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Bell Laboratories RECORD

Around the World by Simulation
The Automatic Card Dialer
Helium and Diffusion Separation
Applications for E6 Repeaters
Displays for Weapons Direction Equipment

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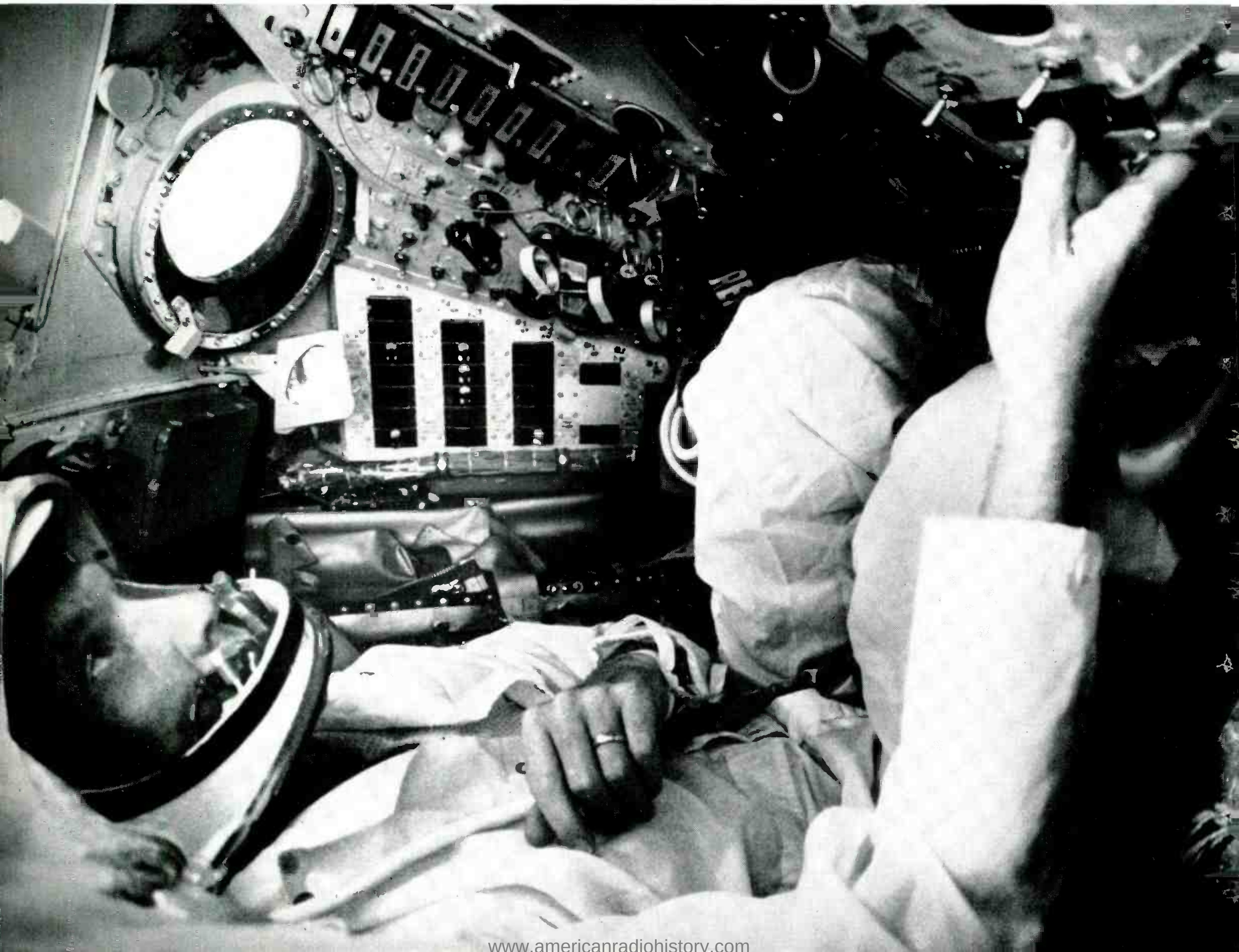
Western Electric technician checks out airborne guidance units in TITAN *missile. The Laboratories developed the guidance system, and Western produced the ground-based radar and the airborne equipment for the first six* TITAN ICBM *squadrons (see page 374).*

Though no astronaut will rocket aloft today, a group of men started working intensely at Cape Canaveral long before the dawn. These men are the Project Mercury flight controllers, continuing their vital training aimed at control of a manned space flight.

AROUND THE WORLD BY



H. D. Irvin and W. L. Cowperthwait

SIMULATION

When Alan Shepard climbed into the Mercury capsule last spring, much of his confidence in the success of the mission necessarily rested on the capabilities of a conscientious group of men in the Project Mercury Control Center at Cape Canaveral. These were the flight controllers—men who make vital decisions during a Mercury mission and who issue or authorize commands affecting it.

These men did not learn their jobs overnight. In fact, the effectiveness of every person involved in the Mercury missions has been the result of countless hours of specialized training. Obviously, little of this training can be conducted "live"; it must be done through simulation.

When the Mercury program was initiated, the National Aeronautics and Space Administration recognized the need to train all participants before the missions began, and to continue this training between missions. Consequently, the NASA authorized the Western Electric Co. to provide specialized training facilities. The Training Simulation System for the Mercury Control Center at Cape Canaveral, Florida, is one of the installations designed for use during this training program.

Through the joint efforts of the NASA and Bell Laboratories, with their associated contractors and subcontractors, a NASA specification was issued early in 1960 which established the design philosophy for the simulation system. The other participating companies included Western Electric, McDonnell Aircraft Corporation, International Business Machines Corporation, Bendix Corporation and General Dynamics Corporation.

Technical direction and responsibility for coordinating the work on the simulation system were assigned to Bell Laboratories by Western Electric. The task included administering the system design and monitoring the various phases of equipment fabrication, installation, testing, and documentation.

To understand how the simulation system is used, it is helpful first to consider briefly the normal operation of the Mercury system during an actual mission. The more important elements of the operational system at Cape Canaveral include the Mercury Control Center Building, with its telemetry and communications facilities for direct contact with the capsule, the launch pad and its associated blockhouse for firing the booster, and the booster guidance facility, with its associated radars and computers. These elements are shown in the diagram on page 346.

This complex at "the Cape" is connected to computing and communications facilities of the Goddard Space Flight Center at Greenbelt, Maryland via high-speed data circuits, and teletypewriter and voice circuits. Goddard, in turn, is linked by teletypewriter and voice circuits to 16 remote tracking and voice-communications stations, strategically located around the world.

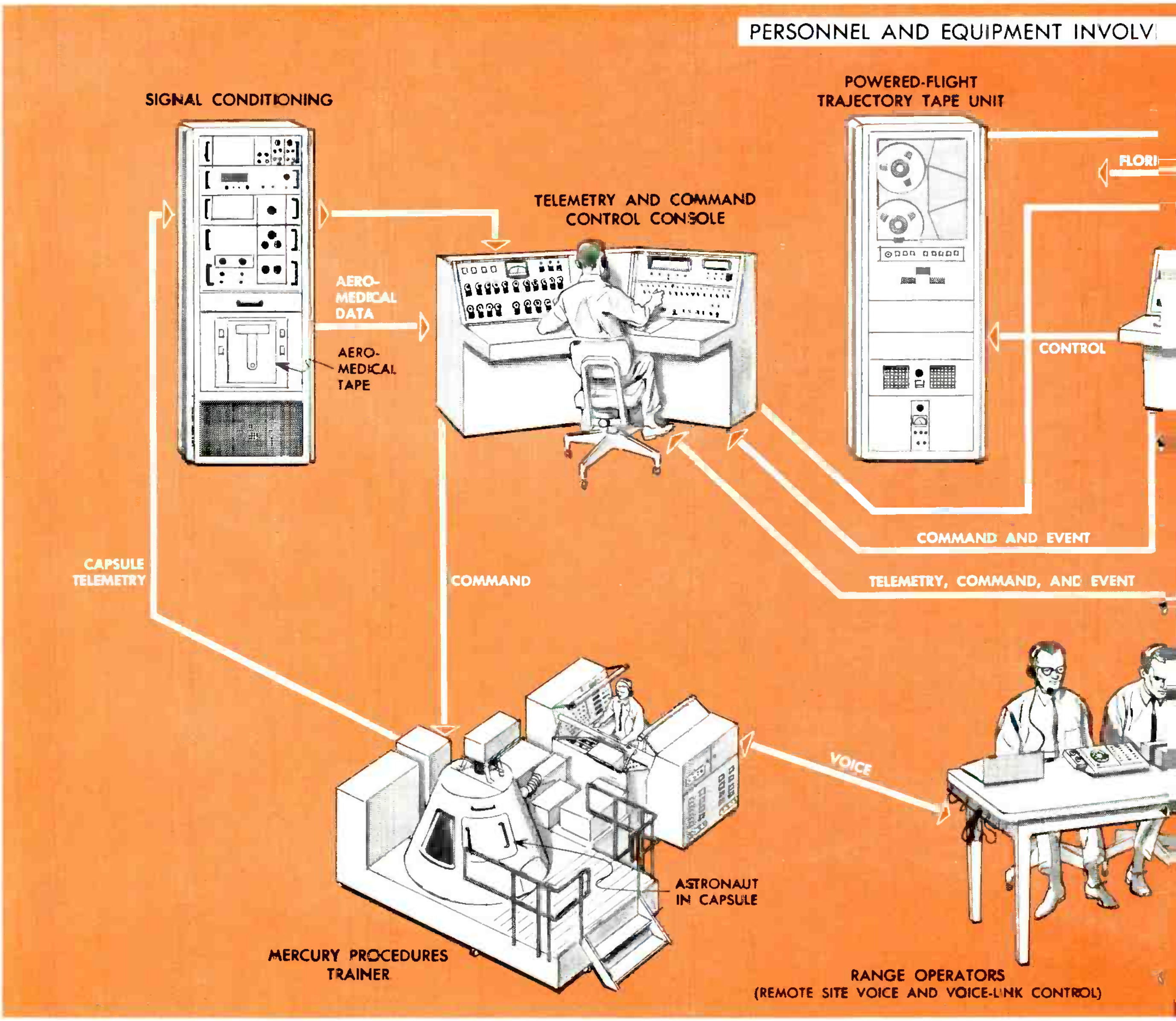
The Mercury Control Center controls the entire Mercury operation from before the rocket is launched through the time the capsule is recovered. During actual missions, the center serves in three capacities:

1. It monitors the launching of each booster and controls or commands the abort of a mission if such action is required.
2. It serves as one of the world-wide sites for tracking, telemetry receiving, command, and voice communications during orbital passes of the capsule.
3. It monitors normal re-entry of a capsule into the earth's atmosphere and directs the recovery operations.

During the prelaunch phases of a mission, the Control Center receives information on the state of readiness of each remote site via teletypewriter messages through Goddard. The center also receives information from the launch pad regarding the progress of the countdown and the condition of the astronaut.

As soon as the booster is fired and lifts off the launching pad, the guidance facilities start transmitting data to the Control Center on the performance and trajectory of the booster. From

Astronaut John H. Glenn, Jr., maintains radio contact with Mercury flight controllers from his capsule simulator (NASA photo from UPI).

