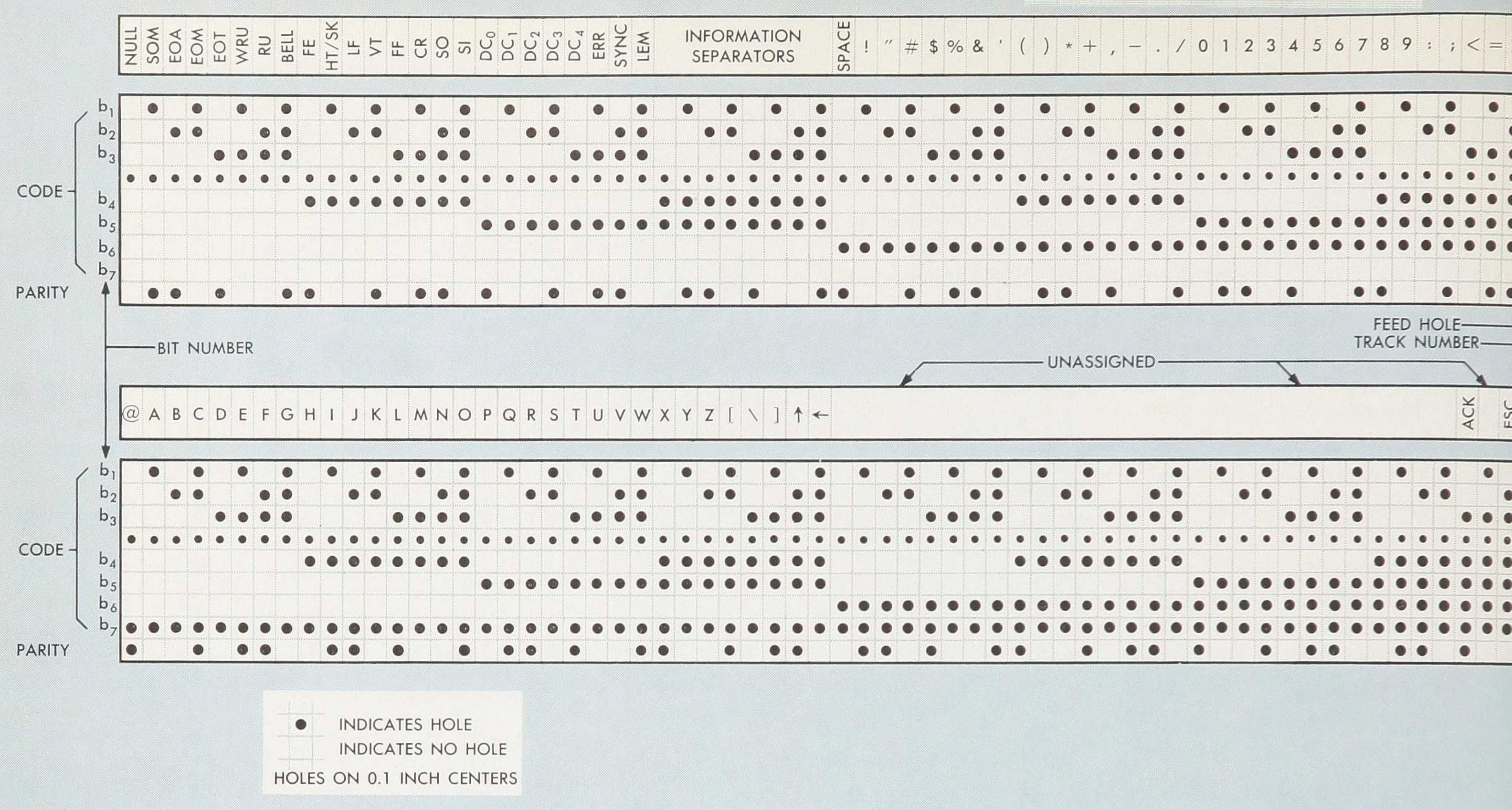
The new ASCII code shown in binary order. The extreme left of the drawing shows the five lower order bits. At top are the two higher order bits. The symbol (") appears on the same key as 2 by a "shift" of bit 5.

1950s, represented a major improvement over prior pactices, but on analysis it too exhibited deficiencies in natural collating order and caused problems when used with foreign alphabets containing more than twenty-six characters.

Consequently the group turned its attention to the development of an appropriate code proposal. After several months of trying without success to adopt a sixty-four character code having a six-bit structure, the group settled upon a seven-bit set of 128 character capacity. Agreed upon late in 1961, this set was subsequently revised in the spring of 1962 to meet some recent European requirements. It is this seven bit code which was approved as an American Standard this summer and has successfully completed the first of two formal steps toward international standardization under the auspices of the International Standards Organization.

The New Code

As presently approved the ASCII code is not a complete standard. Its representation is media such as punched tape, magnetic tape, and punched cards is currently being defined by the same group that developed the code. The drawing on this page shows the code in (binary) arithmetic order; the value of the permutation increases



A rendering of the 8-level teletypewriter tape. Present Bell System usage is to make the eighth track always marking. Optional vertical parity in the eighth track will accord with this drawing.

from 0000000 (binary zero) to 1111111 (binary 127). For convenience, the permutations are divided into four columns, with the five low order binary digits (bits) on the left side and the two high order bits at the top. This representation clearly shows the binary relationships of the characters within the code.

The two center columns of the code contain printing graphics. The first character is SPACE, the "word separator," which can be thought of as an "invisible graphic." Following SPACE in ascending binary order is a set of special symbols, the ten decimal digits, a group of six more special symbols, and finally the alphabet. In total, sixty-four printing graphics are provided so that all the sixty-four permutations of a 6-bit binary computer could, for instance, be interchanged without fear of the inadvertent generation of significant control characters. These graphics were placed in the center two columns so as not to conflict with the peculiar requirements which transmission systems place on the "NULL," or "all 0's," combination, and the equal restrictions placed on the "all 1's" combination (DELETE) by its use as a rub-out in punched tape.

After the position of the graphics was picked, approximately one-half the remaining permutations were assigned to control functions; the remainder have not as yet been assigned. The use of this unassigned area is now being debated between those who would like to use it for additional graphics, particularly a lower case alphabet, and those who see a need for additional control characters.

Logical Design

Every effort was made to design the set logically. To the extent possible, like classes of characters were placed in contiguous binary areas so they could be recognized by examination of a minimum number of bits or through simple arithmetical tests. Punctuation marks (or special symbols) were placed at the beginning (low binary end) of the 64 character graphic subset since punctuation needs usually come before digits and alphabetical characters in listing information, ROY, C. comes before ROYAL, C. in the telephone directory, a simple example of comma (,) preceding O in order. The alphabet was placed in one-half of the six bit graphic subset to simplify its identification. This logical structure facilitates data sorting and grouping. The location of the alphabet within its five bit (32 character) frame was dictated primarily by the desire to accommodate more than twenty-six alphabetical characters, a necessity in certain European languages. The chosen placement permits the addition of up to 5 alphabetic letters following the character Z.

To facilitate this substitution the five characters placed in those positions are of secondary importance. International acceptability was one of the prime targets in the code's design. To faciliate machine arithmetic, the decimal digits were coded so that their four low-order bits represent the binary equivalent of the decimal value. Thus the bits b_4 through b_1 of the digit "zero" are 0000 and of the digit "nine," 1001.

Placing Special Symbols

Great care was taken in the placement of the special symbols. The most natural human collating order was reduced to a binary order, permitting low-cost collating by arithmetic instead of "table look-up" techniques. Not only were the common special symbols (! through /) assigned a lower binary value than the digits to provide an ordering or collating sequence (Symbols, Digits, Alphabetics) compatible with normal human usage, but also care was taken that no symbols important today in collating schemes should lie between the numerical and alphabetical fields. In this way the alternative collating sequence, Symbols, Alphabetics, Digits, which is also used quite widely today, can be obtained within a processor through a simple "Exclusive OR" device in logic.

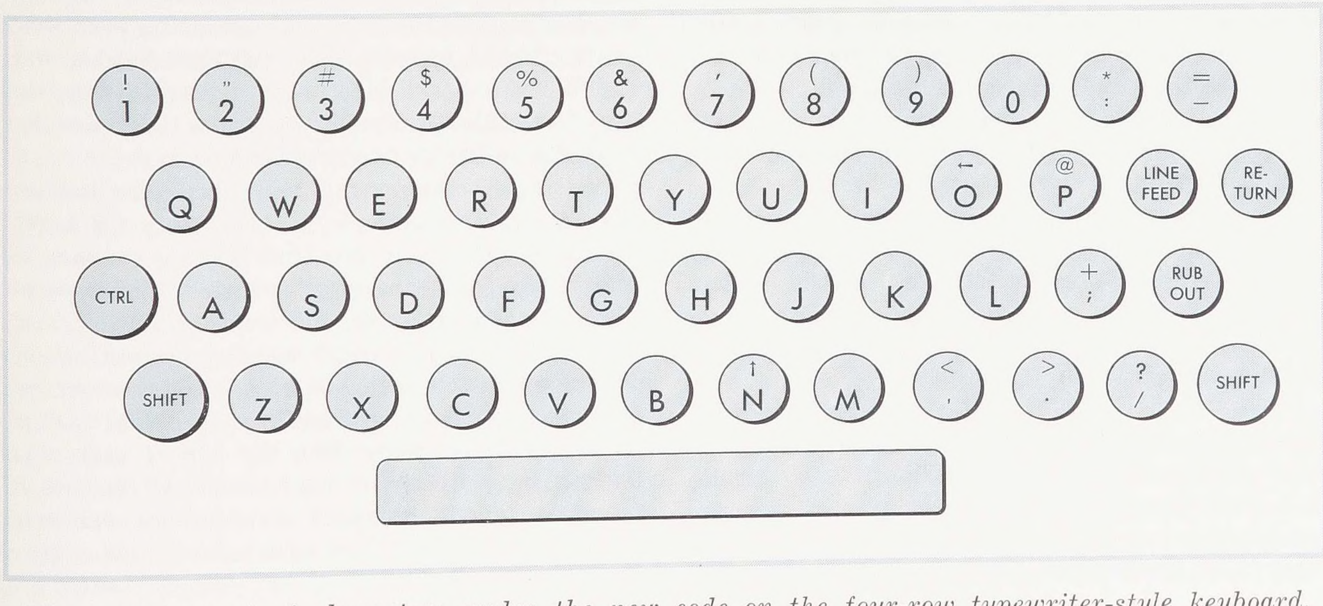
The symbols, colon and semicolon, considered less important than many of the other symbols, were placed so they could be replaced by "10" and "11" in Sterling monetary areas where use of the single digits 10 and 11 for English pence is common. The symbols in the upper half of the second column were assigned to facilitate pairing of symbols and numerals on teletypewriter keys. Note that the symbol (") can be generated by the same key as the numeral 2, and (%) by the same key as 5—quite like the ordinary typewriter—by a simple change, or "shift," in the state of bit b_5.

Contracting The Set

The symbols also were placed so as to simplify the seven-bit set's relation to a preferred European six-bit computer set. In fact the whole set can be contracted in a regularized manner. If bit $_6$ or b_7 is ignored a large variety of six-bit sets can be obtained for possible internal use in equipment. One such set might be the pure graphic subset contained in the center two columns; another would be similar but with the substitution of LINE FEED and CARRIAGE RETURN for the symbols asterisk (*) and hyphen (-). By slightly more complex contractions, involving the manipulation of bit b_5, still other six bit sets can be obtained. The flexibility afforded designers of six-bit processors is great, and it is not at the expense of a uniform data interchange convention.

Further, by striking out bits b_5, b_6 and b_7, a very neat four-bit subset, indicated in the drawing on page 397 and containing not only the decimal digits but also a very useful set of punctuation marks, is obtained. This latter set should prove handy for cash registers and other basically numeric-only devices. Similar considerations for expansion to an eight-bit set contributed to the design of the code.

A fundamental means of departure from the basic set is provided by the ESCAPE. While the use of this character has not yet been officially defined,



The arrangement of characters under the new code on the four-row typewriter-style keyboard.

it is conceived of as indicating that the data which follows is not in the standard code. This feature will be very useful since no finite set of characters can ever anticipate the variety of problems to be faced in the future. The definition and identification of alternate domains into which the coded system "escapes" is the subject of current standardization activity.

The column of controls can be viewed as providing essentially four equal sized groups of characters. The first eight, NULL through BELL, are useful to the communicator. The second group of eight consists of the "format effectors" which, like LINE FEED and TABULATE, organize printed data on a page. The third group, in addition to providing controls for operating auxiliary apparatus, contains signals to (1) indicate an error in data (ERR), (2) provide a synchronizing pattern for use by synchronous communication terminals (SYNC) and (3) indicate the end of useable information (LEM-"Logical End of Medium" as in "end-of-card"). These second and third groups are equally useful to the communicator and the data processor. The final group of eight controls provides the data processor with data delimiters useful in structuring data into a hierarchical relationship such as ITEM, RECORD, FILE.

Conflicting Requirements

It might be thought from this simple recitation of the features of the code that its generation was straightforward. This was not the case. There were typewriter requirements and computer requirements, card equipment requirements and magnetic tape equipment requirements, programming and hardware requirements, transmission requirements and collating requirements. In addition there were military, domestic, and international requirements. These needs conflicted and the only solution was compromise. The code in the drawing on page 397 appears to be an almost ideal compromise between the conflicting requirements. One "requirement" it does not meet; it breaks completely with the past. It is quite incompatible with both the CCITT No. 2 alphabet and its derivatives, widely used in communications, and the punched card code used extensively in tabulating machinery. It looks to the future.

In 1962 the Bell System Teletypewriter Exchange Service (TWX) was converted from manual to dial operation. (RECORD, *July-August* 1962) A new transmission arrangement which accompanied this conversion made possible the introduction of a 100 word per minute service to compliment the existing 60 words per minute operation.

Since the majority of the teletypewriters in service were Model 15 units incapable of speeds in excess of 75 wpm, any move to the higher speed presaged the replacement of these units. But if they were to be replaced, why not escape from the limitations of the 5-level code and its 3-row keyboard? Now, if ever, seemed the time to take such a step.

Decision Made

So the decision was made. Thereafter, it remained only to pick the code and alphabet on which the new machines would operate. It was in this environment that the Bell System joined the code standardization effort late in 1960 and adopted the conclusions of the standardization work as rapidly as formulated.