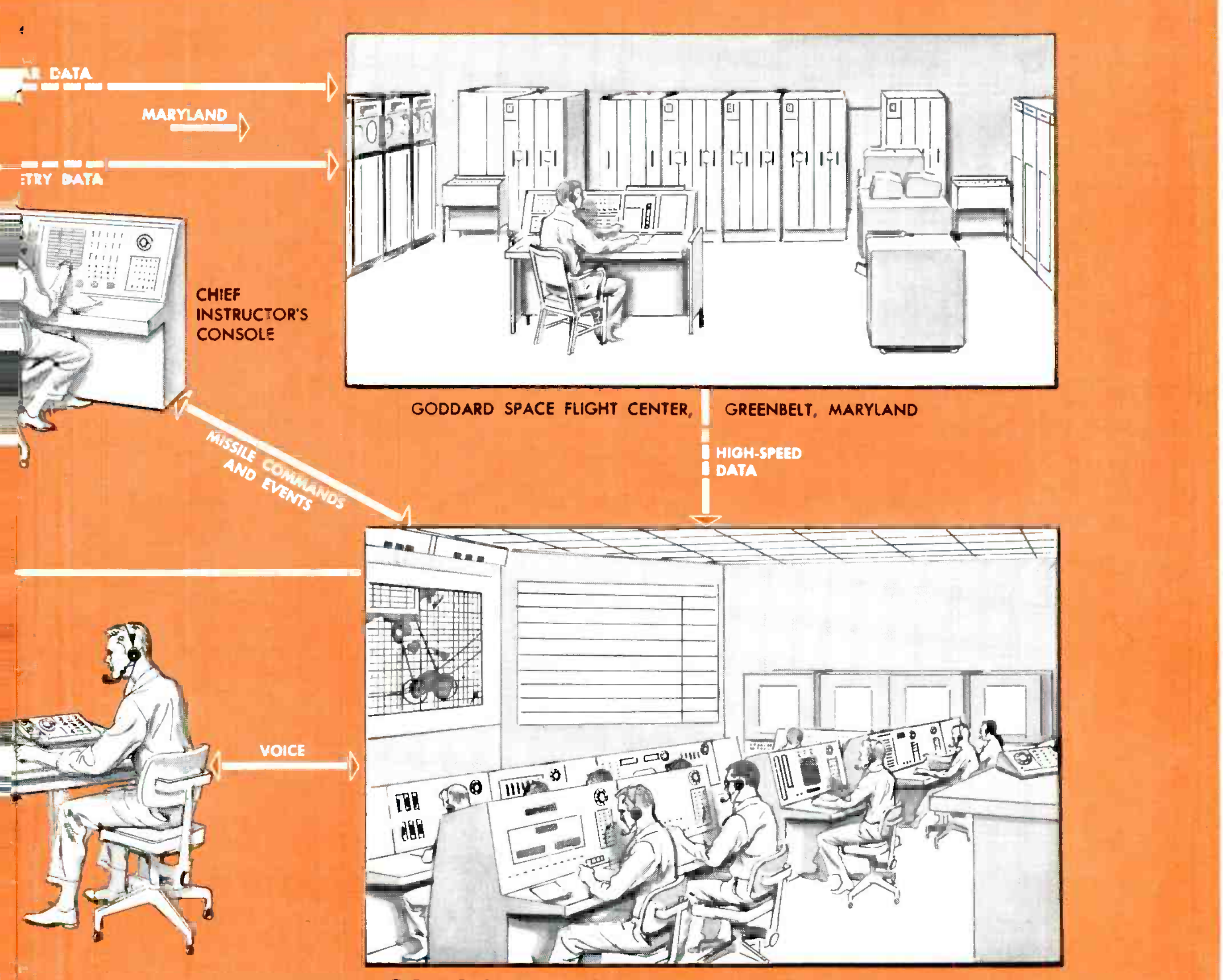


the center, these data are rerouted over high-speed transmission circuits to computers at Goddard. After being processed at Goddard, some of the resultant data go back to the Control Center at Cape Canaveral to be displayed on plot boards, meters, or similar equipment.

The telemetry, voice, and command channels between the Control Center and the capsule are also activated as the booster lifts off the launch pad. Telemetered information from the capsule is displayed to the flight controllers by suitable equipment such as oscilloscopes, pen recorders, and meters. Simultaneously, and as long as the capsule remains within range of Cape Canaveral, certain of the telemetered events are sent to the Goddard computers.

As the Mercury capsule goes into orbit and recedes from radar view at Cape Canaveral, successive remote sites of the world-wide network pick it up and monitor its operation by voice and telemetry links and, at some sites, by radar tracking. During orbital passes, each site receives information from the capsule and from the astronaut. When this information is received at Goddard, some of the data are relayed to Cape Canaveral and to the other Mercury sites. Other data are "digested" by the Goddard computers for use in following and predicting the capsule's

PROJECT MERCURY SIMULATION EXERCISES



OPERATIONS ROOM, MERCURY CONTROL CENTER, CAPE CANAVERAL, FLORIDA

flight, and the results of this analysis are passed to Canaveral.

In this way, a continuous flow of information to and from the Control Center is maintained throughout the entire mission. Even after the capsule has landed and the ships and aircraft of the recovery task force go into action, the Control Center coordinates the recovery operation until it is completed.

To accomplish such a mission, effective coordination between the many people involved is vital. The Training Simulation System for the Mercury Control Center has been designed to provide the facilities for training which will insure this coordination. The system feeds information to the operations room at the center to duplicate normal and abnormal conditions that may occur during an actual mission. It also accepts as inputs to the Mercury system the normal or emergency actions taken by the flight controllers, so that results of their actions can be noted, and necessary corrective training given.

Simulation system instructors devise a variety of missions to be simulated for training purposes. Switching arrangements allow simulation of either short suborbital or full orbital missions. These simulated missions give experience both to the flight controllers and to many of the supporting personnel. Training of the astronaut is integrated with that of the Control Center personnel by having the capsule of the Mercury Procedures Trainer manned by an astronaut during simulation exercises.

During an operational mission, the operations room at the Control Center is normally manned by more than twenty people. The flight controllers, each serving in a specific technical capacity, comprise about half of this group. Besides the controllers, there are the Operations Director, who has over-all mission responsibility, mission observers, and technical support personnel who operate and maintain equipment in the operations room. In addition, many technicians are required to operate and maintain equipment in the communications, telemetry, data-selection, and capsule-recovery areas of the Control Center. All of these people, plus the astronauts, are candidates for training during simulated missions.

Basic Design Criteria

Designers of the simulation system were guided by two basic design criteria. First, the system should employ as much of the normal operational equipment as possible. Second, the reliability of the operational system should in no way be jeopardized when switching between operational and simulation conditions. To comply with these requirements, the simulation system was divided into a group of functional subsystems, interconnected by suitable cables or switches. The major subsystems include the Mercury Procedures Trainer, the Telemetry and Command Control Console with its associated Aeromedical Tape-Drive Unit, the Chief Instructor's Console, the Trajectory Subsystem, and the Intercommunications Subsystem.

The Mercury Procedures Trainer, developed by McDonnell Aircraft and supplied by the NASA, is essentially a complete Mercury capsule with control consoles. During a simulated mission it serves as a source of telemetered signals and events and as a receiver for radioed commands. When manned by an astronaut, it can supply voice communication from the capsule. For a particular training exercise, the instructor at the trainer follows a mission "script" to operate the equipment as specified and to generate and accept signals or respond to commands from the other instructors or from trainees.

The operator of the Telemetry and Command Control Console controls the flow of information between the Procedures Trainer and the rest of the Mercury system used during a simulated mission. He can produce simulated telemetry signals independent of the Procedures Trainer, interrupt signals, introduce noise on telemetry channels, generate spurious signals, and forward commands to the Procedures Trainer. This operator also controls the operation of the Aeromedical Tape-Drive Unit, which supplies prerecorded heart and respiration data similar to those which would be received from an astronaut under unstressed or stressed flight conditions.

The instructor at the Chief Instructor's Console follows a master script of the simulated mission. His position supplies commands such as booster-firing and abort signals which normally originate from the launch pad blockhouse during the powered-flight phase of an actual mission. During the balance of the mission—the orbital and re-entry phases—the chief instructor monitors the communications channels, advises and directs other simulation operators, and accepts and relays messages to and from all simulation operators.

The Trajectory Subsystem is a special high-speed tape unit with associated control circuits designed to supply prerecorded tape data. These data simulates the data that would normally be associated with missile guidance during the powered-flight phase of a mission.

The Intercommunications Subsystem provides extensive voice communication and monitoring facilities throughout the Control Center by special telephone keyset equipment strategically located on all consoles in the various equipment operating areas and at a range conference table in the simulation room. Instructors at this table work from scripts to simulate voice communications to and from the remote world-wide sites.

To a visitor in the windowless operations room during a simulated mission, the effect of realism is striking. So strong does it sometimes become that he is almost compelled to go outside to see if there actually is a Mercury rocket standing on the pad, shrouded in frost and clouds of vapor, awaiting the firing signal.

The flight controllers man their positions in the operations room as they would for an actual mission and follow precisely the same rules of action. As the prelaunch countdown proceeds, and this may last for hours, operators in the simulation room talk to the flight controllers. During this period they simulate personnel at the launch pad, and the "voices" the controllers hear carry out the vast number of checks that must be made to assure the readiness of the capsule and the booster, and of the complex radars and guidance facilities at the Cape. Other voice operators "act" as talkers at the remote tracking sites around the world. They report in to the Mercury Control Center on the status of their sites; the wording is brief, the meaning precise:

"All systems condition green, except acquisition red. Estimate fix in 20 minutes. Over."

"Roger. Advise when status green. This is Canaveral. Out."

Messengers pass quickly among the rows of consoles, delivering simulated reports from the Mercury network to the flight controllers and taking outgoing messages for transmission. Periodically, as the countdown clock ticks off the seconds, a status announcement is made over the loudspeaker system.

"T minus 180 minutes and counting."

At the same moment in the countdown at which an astronaut would be scheduled to enter the Mercury capsule atop the booster, one of the "seven" walks into the simulation room and is assisted into the Procedures Trainer. He is sealed in the semi-darkness of the capsule's instrument lights; his only contact with the outside is by the simulation communications. As he begins the detailed tests of his vehicle, his voice is heard in the headsets of the flight controllers. A voice operator simulates the Capsule Test Conductor.

The simulation operator at the Telemetry and Command Control Console flips the ON switch of the Aeromedical Tape Unit. Out in the operations room, an oscilloscope on the Flight Surgeon's console comes alive, displaying a prerecorded electrocardiogram. Meters on this and other consoles show prerecorded respiration rates and temperatures typical of the astronaut's own, as well as the capsule's battery voltages and currents and a myriad of other telemetered quantities.

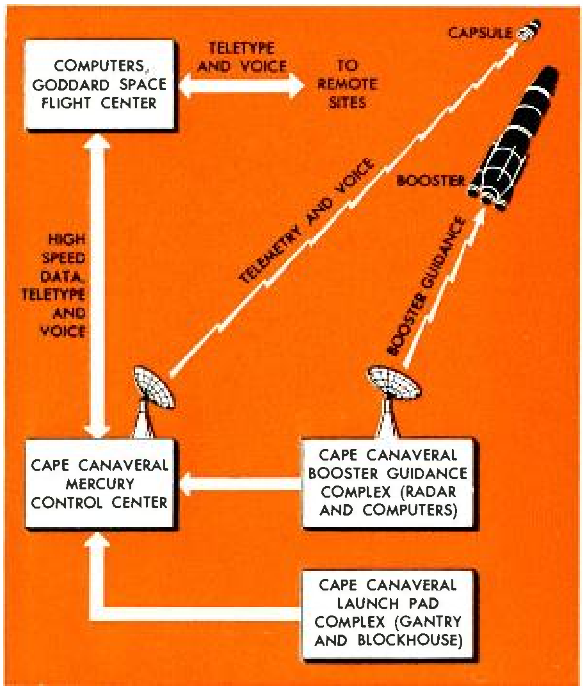
The simulation instructors critically monitor the operations of the flight controllers throughout the exercise, noting any procedural difficulties for discussion at the debriefing session which will follow. The script for today's exercise, whose contents are not known to the flight controllers, calls for the instructors to simulate several abnormal conditions aboard the capsule during both the countdown and the flight. These are conditions which conceivably might occur in a real Mercury mission, and they will require quick decisions by the Flight Director and his

During simulation: two consoles (center) are the Telemetry and Command Subsystem and Chief Instructor's position. Range conference table is in foreground, Procedures Trainer in background.

flight controllers to take corrective actions. One possible corrective action might be to bring into service spare facilities which have been provided for just such eventualities. The instructors carefully observe the performance of the flight-controller team under these conditions.

At a signal from the Chief Instructor, the first abnormal condition called for in today's script is simulated. The operator of the Telemetry and Command Console adjusts a small knob. In the operations room, the Capsule Systems Monitor sees the telemetered temperature of a small unit in the capsule begin to rise. Over the voice circuits he can be heard informing the Flight Director that there may be a problem. Then, as the temperature ceases to rise and remains below a dangerous level, the decision is made that the mission is still in a "go" condition, with all systems functioning well enough to proceed.

As the countdown nears zero, a growing tension can be detected in the operations room, just as it would be during an actual Mercury mission. The same tension also is felt in the simulation room, where the instructors must work as a smooth team in operating the complex simulation system to provide a realistic set of signals to the operations room. The Chief Instructor watches the clock closely, with his hand resting on the switch that will give the firing signal and start the simulation equipment into the dynamic phase of the exercise:



Important elements of the operational system for Project Mercury, including those at Cape Canaveral and Goddard Space Flight Center.

"Five . . . four . . . three . . . two . . . one . . . zero . . . LIFTOFF."

The powered-flight trajectory tape begins to roll, feeding simulated radar data over high-speed data lines to the computers at Goddard Space Flight Center eight hundred miles away. The computers analyze the data received and return the results to Cape Canaveral for display in the operations room. The Telemetry and Command Control Operator presses a button marked STRESS, and the heart and respiration rates displayed to the Flight Surgeon change to those of a man experiencing the stresses of rocket flight.

The pens on the trajectory plotboards crawl upwards, describing the arc of a booster's flight to the Flight Dynamics Officer. A voice-system operator in the simulation room adjusts controls so that the astronaut's voice is now heard through realistic static and fading as he maintains constant contact with the Capsule Communicator.

Now, just before the engines of the rocket booster are to be shut off to end the powered phase of the flight, the Chief Inspector throws a switch which keeps the signal indicating one of several significant events from being transmitted to the Mercury Control Center. When the event indication fails to occur at the scheduled time, the flight controllers can be heard questioning the astronaut over the simulated radio circuit. He assures them that all indications are "OK" in the capsule, and the Chief Instructor monitors the quick reactions to this situation by the flight controllers.

As the capsule's imaginary flight takes it over the horizon away from Cape Canaveral, the Voice-System Operator causes the radio link to fade. A few moments later, a range-station operator in the simulation room calls into the Control Center, as if from a remote site in the Atlantic Ocean, to report that the capsule is in a satisfactory orbit, and all is well aboard. During each ninety-minute orbit of the capsule, messages simulating those from each of the world-wide Mercury stations arrive in the operations room by voice and teletypewriter. Finally, word arrives that the retrorockets have been fired to slow the capsule from its 17,000 mph orbital speed, bringing it back to earth.

The capsule is scheduled to pass in radio "view" of Cape Canaveral during descent, and the simulation instructors re-establish voice and telemetry links to the center at the proper time.

While the astronaut is resuming voice contact with Cape Canaveral, "event" displays before the flight controllers light up to show "Drogue Chute Deployed," then "Main Chute Deployed." Shortly afterward the announcement is heard on the intercom circuits that the capsule has landed safely in the ocean and is being retrieved.

As the hatch cover is removed and the astronaut climbs out of the Procedures Trainer capsule to join the simulation instructors in the operations room for a critique of the exercise, there is a visible relaxation among the flight controllers. This, as much as anything, attests to the realism of the simulation exercises.

The flight controllers call these exercises "playing the game," but it is a strict game, played seriously and well. For only through constant practice such as this do these men develop their skills, individually and as a team, ready to act with split-second timing when the day of the actual mission arrives.

The first real "exam" came last May when the first American astronaut made his flight under the control of the dedicated group of flight controllers at the Mercury Control Center. And how did Astronaut Shepard feel about the preparations? Shortly after the flight he put it succinctly: "Our training has been extremely thorough."

Mercury Spacecraft "Proves In" Ground Tracking Network

The most comprehensive test of Project Mercury to date—orbital flight and re-entry of an unmanned Mercury spacecraft on a completely automatic basis—was successfully completed last month. The flight of the spacecraft was tracked by a world-wide network of tracking and monitoring stations which Western Electric turned over to the National Aeronautics and Space Administration earlier this year. (RECORD, *June*, 1961.)

Through the 18-station network, which will track, monitor and provide communications with manned orbiting spacecraft in the future, came all the information necessary to monitor and control the unmanned orbital flight. NASA flight controllers at the Mercury Control Center at Cape Canaveral made all the vital decisions required for the flight in the operations room. The design and installation of this room was one of the responsibilities assigned to the Laboratories by Western. The Laboratories also implemented the operations at the Bermuda site, designed and installed a flight-controller training simulator, as described in the preceding article, served as consultant on technical phases of the project, was responsible for assessing the capability of equipment to fullfill operations plans and handled operational tests of the network.

Mercury's Control Center has a large animated map in the front of the room that displays the status of equipment at all tracking sites. It also shows the position of preferred recovery areas and indicates the position of the orbiting spacecraft. On each side of the map are "trend" plots which record conditions inside the spacecraft. When the manned spacecraft is launched into orbit these monitors will provide information concerning the astronauts heart rate, respiration rate and body temperature, as well as the oxygen supply, temperature and quantity of coolant in the spacecraft.

The complete communications network comprises a 60,000 mile route representing more than 140,000 circuit miles. Included are about 100,000 miles of teletypewriter circuits, 35,000 miles of telephone circuits and more than 5,000 miles of high-speed data circuits.

Astronaut Donald Slayton (right) discusses launching procedure with a flight controller (UPI photo).

In this modern whirlwind world we welcome any device that saves us time. The latest candidate for stretching our days is an automatic card instrument designed to speed up the dialing of commonly called telephone numbers.

W. Pferd and H. J. Hershey

The Automatic Card Dialer

A new member has been added to the Bell System family of dialing instruments. This is the 40A card dial, recently developed to join the family of dialing arrangements as a customer-controlled signalling device. The new dial provides fast, automatic, and convenient service. Placing a call requires only inserting a small plastic card into a slot in the telephone, waiting for dial tone and depressing the "start" button. The automatic dial does the rest—sensing the code on the card and generating a train of dial pulses for detection by central-office equipment in establishing the connection.

Telephone engineers recognized the need for an aid to dialing soon after the introduction of the finger wheel dial. For example, a patent granted around 1900 shows spring-driven commutators for reading codes established by selective wiring. The early proposals were prohibitive, however, because they were expensive and inflexible, but they did indicate that three essential elements are required for automatic dialing. These elements—memory, power for code reading, and pulse generation—have been resolved in many different ways. During the 1930's, an automatic dial was developed that used brass disks for memory, a clock spring wound by the telephone user for power, and a rotary-dial pulse generator. More recently, a plastic disk dial powered locally was designed at Bell Laboratories and placed on limited trial in Akron, Ohio. A Laboratories designed magnetic-drum automatic dialing telephone is now being developed, and a limited trial of the unit has been planned for the near future.

All of these dials, while providing added convenience for the customer, are relatively large and expensive. A prime objective in designing the new dial was to provide automatic calling as economically as possible. This objective has been met at Bell Laboratories through new types of memory, power and pulse generation and by combining the new dial with the other telephone instruments to make an integrated set.

What type of memory to use has always perplexed the designer as seen from the wide range of types employed in the past. Chief among them are paper rolls, magnetic tape, and plastic and metal discs. These memories require an auxiliary way to code a telephone number and an additional way to identify the entry. Furthermore, these are "internal" memories, and the coding, access, and display equipment required for them add to the cost of the automatic dial.

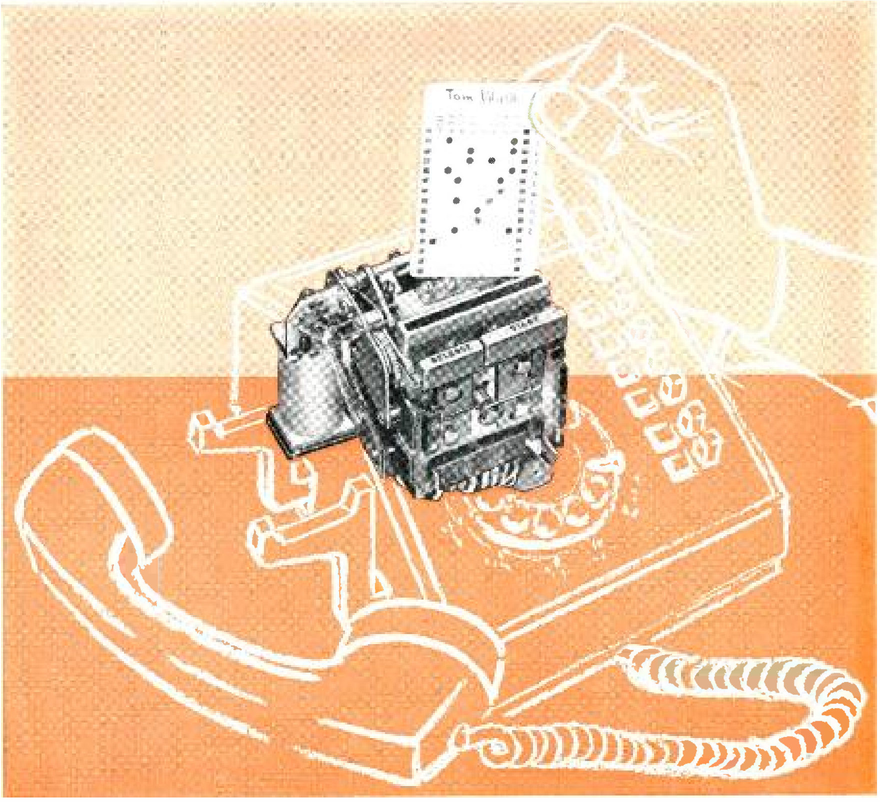
This expense is eliminated in the 40A card dial by using a memory card coded by the customer. A card for each telephone number is inexpensive and permits easy growth of and complete access to the memory. Pockets in the telephone housing permits frequently used cards to be displayed. Additional cards can be kept at any conveniently close point. Customer control of the coding of cards and arranging of cards in the store permits maximum flexibility in repertories.