Owing to the needs of its business, the Bell System has been forced to choose a punched tape representation of the code before a standard representation could be worked out. This tape representation is shown in the drawing on page 398. It is based on the simple idea that bit 1 of the code should lie in track 1 of the punched tape, and so on, through track 7. The 8th track is currently unused, being left constantly in the "marking" or "1's" condition. It will undoubtedly find future use as a parity bit.

This simple relationship between bit number and track number has been carried one step further. Since track 1 of a punched tape is traditionally transmitted first in time, bit 1 of the code becomes impulse No. 1 of the transmitted teletypewriter signal. This compatible numbering system will be of the greatest value in training of personnel, in analysis of errors, and in simplifying maintenance and operating practices. For keyboard use, too, the code has worked out well. The keyboard, as shown in the drawing on page 399, differs only slightly from the one widely used in office typewriters today.

The code is beginning to find accelerated acceptance in the industry. Some users generally the smaller one, may feel that there is no need to change their existing practices since their operations are primarily in one location. In such instances no change should be expected until some other need, such as lower cost, expansion or replacement of their data facilities provides the opportunity for change. But the larger users are finding its promise of uniformity attractive. It is not too much to expect that the new code will be in extensive use throughout the world within the next decade.

Mrs. J. L. Bertels
R. I. Nolan

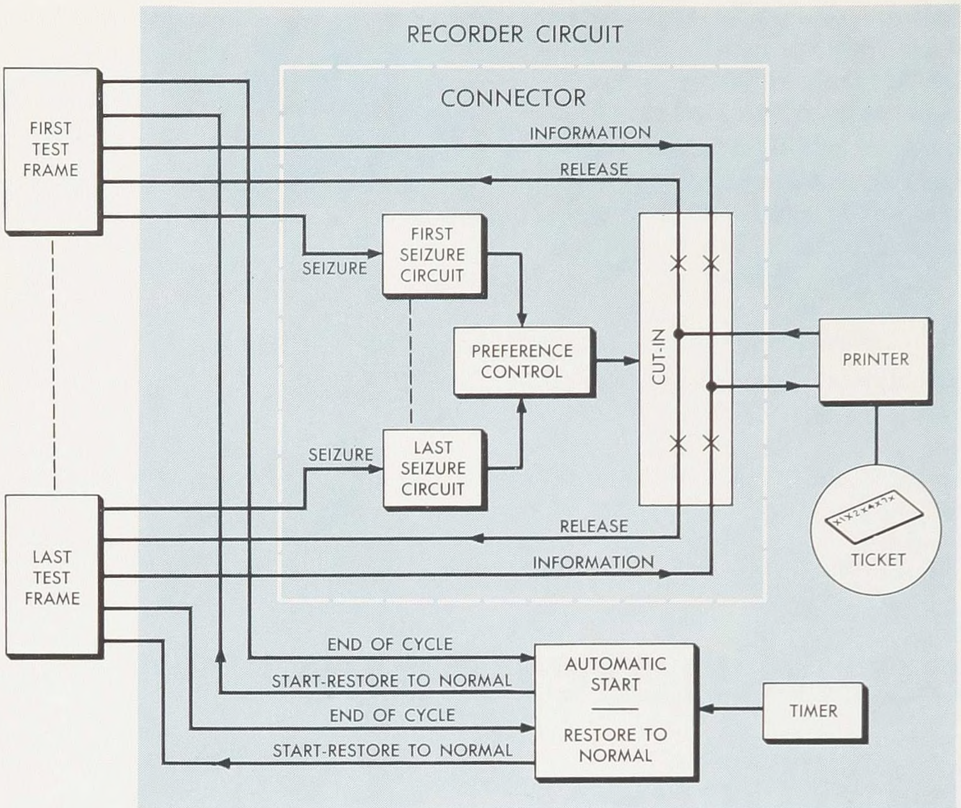
Automation of trouble detection functions and application of new maintenance techniques point up an improved maintenance program in panel offices

Improving Maintenance In Panel Offices

Although panel switching offices represent only a small percentage of the total installations in the Bell System, their strategic location in large metropolitan areas having a high calling rate makes them a vital and valuable part of the system. These offices have been in use for a long time—average age is 25 years—and it is therefore necessary to modernize maintenance facilities to insure the continued fulfillment of high service objectives.

Panel switching equipment is composed primarily of power-driven apparatus controlled by signals from a sender circuit that converts the customer dial pulses into useful switching information. The system received its name from the large flat panels of terminals located on the frames of the selector switches. Brushes carried by vertical sliding rods move over these terminals to make a particular selection. The selector switch is actuated through the operation of magnetically-controlled clutches that engage one of two or three continuously rotating, motor-driven cork rods with a rack connected to the bottom of the selector rod. When a clutch is engaged, the action of a cork roller against the rack moves the rod up or down at a slow or fast rate as required. Electrical connection is made from the panel terminals to the selector circuit by wires connected through the rod from the brushes to sliding contacts riding a commutator strip located at the top of the selector frame. Four or five different selector switches are involved in the connection of a call between two panel office customers.

A sequence switch—a power-driven rotary switching device—also is used in the panel system. A vertically-rotating shaft is engaged by a magnetically-operated clutch, that in turn drives the horizontal shaft of the switch that has up to 26 cams. Four brushes contact each cam and make or break electrical connections in a definite sequence



This block diagram of the recorder shows its components and control paths between these components and the test frames.

of operations depending upon the notches cut in the cams. The sequence switch performs the functions of a large number of relays, and is used in the selector circuit to control the sequence of operations in the system, including the operation of the selector switches.

This equipment has been reviewed briefly to illustrate how the efficient operation of a panel office depends upon the interaction of mechanical parts, as well as the functioning of electrical circuit elements, to complete its switching functions.

With the routine automatic testing equipment presently available in panel offices, a malfunctioning selector circuit often escapes detection or releases before a trouble can be traced. Circuit irregularities due to mechanical maladjustments sometimes persist because the only means of detection is by visual observation.

More Effective Maintenance

The need for a more effective maintenance program has been met by the development of a number of new features which have been made available. Three of the features that will be described operate in conjunction with the automatic testing equipment already furnished and provide a means of pinpointing a trouble condition. A fourth feature functions independently of the test frame and performs automatically one of the routine trouble detecting operations which formerly consumed the time of the maintenance personnel.

At present, some routines—such as testing district, office, incoming, and final selector circuits by automatic test circuits—require a maintenance man to retire any test circuit alarm condition due to a busy or trouble condition in the selector circuit under test. If the maintenance man is not immediately available to retire the alarm, the test circuit can not proceed to test the next selector circuit. Therefore, the test circuit is able to test only a fraction of those circuits it should test within an allotted time interval.

The selector test circuit can also be set so it will pass by a busy selector circuit. If this feature is used, the maintenance man does not know how many or which selector circuits were not tested because they were busy. Thus, some selector circuits might not be tested for long periods.

To relieve the maintenance man of the tedious task of standing by to record alarm conditions and release the test circuit, a recorder circuit capable of performing these functions has been developed. The recorder circuit can control simultaneously the various automatic selector test circuits: starting them, printing their alarm condition on a ticket, releasing them to advance to the next selector circuit, detecting when they have completed the test cycles, and restoring them to normal. A maximum of ten automatic test circuits can be controlled by one recorder circuit. This recorder circuit is shown in the block diagram on page 402. Its main components are a connector, a printer, an automatic start and restore to normal circuit, and a timer.