Each plastic card, which measures 3-7/16 by 2-7/32 inches, is injection molded to permit shaping the circular knock-outs for coding. A rack configuration down either side of the card meshes with sprocket wheels inside the dial mechanism to wind up a spring during insertion. The rack then orients the card properly for row-by-row ejection during dialing.

To code a card, the customer first writes the name of a person or concern he often calls across the top of the card. He then writes each of the digits of the telephone number (translating any letters to their corresponding numbers) down the right side of the card, starting with the first digit at the top. The code, a modified 2-out-of-7 one, was chosen over a 10-position code to simplify the mechanism and permit a minimum number of scanning contacts. It means that digits 1 to 9 require the two knock-outs to be removed while digit zero is coded by removing a knock-out from the center row only. The customer can use a pencil or ball point pen to press out the plastic knock-out discs.

A card with a code for direct distance dialing (DDD) plus the seven-digit exchange number, is shown in the illustration below. A knockout has been removed from one of the three columns of each 1 to 9 group at the point where the column which contains the digit being coded intersects the row for that digit. The holes in the center column code the two zeros in the telephone number.

This coding arrangement would permit TOUCH-TONE Calling signals to be generated where this dialing is available. A tone card-dial, planned for the future, will operate with similar cards



Customer-coded card is inserted into slot atop the 40A dial mechanism, shown here in its relation to rest of the telephone set.

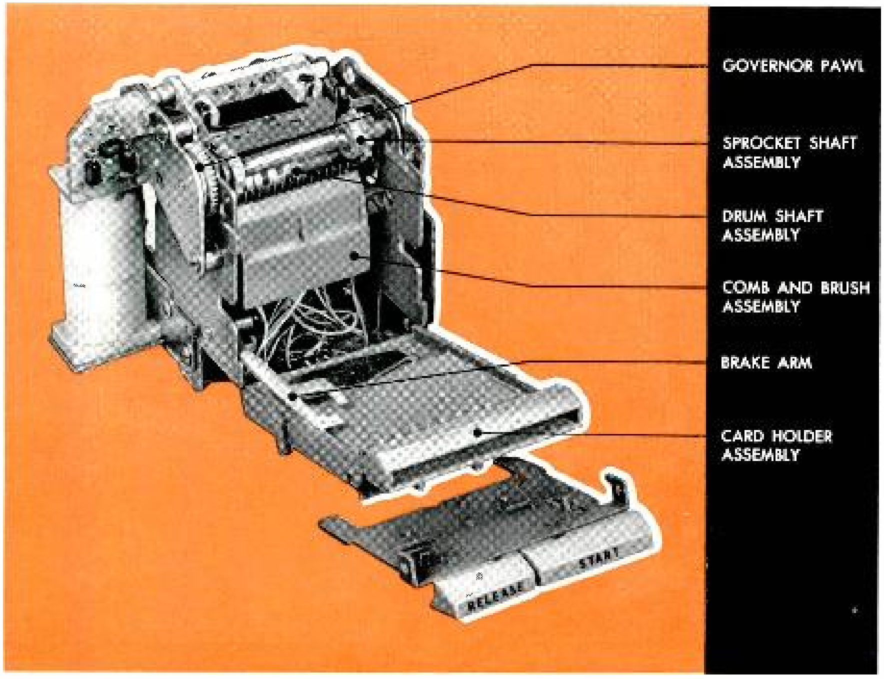
coded in the same manner as for pulse dialing. This combination card was planned for system-wide use of a single type card. The 14-digit capacity of the card permits coding the longest number expected for DDD and world-wide dialing. For the more frequently called shorter numbers, a knock-out in the "stop" column on the left side of the card is removed after the last coded row. Contacts sense this column to stop the dial. The stop column is also used to interrupt the dial after pulsing special access codes and permits the user to detect second dial tone before restarting the instrument by depressing the "start" button a second time.

Previous automatic dials have used either heavy clock springs or electric motors powered locally to read the code for dialing a number. Considerable energy is required for this function and, for an average digit (the "5"), must be controlled for a pulsing and interdigital time of 1.1 seconds. In the new dial, power from the telephone line is used to scan the code and generate the pulses. It is done by a self-stepping electromagnet. This also releases energy stored in a motor spring when the card is inserted, to advance the card row-by-row out of the dial. Using central-office power eliminates problems caused by local-power wiring and gives the dial the reliability of other telephone functions powered at the central office.

To dial a telephone number, the customer pushes the previously coded card into the dial until the top edge of the card is flush with the top of the gauge. He then depresses the "start" button to remove the talking circuit from the line and to substitute the 40A dial. As the card begins to move out, small plastic rollers, one for each column, press against the card, moving into the coded holes to operate the card-sensing contacts. These contacts and other functional elements of the automatic dial and telephone are shown on the block diagram on the next page.

Circuit Action

As soon as the start button is depressed, current flows in the electromagnet in series with the dial-pulse generating contact. This contact and the electromagnet are paralleled by the card contacts in series with contacts operated by a printed-circuit commutator that is rotated by the electromagnet. Additional parallel paths around the electromagnet and card-commutator contacts provide pulse blanking and interdigital time. Each time the electromagnet operates, the dial-pulse contact transfers to complete a circuit around the electromagnet, and a pulse is generated if the card-commutator contacts are open to blanking or interdigital paths. The electromagnet steps itself to generate dial pulses at the required rate.



The 40A dial mechanism, designed to be integral with customer's set, combines the memory, power, and pulse generation units into one compact package.

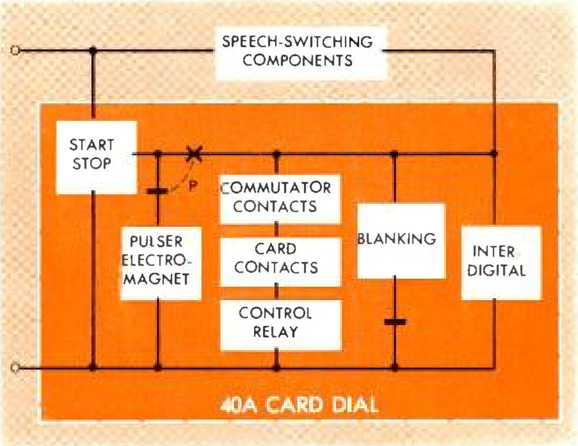
As a digit is dialed, the armature of the electromagnet moves a plastic pawl which rotates the commutator one sixteenth of a revolution. At each of the first ten angular positions of the commutator, a different contact array is placed in series with the card contacts. If no continuity exists through these two sets of contacts, a dial pulse is generated while the control circuit operates the pulser electromagnet. Since the electromagnet self-steps, pulses are continuously generated until the commutator is rotated to a position which permits a shorting circuit through the commutator and card contacts. This circuit causes the control relay to be energized and its contact to close the blanking path. This bistable contact remains operated and blanks the pulses during the remainder of the ten pulsing steps. During this blanking period, control-relay contacts permit the electromagnet to self-step at 20 pulses per second. This action shortens the total time required to scan a line on the card. The control relay employs glass-enclosed contacts magnetically biased and is mounted on the left side of the dial.

Interdigital Time

After the electromagnet generates pulses equivalent to the first digit coded on the card, and blanks the additional pulses, it returns to 10 pps operation while rotating the commutator through six interdigital positions. This guarantees sufficient interdigital time for the central office to sense the end of the digit. During two of these later steps, a cam on the commutator shaft operates an escapement which releases the gear train. This action permits the motor spring, previously wound up on insertion of the card, to rotate the sprocket wheel shaft. The card then moves so that the second coded row is positioned in front of the card-contact rollers.

The pulser continues to rotate the commutator. Pulses equivalent to the new digit are generated until the commutator and card contacts provide a path for current to operate the control relay. This sequence of operation—pulsing, blanking, and card advance during interdigital time—repeats until the complete telephone number is dialed. For the "stop" hole, the electromagnet circuit opens as the roller for this column moves into the hole. The action also re-connects the speech portion of the telephone so that the customer can begin his conversation.

At the end of the conversation and after replacing the handset, the customer pushes the release button to eject the card. The release button can also be used to eject a card during dialing if the customer decides to abandon the call.



Major components of 40A card dial as designed to be part of the circuit in the telephone-set itself.

Ideas embodied in the 40A dial were initially explored with field test units at Birmingham, Michigan during 1960. The instruments, built by the Western Electric model shop in Indianapolis, proved the technical feasibility of the proposal. Favorable comments by business and residential customers cooperating in the tests prompted the decision to proceed with development of new telephones equipped with the automatic dial.

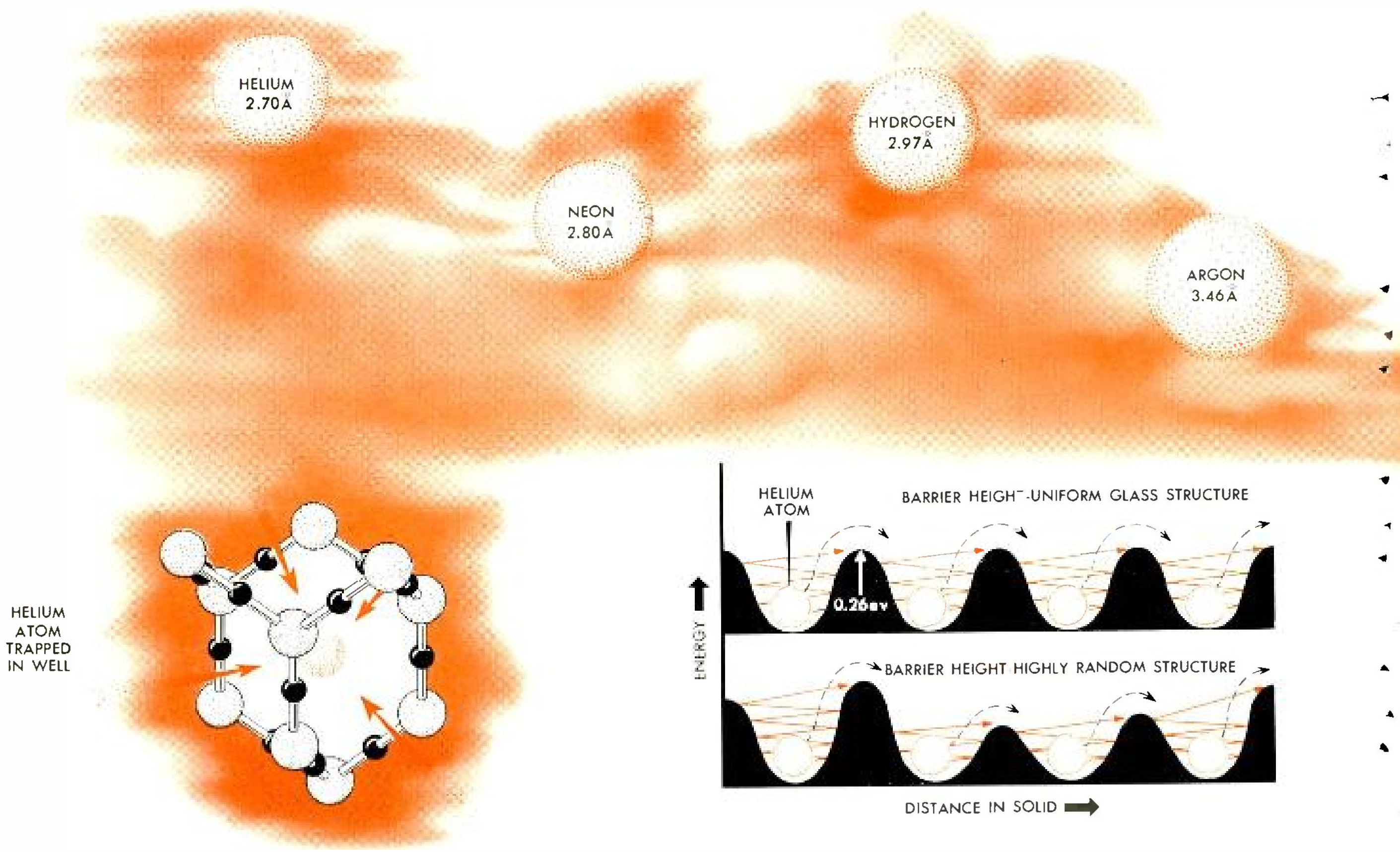
The close cooperation between the development and appraisal groups at Bell Laboratories and the manufacturing engineers at Western Electric's Indianapolis plant permitted the business version of the automatic dial telephone to become available in a short time. Intricate, yet easily mass produced, components and contact assemblies were devised for the production design. Using plastic moldings for the card and many of the dial parts permits complex interacting details that have close tolerances and smooth surfaces for proper operation.

Early production units of the 661 type automatic dialing telephone, using the 40A dial, have been field tested at Richmond, Va., with favorable results. These units are presently being tested at Minneapolis, Minn., with an enlarged sample. The new telephone will be marketed on a limited basis during 1961. Favorable response from customers during the early trials, however, forecast a growing demand for the speed, accuracy and convenience of calling with this new customer product.

Of all the elements, helium has some of the most unusual physical properties. Because of its unique ability to pass through certain solid structures, chemical physicists at Bell Laboratories could devise a way to separate helium from other gases by what might be called an "atomic sieve" technique.

K. B. McAfee, Jr.

Helium and Diffusion Separation



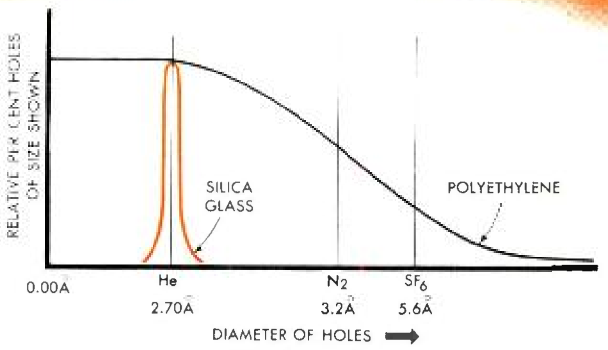
In 1868, the English astronomer J. N. Lockyer observed a strange phenomonon in the corona of the sun. Through his spectroscope, he saw that one of the emission lines in the sun's spectra did not correspond to any of the then-known elements. Several years later, the line was recognized as originating from a new element, which was named helium, from the Greek word "helios" or sun. This was the first discovery of an element that was not previously known to exist on earth. It was not until 1905 that H. P. Cady of Kansas University discovered the source of helium which today furnishes us with our main source of supply —natural gas.

Since that time, because of its many curious and unique properties, helium has intrigued physical scientists. For many years after its isolation and identification, attempts to liquefy the gas failed. When it finally was liquefied at only four degrees above absolute zero, research workers found that they could produce a second liquid form by cooling it another few degrees to 2.18 degrees K. Helium I, the normal liquid, exists above this temperature, while helium II, a liquid with unique properties, exists below it.

For example, if an empty glass beaker is partially immersed in a bath of helium II, the liquid will flow steadily *upwards* over the lip of the glass, against gravity, into the beaker until it reaches the level of the helium outside the beaker. Similarly, if the filled beaker is removed from the bath, the helium II inside again flows up over the lip, down the sides, and then drips back into the bath. This behavior results from a property called superfluidity, unique with the element helium.

Liquid helium is now fairly readily available, and the near absolute zero temperatures which it produces have made the element extremely important in scientific research at Bell Laboratories and elsewhere. It has also been used to achieve important technological ends in communications. For example, the maser amplifiers used in satellite communication experiments were cooled in liquid helium to achieve the low noise characteristics needed for the faint signals involved. Research in solid-state physics to determine the ultimate nature of materials also depends heavily on the low temperatures produced. New electronic devices have been developed which depend upon liquid helium temperatures for their operation.

One of the areas where the extremely low temperatures made possible by liquid helium are of interest is that of superconductivity. In this condition, which many materials exhibit at low temperatures, electrical resistance drops to essentially zero, and a current started in a superconducting ring will continue unchanged almost indefinitely (RECORD, *March*, 1958). Recently, Laboratories scientists demonstrated how this phenomenon can be used in the production of extremely large magnetic fields, using superconducting solenoids. One new material, niobium-tin, has sustained fields of nearly 100,000 gauss (RECORD, *March*, 1961). Magnets of this type could extend the operating frequencies of communication devices and open new fields. They may also be important in containing high-speed particles in thermonuclear fusion.



Another of helium's unique properties is its extremely rapid flow rate in the gaseous state. Measurements indicate that it can diffuse through solids at rates thousands and even millions of times faster than can hydrogen or neon under the same conditions. The diffusion of gases in solids is a subject of fundamental interest and this property of helium has been extensively investigated at the Laboratories. A main practical reason for this concern is that communication equipment must often operate under conditions which favor diffusion. Submarine cables, for example, operate under great hydrostatic pressures at the sea bottom, and the diffusion of water molecules, ions, and dissolved gases must be controlled and understood. Experiments designed to study these effects showed that helium alone exhibited the remarkable diffusion rates in glass, polyethylene, and other solids.

Chemical physicists at the Laboratories found that the rate of flow of gaseous helium through certain glasses is so rapid that 20 pounds of glass tubing inside a helium diffusion cell could pass about two million cubic feet of helium in one day. This is equivalent to the daily production rate of helium in the United States. Although this extraordinarily high flow rate of gaseous helium is not directly related to helium's behavior as a "quantum liquid," scientists believe that it is another consequence of the unique atomic structure of helium.

Helium can permeate some crystalline materials and almost all glasses and polymeric materials by the process of atomic diffusion. The rapid flow of helium through these materials results in part from the presence of atomic-sized "wells" in the materials and in part from the ease with which helium atoms cross the barriers separating these wells. In addition to being an interesting phenomenon in itself, the diffusion of helium through various types of glass is a useful technique for investigating solid-state structures.

The relative size of the barriers in silica glass is shown on pages 354 and 355 along with atoms of helium, neon, argon, and the hydrogen molecule. The helium atoms consists of its nucleus and two electrons. It can be thought of as a sphere whose diameter is slightly less than that of the hole in the lattice-like network of silicon and oxygen ions which make up the solid state structure of silica glass. Of course, the picture of an atom as a sphere is a highly idealized one. It is more nearly correct to regard the atom or molecule as a very small hard core or nucleus surrounded by an electron cloud which becomes progressively less dense as the distance from the nucleus increases. The radius of an atom in the figure represents one half the average distance of closest approach between the nuclei of two like atoms which have collided head on.

The diffusion of a helium atom through a structure such as glass can be thought of as a transition of the atom from a state where it is trapped but vibrating rapidly in a well, as shown on page 354, to a state where it acquires sufficient thermal energy to jump over the barrier which encloses the well. Once it crosses the barrier, the helium atom loses its excited vibrational energy and drops into an adjoining well. Here it must await a certain amount of thermal energy before making another atomic jump.

The diagram on page 355 makes it appear that a properly directed helium atom of any energy could make the passage through the hole in the structure. However, the circle representing the helium atom, as well as the circles representing the oxygen and silicon ions, do not take into account the diffuse character of the electron cloud mentioned above. Further, a diagram cannot describe the electrostatic forces exerted on the atoms and ions. These forces repel a helium atom even when its diameter is less than the diameter of the hole in the glass structure. Therefore, the atom must gain an added amount of energy—activation energy—to overcome this resistance.

Two conditions must then be met before rapid diffusion can take place: (1) the wells must be large enough to accommodate an atom, and (2) the barriers separating the wells must permit the vibrationally excited atom to make its transition from one well to the next.

The magnitude of the repulsive force which seeks to prevent an atom from passing from one well to another depends to a great extent on the size and the shape of the diffusing atom. This is evident by comparing the rates of diffusion of helium, hydrogen, deuterium, neon and argon as shown below:

Atom or Molecule	Effective "Diameter" (Angstroms)	Diffusion Rate cm2/sec	Activation Energy (ev)
He	2.70	2.0×10^{-6}	0.26
Ne	2.80	$\simeq 7.0 \times 10^{-8}$	0.42
H_2	2.97	7.4×10^{-8}	0.43
D_2	2.97	4.4×10^{-8}	0.43
A	3.46	3.0×10^{-14}	1.82

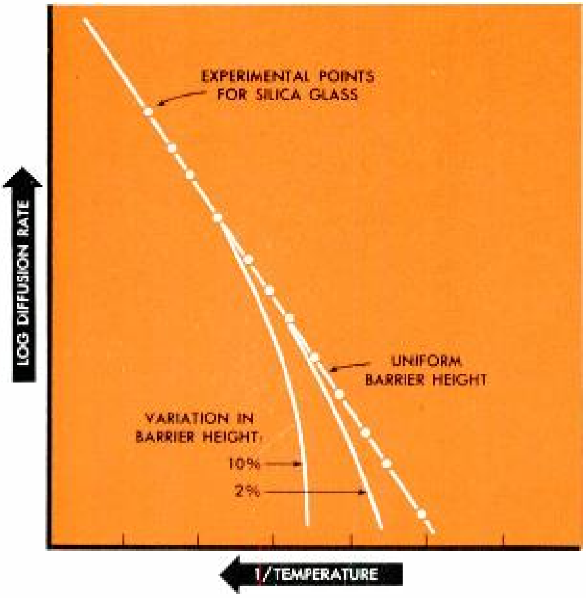
These are the only known atoms or molecules that can pass through glass. From this table it can be seen that the process of diffusion is extremely selective even between atoms such as helium and neon which differ only a few per cent in effective diameter. Note that even though hydrogen and deuterium have the same "diameter," the rate of hydrogen diffusion is greater than that of deuterium by nearly the square root of two. The hydrogen rate is greater since for equal energies hydrogen molecules have greater velocities than those of the heavier deuterium by that same ratio.