To use the recorder circuit, the maintenance man programs the automatic selector test circuits to perform the desired tests and then operates associated keys at the recorder circuit to give the respective test circuits access to the recorder circuit. He may then start the test circuits manually or he may start them at some later more convenient time such as after the evening busy hour. In manual operation, the attendant simply operates the start key at each automatic test frame. For delayed start, he sets a timer of the automatic start circuit of the recorder circuit. When the timer functions, all the programmed automatic test circuits are started.

Grounding A Lead

In either case, when a test circuit encounters a busy or trouble condition on a selector, it "bids" for the recorder by grounding a lead to the connector. If more than one test circuit simultaneously bids for the recorder only the connector relays for the preferred test circuit operate to connect through information leads to the printer. On recorder seizure, the ticketer motor is started and the test circuit number, the type of record (busy or trouble), the identity of the circuit under test, and the type of test or progress of the test is printed on the ticket in sequence. After the last bit of information is printed, the ticket is cut and the recorder circuit causes the automatic test circuit to pass busy or advance, whichever is required.

As each automatic test circuit reaches the end of the cycle, it signals the recorder circuit. If the test circuit has been started automatically by the recorder circuit, the recorder circuit causes that particular test circuit to return to normal.

Manual Operation

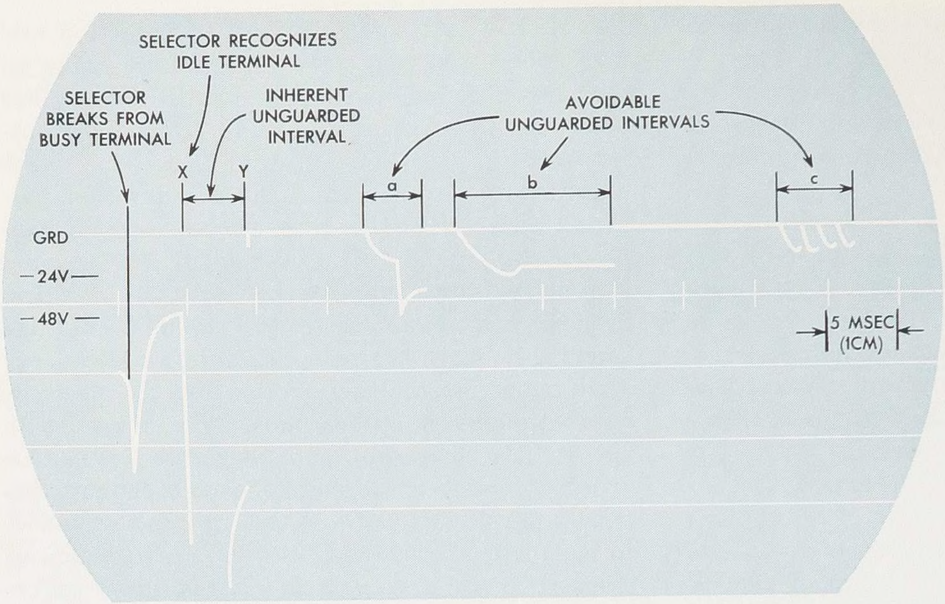
If the maintenance man has manually started the test circuit, then he must manually restore it to normal. The recorder circuit will, in the meantime, prevent that manually started test circuit from reseizing the recorder.

At his convenience, the maintenance man examines the tickets and then manually tests those selector circuits that had been busy or in trouble during the automatic routine test.

A trouble condition typical of those that required trial and error methods of detection and correction is the unguarded interval occurring on the sleeve lead of a selected trunk after it has been seized by a selector circuit. A selector hunting over a panel of terminals first tests the sleeve lead of a trunk for an idle condition and then performs a sequence of operations that results in connection of ground to the sleeve lead. This ground is a busy indication to other selectors hunting over the same panel of sleeve terminals. The time interval between the recognition of an idle sleeve and connection of busy ground to that sleeve is approximately 5 milliseconds. It is inherent in the circuit operation and therefore cannot be avoided. However, the sleeve may subsequently become ungrounded as the selector circuit advances to complete its functions if the moving parts of the switch are not in proper adjustment. Referring to the earlier discussion of the selector switch, this may involve the adjustment of the sleeve brush that contacts the panel terminals, the commutator brush, the cork roll, the magnetic clutch that engages for the updrive, or the pawl that engages the rack to hold it in position. The physical relationship of these parts with respect to each other is important. The cumulative effect of maladjustments causes the sleeve brush to override the selected terminal resulting in a long unguarded interval or possibly a false seizure of the next terminal.

Unguarded Interval Test Set

The unguarded interval problem presented a two-fold challenge: first, to provide a means of identifying the selector circuits with excessive unguarded intervals, then to provide a means of locating the source of trouble. The solution to the first phase of the problem was the development of an unguarded interval test set that can be patched to the routine selector test frame by means of cords and jacks. On each cycle of the test frame, the test set monitors the sleeve lead of the selector under test and times any open interval that occurs from the time busy ground is applied until the selector completes its functions. This device may be preset to provide one of six different timing intervals by using a flexible terminal strapping arrangement and a three-position key. When the "open" on the sleeve lead exceeds the time interval of the test set, the frame "blocks" and operates an alarm. By adjusting the unguarded interval test set to its maximum time interval of 40 milliseconds, the selector circuits that are the worst offenders are detected first. The testing procedure is then repeated with the test set adjusted



Oscilloscope trace shows unguarded intervals on the sleeve lead of selector circuit and method of analyzing trouble conditions.

UNGUARDED INTERVAL	CIRCUIT ACTION	PROBABLE CAUSE
a	FALSE OPERATION OF L RELAY	L RELAY AND UPDRIVE MAGNET INTERACTION, L RELAY TENSION, IMPROPER ADJUSTMENT OF CLUTCH MAGNET
b	SLEEVE BRUSH OVERRIDES SELECTED TERMINAL	SAME AS INTERVAL a OR IMPROPER ADJUSTMENT OF COMMUTATOR AND SLEEVE BRUSHES, UNEVEN CORK ROLL
c	INTERMITTENT OPEN	DIRTY OR PITTED CONTACTS IN GROUND PATH

for shorter and shorter intervals until all faulty selector circuits in an office have been detected.

The solution to the second phase of the unguarded interval problem uses a tool that is now recognized as an important aid to maintenance in telephone offices—the oscilloscope. When a faulty selector circuit has been detected with the unguarded interval test set, the circuit can be analyzed with the use of an oscilloscope to determine the source of trouble.

A typical oscilloscope trace of the condition on a sleeve lead of a selector circuit is shown on this page. The trace has been exaggerated to illustrate salient points of this discussion. Since the open input trace (base line) of the oscilloscope coincides with the ground input trace, the probe of the oscilloscope that is connected to the sleeve terminal is biased to —24 volts to provide a distinctive trace when an open occurs. The condition on the sleeve head, represented schematically on page 405, is observed from the instant that the leading edge of the sleeve brush touches the selected terminal to 50 milliseconds following.

At the start of the trace, the lower edge of the sleeve brush breaks from the grounded terminal below. This induces a negative surge in the winding of the selector relay (relay L) connected to the sleeve. The surge gradually decays to —48 volts. A second negative surge is induced in this winding as the commutator brush breaks from the segment that connected ground to the secondary winding of the L relay. The decay of this surge is cut off by the closure of ground to the sleeve lead as the L relay releases. The sleeve should remain grounded for the remainder of the trace.