To appreciate the path that a helium atom follows when it diffuses through a glass structure imagine a man setting out for a walk on city streets. He walks to a corner and rolls a four-sided dice to decide which of the four possible directions to continue. At each intersection he repeats the procedure of rolling the dice to select his direction.

His path is known as a random walk. If he walked at a constant rate, the average distance he would travel from his starting point in a given length of time could be calculated. The average of the squares of the net distances traveled from the starting point after many walks divided by the elapsed time is a constant of his motion. If he walks twice as long, he will not be twice as far on the average from his starting point. On his longer walk, he will be the square root of two farther. The path of a helium atom in glass—a three-dimensional extension of a random walk—is called random flight. This flight path is mathematically similar to the path of the man on a random walk and his constant of motion corresponds to the diffusion rate of the atom.

To apply the concept of random flight to an atom of helium in a network such as glass, assume that each street corner represents a well where the atom is trapped. Here the atom awaits vibrational energy to surmount the barrier before it passes randomly to the next corner. By adding up all the time spent in the wells before making a transition and knowing the velocity of the atom during its transition to the next well (usually negligible compared with the time spent in the well) the height of the barrier can be calculated.

Although it might seem to be an extremely complicated situation to analyze, the amount of energy an atom requires to pass over the barrier can be calculated (shown in tabulation at left). The random flight solution, however, gives us an added amount of information concerning the height of the barriers when we ask what happens when the barriers themselves vary in height. We find that a variation of barrier heights gives an entirely different temperature dependence of the diffusion rate than the case where all of the barrier heights are the same, as shown in lower right, page 354. The results shown on the graph on this page lead to the surprising conclusion that, from the standpoint of atomic diffusion, the structure of glass is exceedingly uniform, considerably more so than has been believed previously. Using the random flight theory, it has been possible to estimate the degree of this uniformity.



Diffusion temperature and structural disorder.

The curved lines in the same graph show that at low temperatures atoms tend to become trapped in deeper wells. Thus, low temperature would be expected to reduce the diffusion rate from the value it would have if all the wells were of the same height. In experiments at the Laboratories, the absence of deep wells was indicated by the experimental points falling on a straight line in the plot. Glass behaved as if its wells for helium were all of almost the same depth (page 354).

It is interesting to compare the uniform structure found in glass with that observed in a material such as polyethylene where barriers of almost every depth are found. This comparison is shown on page 355. Even large molecules, such as sulphur hexafluoride, pass through polyethylene with relative ease.

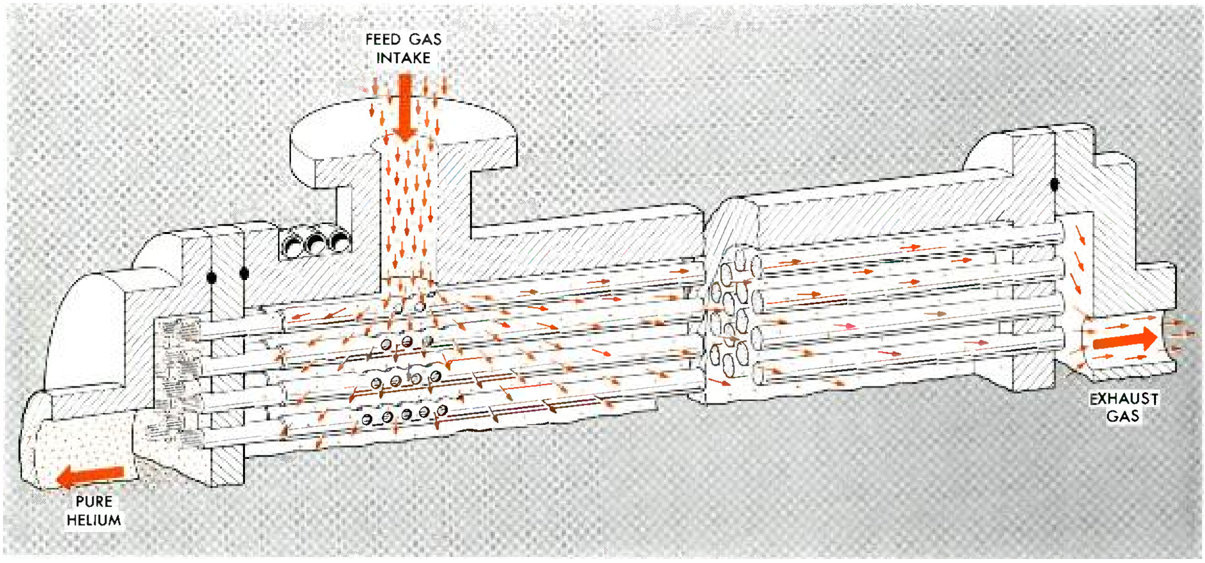
The experimental results on the diffusion of gases through glass led to the belief that glass could be used as a kind of "sieve" to separate gases. It can be used in this way as an element in a separation process somewhat similar to that used to separate the isotopes of uranium at the gaseous-diffusion separation plant in Oak Ridge, Tennessee. However, since glass is far more dense than the barriers used to separate uranium hexafluoride isotopes, the separation of helium by diffusion in glass can be described as the action of an atomic or molecular sieve. By choosing a particular barrier material, we can sometimes obtain a sieve which discriminates almost completely against one molecule while allowing another to pass through unmolested.

To make practical use of such atomic sieves, gases must have access to a large surface area of the glass barrier. A bundle of glass capillary tubes provides the best configuration so far as large surface area and strength is concerned. These tubes (each having an external diameter down to 0.002 inch and a wall thickness of 0.0002 inch) are bound together inside of a steel tube, or diffusion cell. At high pressure and elevated temperature, the mixture of gases is forced around the outer surfaces of these tubes. The helium rapidly diffuses through the glass walls and is recovered through a take-off pipe connected to them; the other gases are exhausted.

The glass barriers, made of silica or pyrex tubing, can withstand extremely high temperatures and pressures. Silica tubing, for example, can operate for long periods at a pressure of 1000 psi at 700 degrees C. At the Laboratories, techniques for bundling miles of this silica tubing in diffusion cells have been developed. The arrangement is such that only helium gas can pass through the cell by diffusing through the thin glass walls.

There are many potential uses of helium diffusion cells and separation processes. They can be used to separate radioactive contaminants from a helium stream in an atomic reactor. Another possibility is as a laboratory source of very pure gas for processing semiconductor materials in an inert atmosphere. Gas chromatography, a rapidly growing technique for chemical analysis, also requires extremely pure helium gas. One of the most recent needs for separation of helium results from its extensive use as a pressurizing agent in missile systems and diffusion cells are an effective means for rapidly purifying the large quantities required at missile bases.

Today, the United States is wasting vast quantities of the helium which is present in natural gas at concentrations of a half per cent or more, and a government program has been instituted to preserve this important natural resource. This loss is critically important, because no new rich deposits of helium are being discovered. Once the supply of natural gas relatively rich in helium is depleted, it may be necessary to consider the extremely expensive process of separating helium from the atmosphere, where it is present in only five parts per million concentration. Diffusion cells at selected locations on gas pipelines could recover the millions of cubic feet of helium now being wasted every day.



Hot feed gas containing helium is fed in through the cell intake, and flows through small ports in thin-walled, steel jacketed cartridges. These cartridges contain thousands of tiny silica glass capillary tubes which act as atomic sieves to filter out the helium, and reject the other gases.

The Bell System Data Processing study at Bell Laboratories was undertaken to determine which routine operations could best be performed by computers, and how these operations could be carried out. The results of this study are now being applied in many Bell System companies.

J. M. Wier

Bell System Data Processing Today

The principles and procedures resulting from the Bell System Data Processing (BSDP) study program conducted at Bell Laboratories have now been put to use in the first major Bell System application. At the Conshohocken Revenue Accounting office of the Bell Telephone Company of Pennsylvania, a field trial is well under way, using electronic data processing (EDP) equipment for billing and collecting operations. For the first time, complete telephone bills are being turned out by electronic data processing equipment. The first two central offices went into EDP operation last December; by mid-June, about 25,000 customers were being serviced by the equipment. The balance of the 300,000 accounts in this suburban Philadelphia accounting center will be progressively cut over to EDP operation by the end of 1961. The equipment has sufficient capacity to handle the 225,000 accounts in the Upper Darby-Delaware accounting area also.

The general-purpose business computer used is capable of reading 62,500 characters per second. It can be programmed to compare data, add, subtract, multiply, divide, and perform any other mathematical operations deemed necessary. More than 100,000 instructions were prepared for the program tapes.

On an average day, when the system is in full operation, it will "rate" 300,000 calls, post 15,000 payments, prepare 15,000 bills, and review and update each of the 300,000 customer account records. Fifteen thousand "treatment notices," such as service-discontinuance, over-due bills, or service transfers can also be prepared daily. The equipment reports statistical information as well.

Although this installation is the first actually in service in the Bell System on this job, several other Operating Telephone Companies are well along on installations to perform similar functions. Also, various other services will be provided by some of the machines now being installed. According to present plans and schedules, at least one city in each of nine companies will be doing all or part of their billing and collecting by electronic data processing by the end of 1962. In addition, the New England Telephone Company will begin a trial this fall in which EDP will ultimately be used in service order processing, disbursements accounting and directory operations work. EDP trials involving other promising work areas are being undertaken by other Bell System companies.

The history of the new concept of billing goes back a number of years to the Bell System Data Processing program at Bell Laboratories, which was aimed at determining which routine operations could be performed by computer equipment, and the best methods for accomplishing the changeover.

Studies were also made to determine the programming and instruction procedures which would enable commercially available equipment to accomplish these ends. Basic operating principles, such as daily updating of all records, and recommendations on basic programming steps came out of these studies. The specific implementation of these basic concepts resulted from cooperative efforts by personnel from the Laboratories, A.T.&T., Bell of Pennsylvania, as well as other Operating Telephone Companies, and the equipment manufacturer, in this case the International Business Machines Corp. The trials getting under way in other Operating Companies use computing equipment provided by different manufacturing concerns.

In addition to the programming and instruction aspects, there were several pieces of special equipment which had to be designed and built to perform specific functions. Perhaps most important of these is a converter to take information

Mrs. Mary Fogel, Bell Telephone Company of Pennsylvania, puts new roll of AMA paper tape on converter to "translate" AMA 2 out of 5 code into binary-coded decimal language on magnetic tape.

from the Automatic Message Accounting tapes and put it on magnetic tapes for input to the computer. In this conversion, a standard 24-line per minute Western Electric reader, normally used to read into an Assembler-Computer, reads instead into a specially designed IBM unit. This unit converts the data in the AMA 2 out of 5 code into a binary-coded decimal language, and records it on magnetic tape. The conversion is one for one, with one character of data on the AMA tape represented by one character on the magnetic tape. Approximately ten AMA reels fill one magnetic tape reel when converted. The AMA information fed into the converter includes 1½ million toll calls and 4½ million message units per month.