Although interval "b" of the trace is the critical open condition that would cause the test frame to block, other portions of the trace are valuable in the analysis. The trace pattern preceding point "Y" may indicate that the commutator and sleeve brushes are not in proper adjustment or that the L relay release time is excessive. This information is necessary if the inherent unguarded interval "X" to "Y" of the trace is to be held to a minimum. This interval that is unavoidable as earlier described can be controlled. The probable causes of the avoidable unguarded intervals "a", "b" and "c" are indicated in the table above. The correction of each of these troubles has a cumulative effect on the elimination of interval "b". With information now made available sleeve traces of faulty selector circuits may be analyzed and corrected so that unguarded interval troubles in an office may be reduced to a minimum.

Certain trouble conditions may exist that tend to slow up the performance of panel switching equipment but are tolerable to the extent that they do not cause circuit failures or trouble alarms. With reference to the earlier description of panel equipment, conditions such as bent vertical drive shafts, bent driving disc spiders (used in transferring vertical motion to horizontal motion in selector sequence switches), slow sequence switches and updrive mechanisms and sluggish relays, all fall into this category.

Selector Timing Test Set

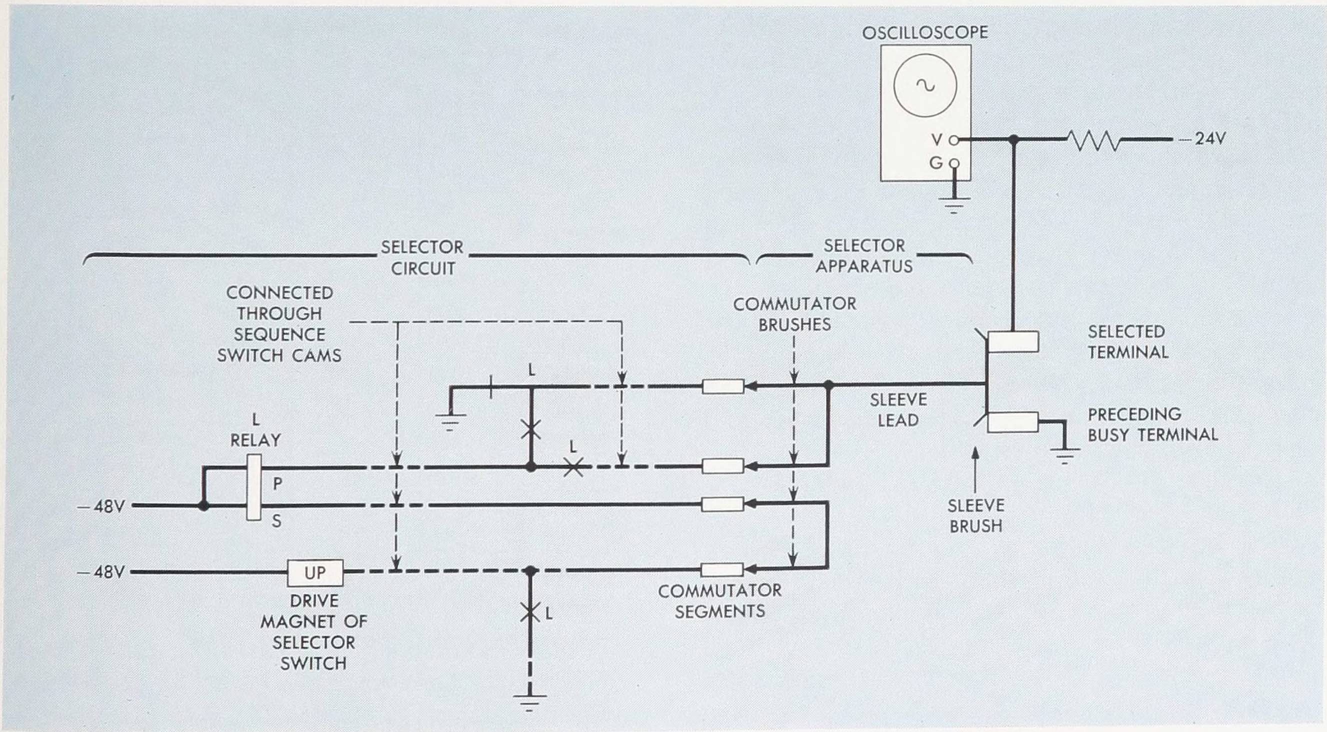
A means of detecting these trouble conditions is now provided by the selector timing test set. The test set is portable and can be patched to any of the district, office, incoming or final selector test frames. The timing test is applied automatically during the routine test cycle on each selector connected to the test frame. By this means, the selector test frame that checks the ability of the selector circuit to complete certain functions is now arranged to check that these functions are completed within a specified time interval. If the performance time exceeds a nominal three second interval, the test frame "blocks" and operates an alarm. The sequence of electromechanical operations used in the performance of these functions is then examined in detail to determine the source of trouble.

Electronic Control

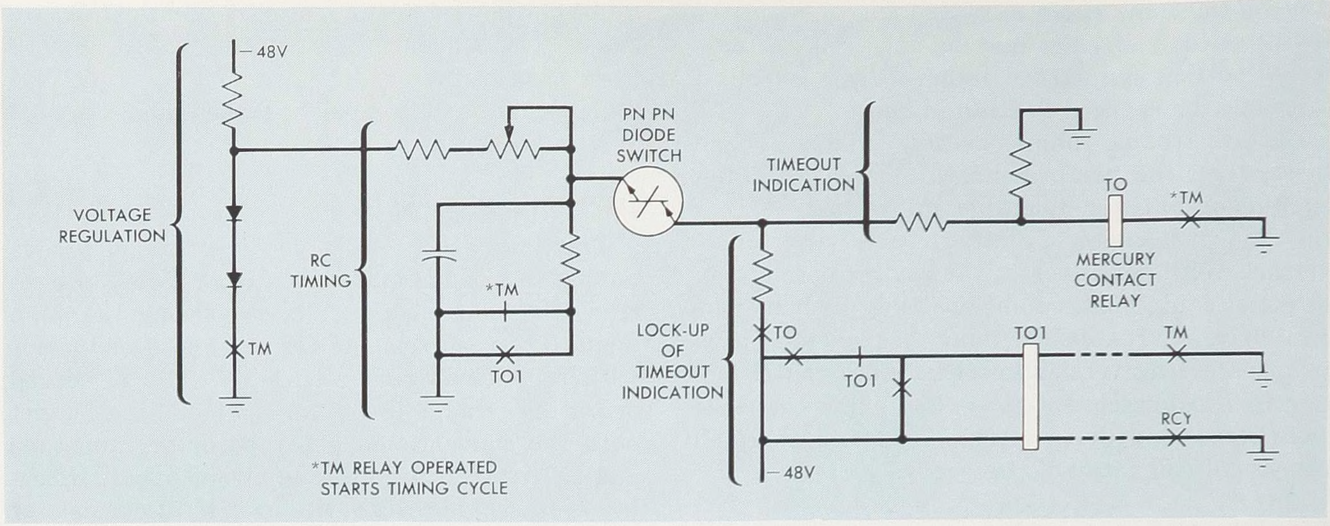
The timing test set designed for this purpose is unique in a panel office since it contains an electronically controlled switching element, the pnpn diode. The requirements for a three second timer with repetitive firing accuracy of ±0.25 second operating from a 48-volt supply could not be met with the conventional gas tube or vacuum tube and RC timing circuit familiar in panel switching systems. The diode timing circuit consists of a pnpn diode, an RC timing circuit, a voltage regulator, and a mercury contact relay. A schematic of the timing circuit is shown on page 406 (top). A control circuit that supplies start and end timing signals, a recycling signal, a lock-out for undesired signals, and a lock-in for alarms is also a part of the portable test unit.