Teletypewriter Tape Converter

A second major converter used in the system converts service orders received from business offices and test centers in the revenue accounting area into suitable form for computer input. These orders are transmitted to the center over TWX circuits, and there punched into standard five-character teletypewriter tape. These tapes are read by a paper-tape reader, and the information is passed through a peripheral computer to magnetic tape for later use in the system. This process proceeds at the rate of 500 characters per second, and can presently handle all the service orders the center receives over the TWX circuits in about thirty minutes per day.

Other accessories provide the essentially standard computer capabilities for inserting and removing information on punched cards and mark sensed cards, and printing out the huge volumes of information required in the billing procedure.

The most significant aspects of the BSDP study in relation to the present installation were the primary studies to determine the specific jobs to be done, and the best ways to do them. In addition to defining what to do, questions such as how often it had to be done, how much of the work was to be processed, how errors were to be checked, how the files were to be arranged for sorting and checking, and how frequently they were to be updated had to be answered. These studies were essential in determining the capacity and speed necessary in a computer system, and showed the computer properties which were most important for the job.

A welcome "fringe benefit" resulted from the BSDP program at Bell Laboratories. During the time the study was going on, there were several men from Operating Companies on loan to the Laboratories, training for such work in their home companies. Many of these men were used in the Conshohoken trial. Because of the Bell Laboratories program, they will form a "cadre" of experienced individuals who will be of great assistance in getting the program underway in the other companies.

Mary O'Byrne, of Pennsylvania Bell, threads teletypewriter tape into reader, transmitting service order information to EDP equipment.

The BSDP study also developed a list of additional tasks which are amenable to computer handling, besides the obvious one of billing and collecting. Among these are service order, directory, payroll, property and cost accounting, supply operations, and a number of engineering applications. Looking ahead, it is expected that all or most companies will be performing these jobs by EDP processes, either on the same computers used for billing and collecting or on separate machine systems.

The decision to go into computer operation is a major one, since computing equipment is inherently expensive and complicated. In addition to equipment costs, personnel training and computer programming add substantially to the overall cost. It is obvious therefore that any savings gained through the use of standard programming in the various applications will be a big factor towards reducing the expense, time, and difficulties involved in this giant step forward.

The first transistorized negative-impedance repeater, designed to improve transmission over local lines, is available to telephone operating companies. This repeater—the E6—is a plug-in unit that requires little power and is easily installed and maintained.

W. J. Kopp

Applications for E6 Repeaters

In the early days of the telephone, if you wanted to place a call from New York to Denver you'd have to give your message to an operator in Chicago and she would repeat that message to the party in Denver. All conversation was passed back and forth by the Chicago operator. Such an operator became known as a "repeater." She was needed because attenuation along a line increases with distance to such an extent that calls over long distances were virtually impossible without her help.

Although the principle of the early "repeater" remains the same, technological research has made possible electronic devices that compensate for attenuation over a telephone line and permit direct conversations throughout the world. Today's telephone repeater does not "repeat" in a literal sense; rather, it amplifies the voice signals that pass through it. Many types of repeaters are used in the telephone plant; some are for carrier and radio transmission, and some are for voice-frequency transmission over local networks connecting several central offices.

Repeaters have been used on toll routes for more than 40 years, but it has been only in the last 12 years that inexpensive voice-frequency repeaters have been available to the local plant. These are negative-impedance type repeaters that not only improve transmission between telephone subscribers but also permit the use of smaller gauge cable which results in considerable savings.

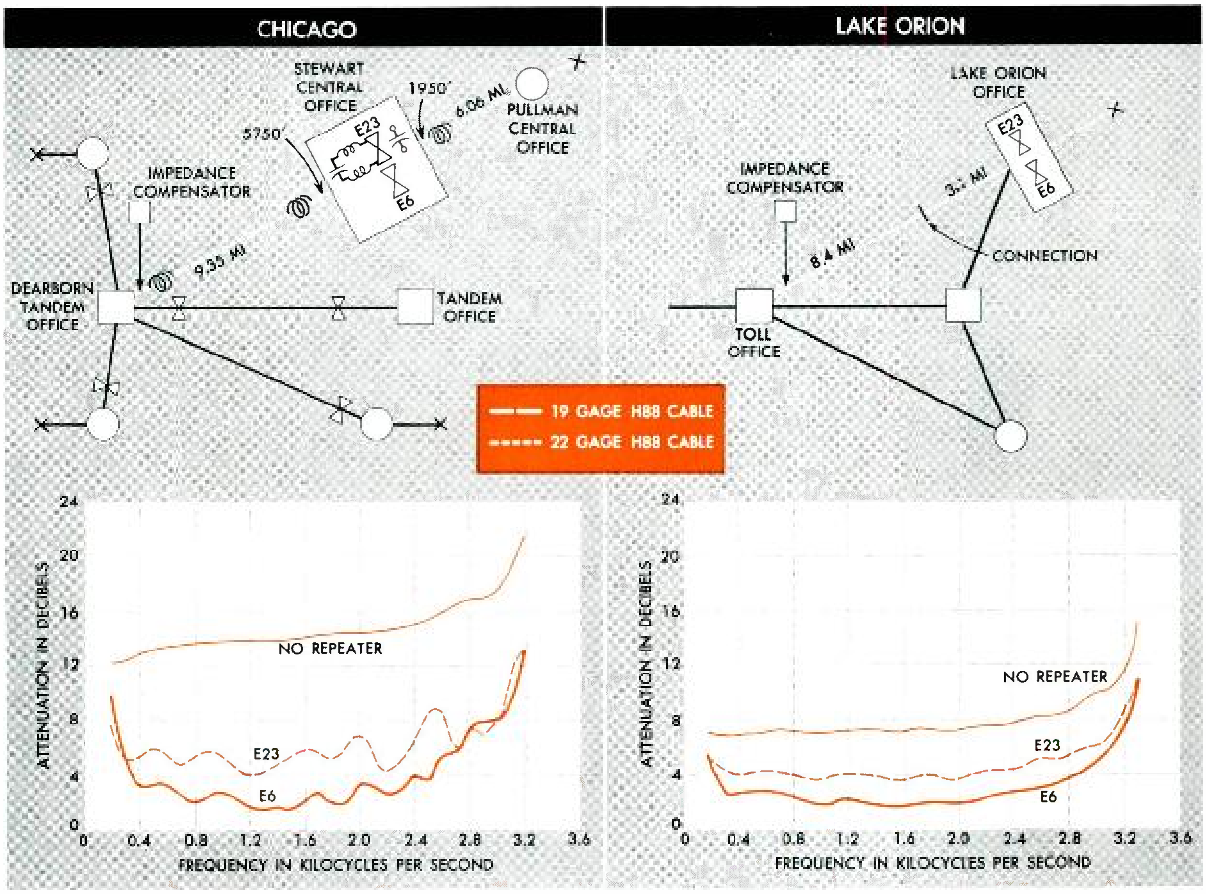
Although negative-impedance repeaters are used primarily in local areas, they are also used to reduce transmission circuit loss in the links between long-distance toll lines and local offices. Today, more than a million local and toll connecting trunks in the Bell System are using negative-impedance repeaters.

In spite of the widespread use and good maintenance history of the early negative-impedance repeaters, some important shortcomings prompted work on a new design. Until recently, all telephone repeaters used electron tubes requiring a 24- or 48-volt battery for the heaters and a 130-volt plate-battery supply. The 130-volt batteries are not available in all central offices and are rather expensive to install. In many places, such as unattended community dial offices, insufficient space for batteries makes it impossible to install repeaters. Where there are many bays of repeaters, the heat produced by the electron tubes can be undesirable. And, because of the large numbers of repeaters being put into service, the Operating Telephone Companies wanted equipment that was easier to install and adjust.

Late in 1959 a new negative-impedance repeater went into production at Western Electric's plant in Merrimack Valley, Mass. This new unit is the E6 telephone repeater. Transistors reduced the power requirements, heat dissipation and size of the repeater (RECORD, *July*, 1961); new packaging and equipment designs made installation and maintenance procedures easier; printed wiring and new assembling techniques cut manufacturing costs. This year, Western Electric will manufacture about 250,000 E6 repeaters. This article describes the E6 repeater—how it operates and how it is used in the telephone plant.

In the previous repeater model, made up of an E2 and E3 unit (designated E23), a complicated network composed of resistors, inductors, and capacitors required an installer to solder individually wires to the network terminals in each of the units. These networks served not only to match the repeater to the line impedance but also to set the amount of gain. Because of this arrangement, central-office personnel had to change the entire wiring combination for each gain step. This is time-consuming both on initial installation and whenever gain changes are necessary. Bell Laboratories engineers used a different approach for the E6 repeater. Instead of matching the impedance of the repeater to the impedance of the line, the E6 designers reversed the process. They developed the line building-out network (LBO), a passive element, and included it as part of the E6. This unit converts the impedance of the line (which heretofore had varied considerably over the frequency range) to a simple impedance of 900 ohms in series with a 2-microfarad capacitor. In this way, the negative-impedance converter, or gain unit, can be made much simpler, and the gain can be controlled by resistors alone. Central-office attendants adjust the LBO and converter units by simply turning screws on a printed-wiring board. This considerably speeds up installation and later adjustments.

In addition to the benefits derived from transistors and easier installation arrangements, there are other advantages obtained with the E6. With a combined series and shunt converter in one housing, almost twice as many E6 repeaters can be installed in a standard equipment bay. A better impedance match between repeater and line makes possible more gain and more stability on a given circuit. This results in circuits with potentially lower net loss (some 1 to 2 db less) than with previous repeaters.



Circuit layouts at Chicago, Ill., and Lake Orion, Mich., showing how the installation of the E6 repeater eliminates external "build-out" equipment and improves transmission performance.

The E6 repeater may be used at either the terminals or at an intermediate central office, or both. A terminal repeater requires only one LBO unit, which not only "builds out" the line to a standard (6000-foot) end section, but also acts as an impedance compensator to match the office impedance. This is another advantage over the older types of E repeaters which required additional equipment to achieve a good impedance match.

Two line-building-out networks are available, one for high-capacitance H88 circuits and the other for low-capacitance H88 circuits. The latter may also be used on high-capacitance D88 cables. These types of facilities constitute the great majority used for voice circuits.

To control crosstalk, gain at a trunk terminal is limited to 7 db. Intermediate repeaters must be used for gains greater than 7 db. This calls for two LBO networks. With the E6 repeater, gain can be adjusted from 1 to 13 db in increments of 0.1 db. Such fine adjustments, not possible heretofore, make for more uniform transmission.

In those repeater bays that have the optional test jacks, the attendants can use the test sets designed for the E6 to check the repeater gain quickly without taking the circuits out of service. Before adjusting the LBO, central-office personnel first check standard charts based on the cable layout. If the cable information is not accurate or if the trunk is not all of the same gauge, the initial settings of the repeaters do not always give satisfactory results. The E6 testing equipment makes it possible to obtain the optimum settings for a particular trunk.

As we have seen, the E6 repeater is not a transistorized copy of the E23 repeater; it does not plug into the E23 repeater shelves. With a few exceptions, such as other types of loading, it may be used on most types of circuits where E23 repeaters are now used. These include interoffice, tandem, toll connecting, and those special-service trunks which are used to extend a telephone loop from one central office to another.