Detecting And Release Circuit

Some offices are troubled by many incoming selectors that remain "off-normal." Origins for some of the causes are uncertain. A time-consuming assignment for a maintenance man is patrol-



Application of oscilloscope for checking unguarded intervals on sleeve lead of selector circuit.



PNPN diode timer used in selector timing test set.

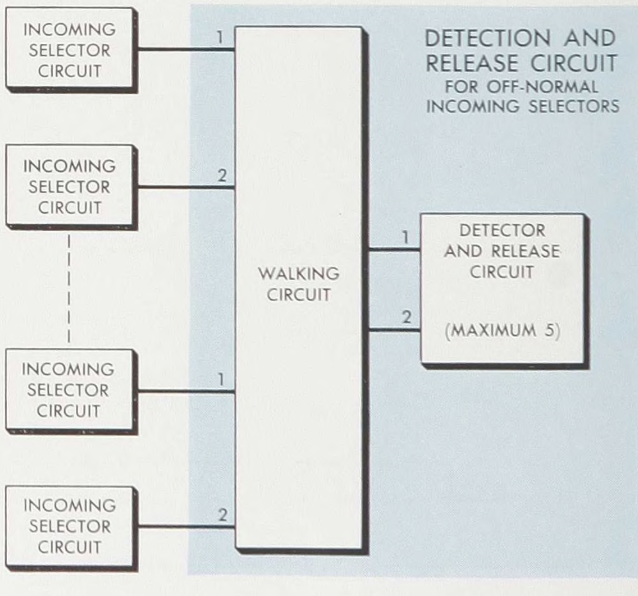
ling the incoming selector frames to determine if any of the full-automatic selectors remain off-normal and releasing them manually. If this is not done the selectors will be released only by customer calls that could not then be completed. In some instances the off-normal selector might hold the called party "out of service."

A detection and release circuit for off-normal incoming selectors has been developed to do this routine work. As shown in the bottom diagram on page 406, it consists of two main parts; the detector and release circuit, and the walking circuit to connect and disconnect incoming selectors to the detector. During operation, two selectors are simultaneously connected to the detector. If a sequence switch of the selector is off-normal in certain positions a ground will appear on a sensing lead of the detector and timing is started. When the ground does not disappear at the completion of timing, the detector and release circuit causes the selector to advance and restore to normal. At the discretion of the maintenance man, a key may be operated that will prevent the restoration of an off-normal selector. Instead, an alarm sounds and a lamp is lighted.

Incoming Selectors

Each detector can serve a maximum of 200 incoming selectors and a walking circuit can serve up to five detector circuits. The walking circuit takes approximately one minute to patrol 1000 incoming selectors if no off-normal conditions are encountered. With a repeat key operated, the cycle will continue to repeat. The speed of each cycle assures that an off-normal incoming selector will be back in service in a matter of minutes.

Although panel offices are no longer provided for new installations, the existing offices will probably be in service for a number of years. With the improvements in maintenance facilities here described, a continued high level of performance may be realized from panel switching equipment.



A simplified diagram of the detection and release circuit shows how each detector simultaneously checks two selectors. Up to ten selectors can be tested at one time.

MAGNETIC FIELD STABILIZED WITH SUPERCONDUCTING TUBE

A stable magnetic field that can also be readily changed has been sought for a long time. Messrs. C. F. Hempstead, Y. B. Kim and R. D. Dunlap, of Bell Telephone Laboratories, recently developed a method of obtaining such fields with the use of a thin-walled superconducting tube.

The tube is made of 15-mil thick niobium-zirconium alloy. It has an inner diameter of 1/2 in. A strong magnetic field is applied along its axis. This induces a current to flow in the tube. Once the current is started, it will persist as long as the tube is kept cooled to -269° C. The current creates a magnetic shield around the portion of the field that is inside the tube. Even if the applied field intensity changes slightly (within a few hundred gauss) the field inside the tube will remain constant.

Previously, stable magnetic fields could be obtained only with difficulty, because if the power supply to the electromagnet coil varied, the magnetic field would vary.

This new method permits easy and accurate control of the field inside the tube. To obtain a higher intensity, the applied field is increased until the internal field reaches the desired strength; then the applied field is reduced slightly to the middle of the stable range. If a lower field is desired, the process is reversed. The superconducting tube stabilizes the field at the new intensity.

The method has been used to investigate the nature of the transition state in superconductors. It is expected to find use in many experiments that require stable and controllable magnetic fields, and in experiments that can be performed at temperatures near absolute zero.

LIGHT ROTATED IN RARE EARTH GLASSES

The Faraday rotation of plane-polarized light has been demonstrated in the rare earth (III) phosphate glasses. Of the 13 glasses placed in a magnetic field, those containing cerium, praseodymium, terbium, and dysprosium rotated light the greatest amount. These four glasses rotate light about twice as much at room temperatures and 140 times as much at liquid helium temperatures as any other glass. The glasses could be used as isolators in optical systems. Stuart B. Berger, Charles B. Rubinstein, Charles R. Kurkjian and Arnold W. Treptow prepared the glasses and ran the experiments.

The author makes a measurement with the 23A set at a test frame in the Murray Hill Laboratory.

P. J. Snyder

The 23A Transmission Measuring Set.

The Portable 23A Transmission Measuring Set

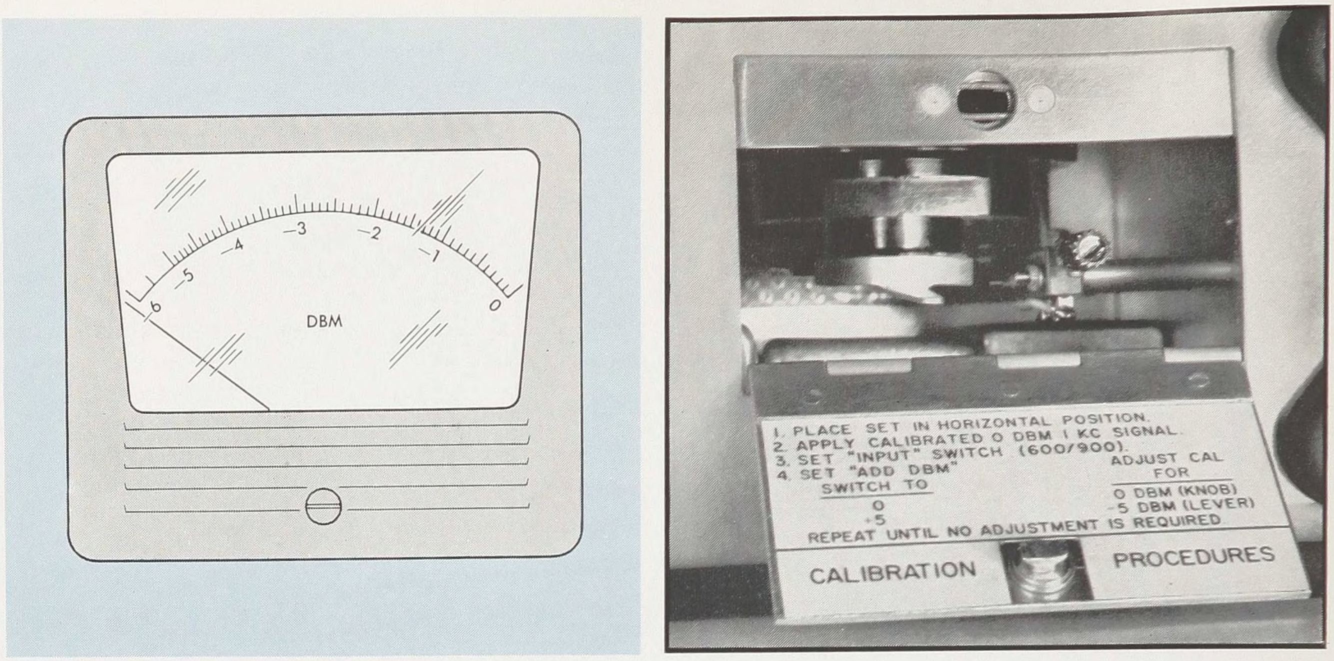
THE TRANSMISSION LOSS OF MESSAGE CIRCUITS must be verified periodically to insure good telephone performance in the Bell System switched network. For over 20 years the 12-Type Transmission Measuring Set has been used for this purpose. However, with the coming of direct distance dialing and extended area dialing, it is necessary to maintain exchange and intertoll trunks closer to their assigned net losses and the old 12-Type set cannot provide this accuracy. The new portable transmission measuring set—23A—has been developed to meet the new requirements.

In typical use, the 23-type sets are connected to a telephone line (frequently at a customer's premises). By connecting a craftman's handset to the 23A test set, a central office test line furnishing a milliwatt of power (0 dbm) at 1000 cycles can be dialed. By resetting a switch on the transmission measuring set, the connection is held and the received signal level is measured. Both 12- and 23-type sets are equipped with a high impedance holding circuit and a dial-through connection for convenience in making the measurement. Similar measurements can be made on trunk circuits.

In these operations, however, the new 23A set has several advantages over the 12-type set. It has increased sensitivity, greater stability, better measurement accuracy, and has provision for measuring on 900- as well as 600-ohm circuits. The set, as shown in the photo, is small (6 lbs., measures 9⅜ in. wide, 6 in. high, and 5¼ in. deep, including cover, hinges, feet and retractable carrying handle) and is packaged in a deep-drawn aluminum case. In addition, the 23A set is passive and requires no battery or external power source.

Multiple jacks and binding posts are provided for making dialing and measuring connections between the 23A set and a variety of switchboards, testboards, test frames, PBX's, and other testing locations. A door on the side of the case provides access to two calibration controls. Instructions for a simple calibration procedure appear on the inside of this door. A rack-mounted version of the 23A set known as the 23B TMS for central office test frames also has been developed.

The 23A set will measure power levels between —25 and +10 dbm in the voice-frequency range. It is accurate to 0.2 dbm at 1000 cycles per



The 23A's calibration controls and procedures are shown at right. The dial is shown on the left.

second and to 0.5 dbm from 400 to over 5000 cycles per second over the temperature range from 40 degrees to 100 degrees F. At usual room temperatures and with care in calibration and reading, the 23A set is accurate to 0.1 dbm for 1000-cycle measurements.

Sensitive Meter Is Used

A sensitive meter is used to achieve the desired sensitivity with a passive circuit. These requirements are met by using a taut-band suspension meter. (The meter, with a range of 6 db. has its movement suspended from a metal band under tension). Thus, the pivot-and-jewel bearings, which are fragile and cause friction, are eliminated. The large dial (3.8 inch arc) with a small db range provides an expanded scale with excellent readability in 0.1 db steps. An attenuator extends the range of the meter so that levels from —25 to +10 dbm can be measured.

The set's sensitive rectifier uses special silicon semiconductor diodes that have a forward voltage drop much smaller than that of conventional diodes. These diodes have a forward characteristic similar to the reverse characteristic of tunnel diodes. Therefore, they are sometimes referred to as backward diodes. They have a reverse-to-forward impedance ratio of greater than 100 to 1 as long as the reverse voltage does not exceed about 0.5 volt peak. This makes them ideal for detecting the low signal voltages involved in this application. An extremely low temperature coefficient—important since the 23A set will be used over a wide ambient temperature range—is another advantage of the backward type diode.

The 23A set provides measurements on both 600- and 900-ohm circuits by matching either impedance to a common circuit impedance with resistance pads. The circuit impedance for the test set is 735 ohms, the geometric mean of the two line impedances. In this way, minimum loss matching pads having the same insertion loss can be used. In addition, the matching pads consist of only a single resistor. This method, compared to transformer matching, is more simple, less costly, takes up less space, and has a flat frequency characteristic.

The frequency characteristic of the 23A set is practically flat in the frequency range of 400 to 5000 cps with a maximum meter deviation of about 0.2 db from the 1000-cycle reference. Below 400 cycles, due to the action of a low-frequency filter, the characteristic falls off. At 180 cps the response is down about 4.5 db and at 60 cps, about 30 db. This reduces measurement error (due to low-frequency noise and hum pickup) that might result from exposure of the circuit under test to low-frequency induction.

As previously noted, this new 23A set is designed to replace the 12-type set. It provides increased sensitivity, greater stability, and better measurement accuracy than the 12-type set. New devices have made possible these improvements in a small, portable set for a comparable price.

Cable With A 'Backbone'

Cable with a prominent "backbone" is beginning to make its appearance on telephone poles across the United States.

The new Bell System product, currently in limited production at Western Electric's Kearny, N. J. plant, is called self-supporting cable, and its name gives some clue to why it will save the Bell telephone companies an estimated $7,000,000 annually through 1970.

In self-supporting cable, the voice-conducting wires and the steel support strand are sealed within a single plastic jacket to form a cable that contains its own "backbone" for support between telephone poles.

Normally, aerial cables are manufactured without a built-in support. During installation, linemen must first run steel strand between poles and then attach the cable to it. This double operation, particularly when performed over difficult wooded terrain, is a time-consuming job that requires a long list of special tools, materials, and apparatus.

With self-supporting cable, installation on the poles can be accomplished in one continuous operation with less time, effort, and equipment.

A "backbone" is not the only innovation in self-supporting cable. An equally important development is the arrangement of the cable's internal voice-carrying wires.

A small amount of excess length is provided in the cable conductors so that after the cable is in place on the poles, some slack remains in the conductors, allowing linemen easy access for making service connections.

Developed jointly by Bell Laboratories and Western Electric, self-supporting cable was tested for economy and durability in various sections of the country before being offered for use.

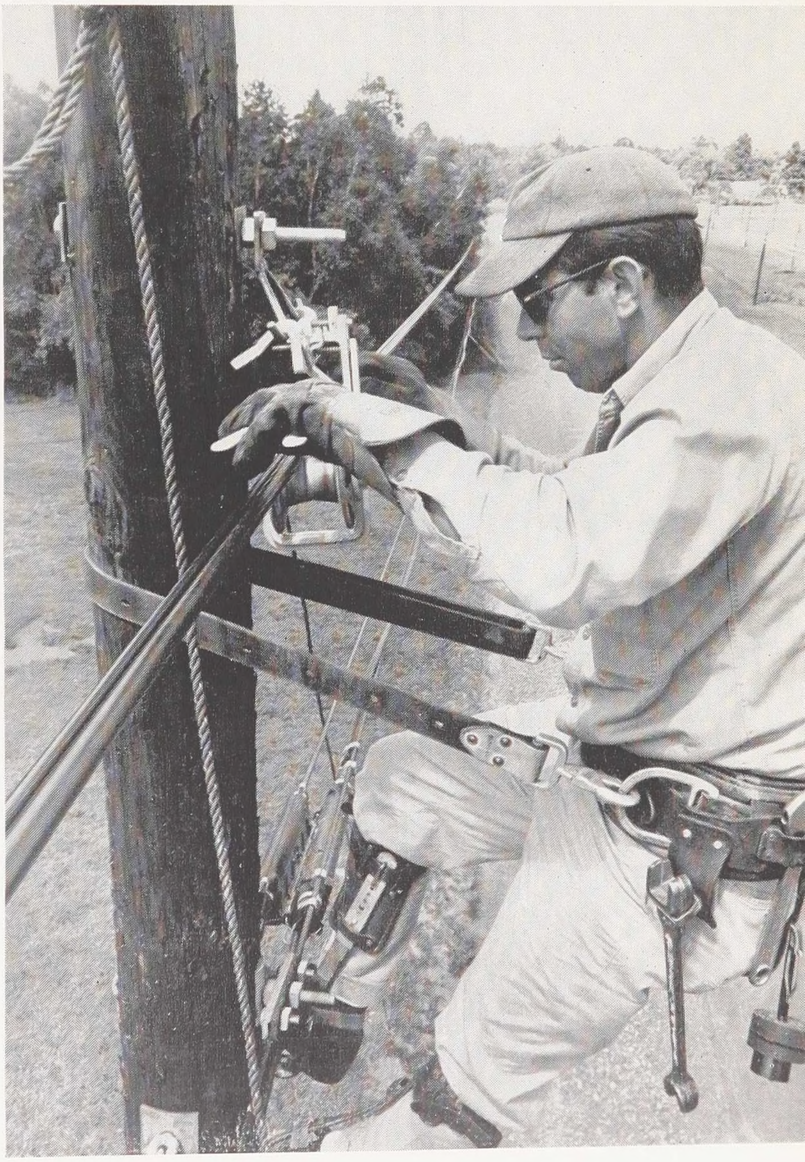
Manufacture of the new cable is accomplished in a series of separate operations on semi-automatic machines.

First, copper wires are drawn down to size, insulated with plastic, twisted into pairs, and spun together to form the cable core. The core is then covered with a clear plastic heat shield and an aluminum lightning shield. Finally, this unit, fed from one supply reel, and a ¼ in. steel support strand, fed from another supply reel, are united and sealed on a single machine that supplies the cable's outer plastic jacket.

Self-supporting cable is being produced at Kearny in sizes up to 100 wire pairs, but the sizes of cable may eventually grow to 400 pairs to accommodate heavily used telephone routes.

Western Electric facilities in Hawthorne, Baltimore, and Omaha will soon join in the production of self-supporting cable to meet growing operating company needs. Western Electric estimates that it will manufacture about 100 million feet of the cable in 1964.

A lineman fastens the new self-supporting cable securely to a telephone pole at Bell Laboratories' Chester, N. J. field station.

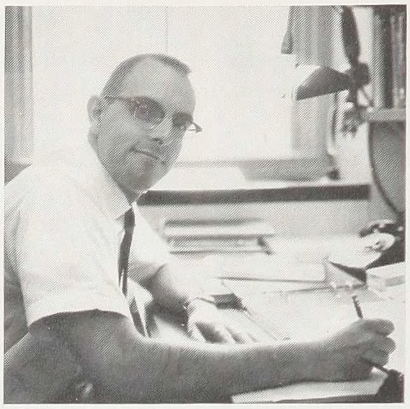


AUTHORS

Oscar H. Williford, author of "The No. 101 Electronic Switching System" in this issue, is a native of Greenwood, Mississippi. He joined Bell Laboratories in 1920. His early assignments included laboratory and field testing of new local office switching systems. He later became associated with the design of the No. 5 Crossbar System, specializing in its maintenance facilities. He was a member of the Laboratories' group that assisted with the installation and cut-over of the first No. 5 Crossbar Office. He later transferred to the Systems Engineering Department and worked on the Englewood, New Jersey Direct Distance Dialing trial and on engineering studies related to the expansion of the dialing network and Systems improvements for PBX Service. Recently, Mr. Williford supervised a group doing Systems engineering planning for the No. 101 ESS. He holds 12 Bell System patents and has 7 patents pending.

O. H. Williford

Gustave P. Marki is a native of San Francisco, California. He received his B.S. degree in Electrical Engineering from the University of California at Berkeley in 1959 and joined the Laboratories' Tranmission Division soon after. He enrolled in the CDT program and received a M.E.E. degree from New York University in 1961.

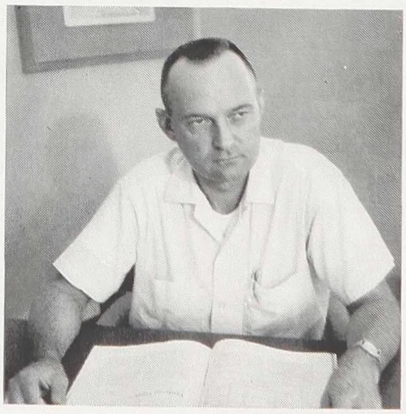


G. P. Marki

Following an initial assignment in TH radio, Mr. Marki was assigned to the L3 carrier department where he worked on the cosine equalizer adjustment set and the protection switching system. At present he is engaged in voice frequency work in the Exchange Transmission Laboratory.

Mr. Marki is a member of Eta Kappa Nu and Tau Beta Pi. He and his family make their home in Fanwood, N. J.

R. D. Johnson, author of "Simulation — Key to NIKE-HERCULES System Testing," joined Bell Laboratories in 1953. A native of Big Rapids, Michigan, he received his BS degree in Physics at Michigan State University in 1949. He has served in the U. S. Navy (1945) and in the U. S. Army (1951-53). After completing the CDT program, he worked at Whippany with the group responsible for the design of the ground guidance computer in the NIKE-HERCULES System. In 1958 he transferred to the White Sands Laboratory as supervisor of a group responsible for NIKE System Testing. Until his recent transfer to Kwajalein as Head, Test Operations Department, Mr. Johnson was responsible for the NIKE-ZEUS and HERCULES Test Planning and Analysis Department at White Sands.



R. D. Johnson

J. F. Auwaerter

John F. Auwaerter, author of "The New Teletypewriter Code" in this issue, is Director of Product Development at the Teletype Corporation, a subsidiary of the Western Electric Co. He joined Teletype Corporation in 1952 as a sales engineer, was transferred to the research and development department in 1953, and was appointed to his present position in 1960. He is responsible for the development of new products in the printing telegraph field.

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