Several pre-production models of the E6 repeater were field-tested in Atlanta, Chicago, Denver, Massapequa, N. Y., Westfield, N. J., Lake Orion, Mich. and Athol, Mass. Trials such as these permit design engineers to see whether the repeaters work as well in the field as in the laboratory. Such trials facilitate checking the new test sets.

The field trial in Chicago is an interesting example of an intermediate repeater application in a tandem-to-local-office system. In this case, the E6 repeater not only improved transmission, but it also enabled telephone company engineers to simplify installation. The circuit layout is shown on page 363. The lower part of the drawing indicates transmission results with no repeater, with the E23 repeater, and with the E6.

C. McGibbon of New Jersey Bell Telephone Co. checks E6 repeater at Westfield, N. J. office.

When the E23 repeater is used on the line, the end section on each side of the repeater must be built out to at least 3000 feet but not more than 4000 feet. When end sections are greater than 4000 feet, a distortion penalty reduces the available gain. To avoid this penalty, the 5750-foot side at the Dearborn office in Chicago was built-out to the equivalent of 6000 feet, and an 88-mh load was added. Capacitors in the E23 repeater were then used to obtain the equivalent of 3000 feet of cable. On the 1950-foot side, an external capacitor was required to bring the end section to an equivalent of 3000 feet of cable. With the E6 repeater, no additional external components were needed because it can be adjusted for end sections from zero to 6000 feet.

Another testing location was Lake Orion, Mich. Here is a case where there were toll-to-local-office trunks with repeaters at the local office. For terminal use, only one LBO network is required. The circuit layout and comparative results are shown in the illustration on page 363. All measurements were made between the main distributing frames and do not include the office equipment. Note the improved transmission obtained with the E6 in contrast with the E23 repeater.

In recent years, the requirement for satisfactory over-all operation of the telephone plant has become more demanding. The E6 telephone repeater helps make it possible to meet these new objectives.

An aircraft detection system is only useful if there is an efficient way to extract the information it collects. This is the job of pictorial and symbolic displays which must quickly and accurately present data on attacking aircraft for weapon direction.

R. Hammell

DISPLAYS FOR WEAPONS DIRECTION EQUIPMENT

Man-machine systems have become so complex that it is often difficult to extract information from the machine and to insert decisions from the man. As a result, designers have had to pay more and more attention to equipment for the display and control of data. This has been particularly true in the Mark 65 Weapon Direction Equipment developed at Bell Laboratories for the U. S. Navy (RECORD, *July*, 1960). This system not only requires the display of large amounts of information to decision-making men, but also requires controls so that these men can execute their decisions quickly and accurately.

In brief, the new Weapon Direction Equipment operates by progressively filtering incoming enemy air traffic to ensure that the guns and missiles aboard a ship fire first on the most threatening targets. The success of such an operation depends on coordination among the men and machines in the several stages of target processing, and on the swift transmission of accurate commands to radars and weapons.

The display and control equipment consists of an assortment of operating consoles. In general, a console presents tactical information to its operator by one or two large cathode-ray screens and by groups of colored lamps. When appropriate, manual controls are grouped around the display devices; other controls are mounted on small auxiliary panels.

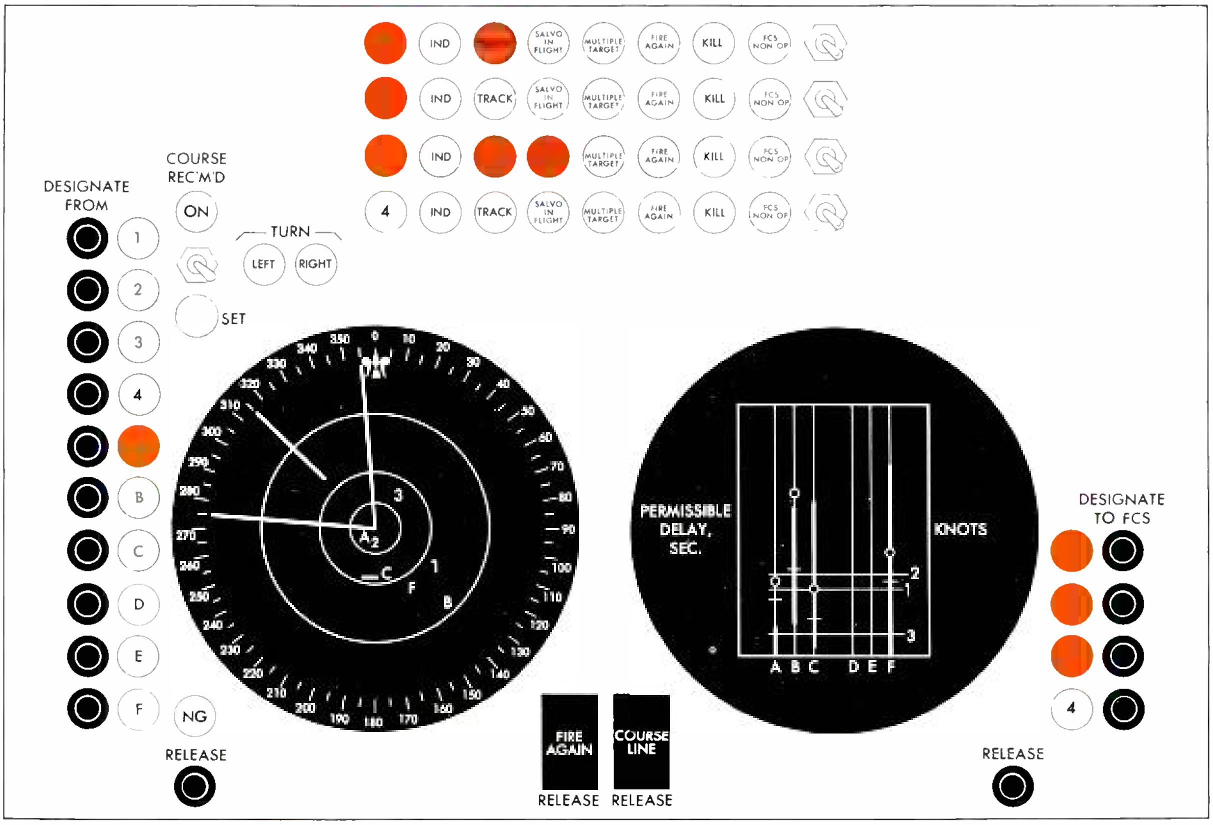
As far as these controls are concerned, a complete antiaircraft engagement is fought in several stages. For example, operators at "first-stage" consoles, viewing the behavior of many airborne attackers, can quickly and accurately select the most threatening ones for immediate action. At a second stage, operators (at different types of consoles) give more detailed attention to the above selected targets, and in turn designate the most critical of these for individual automatic tracking by fire-control radars mounted above the deck. Operators at a third stage must compare the targets being tracked by these fire-control radars, assign idle missile launchers to the selected targets, and initiate the actual firing.

General problems faced by the display designers included (1) showing only those data essential to decision-making at each stage; (2) providing carefully arranged controls for initiating orders to men or machines; (3) displaying feedback information for monitoring the results of the orders. Throughout the project, the designers paid meticulous attention to small details, for the stakes were much higher than those facing a designer of civilian equipment. When a commercial product is not well received, the most serious consequences may be financial embarrassment for the maker. Design deficiencies in a weapons system, however, may lead to military disaster.

After they had broadly defined the major operating tasks in successive stages of target processing, Bell Laboratories designers considered the means of display. They first determined that all normal operating data would be furnished visually, thus reserving the operators' auditory senses for telephone consultation. The advantage of presenting data visually is that the operator can concentrate on one detail at a time, shifting his gaze in whatever sequence he finds necessary. Moreover, visual displays are essential when the positions and motions of many targets must be shown simultaneously. In contrast with this, audible data must be delivered serially, so that the operator must try to retain the information in his memory while he sifts and sorts it. Also, the welter of sounds in many military operating stations makes audible reception very difficult.

To avoid overloading an operator with "too much" information, designers restricted displayed data to a minimum and eliminated distracting details from the field of view. As with electrical-communication channels, a display and control panel has a "signal-to-noise ratio". Although it would be difficult to assign a numerical value to this ratio, it evidently must be greatest when the only details in the field of view are those necessary to the operator's job. "Noise" in this case includes unnecessary protruberances from panel surfaces, long or complex captions, bright backgrounds and extraneous light sources, glare, or controls of little importance.

Of special concern to display designers was the operating environment for the display consoles. To a great degree. room noise has been reduced by the emphasis on visual displays. In addition,



Director assignment console shown in diagrammatic form uses combination of pictorial and symbolic displays to show the tactical situation and permit engaging targets in optimum sequence.

forced-air circulation, or air conditioning, enhances operator physical comfort. But as is usually true in radar operating rooms, lighting presented the most difficult environmental problem.

When radar data are shown on a cathode-ray screen, the light output from the target blips is very low. The phosphors from which most screen coatings are made tend to have very light colors, aggravating the problem of getting high contrast between the light spots and the surrounding screen area. This usually requires darkening the room, making almost every task, other than reading the cathode-ray display, much more difficult.

In the Mark 65 System, captions are lighted from within the panel, using "transillumination." Long used on aircraft equipments, this method involves trapping light in a flat sheet of transparent plastic. On the upper surface of the plastic sheet, translucent captions are surrounded by an opaque background so that the light is emitted only by the captions.

In the over-all effort to raise the visual signal-to-noise ratio, Laboratories designers developed special techniques so that no fasteners would appear on the panel surface. A new kind of lamp socket, which mounts beneath the panel and does not require a through-hole, has aided in the reduction of visible detail. Also, signal-lamp caps are installed below the panel surface. As a result of these measures, the panels have a clean appearance; manual controls are the only projections.

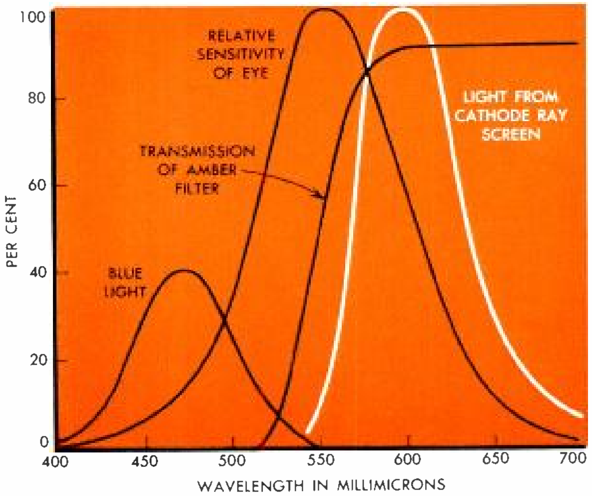
Special Lighting

In recent years, an ingenious method of room lighting was adopted for the SAGE system (RECORD, *October*, 1957) which permits lighting an entire radar room without material effect on scope reading. This method depends on dividing the visible spectrum into two halves, the long-wave portion being reserved for cathode-ray tube data and the short-wave portion being assigned to room lighting. A suitable filter is placed in front of the cathode-ray screen to bar room light from the screen, and thus maintain high background contrast. Blue in appearance, this room lighting is derived from standard white "daylight" fluorescent lamps, surrounded by blue plastic cylinders, and equipped with a special dimming system.

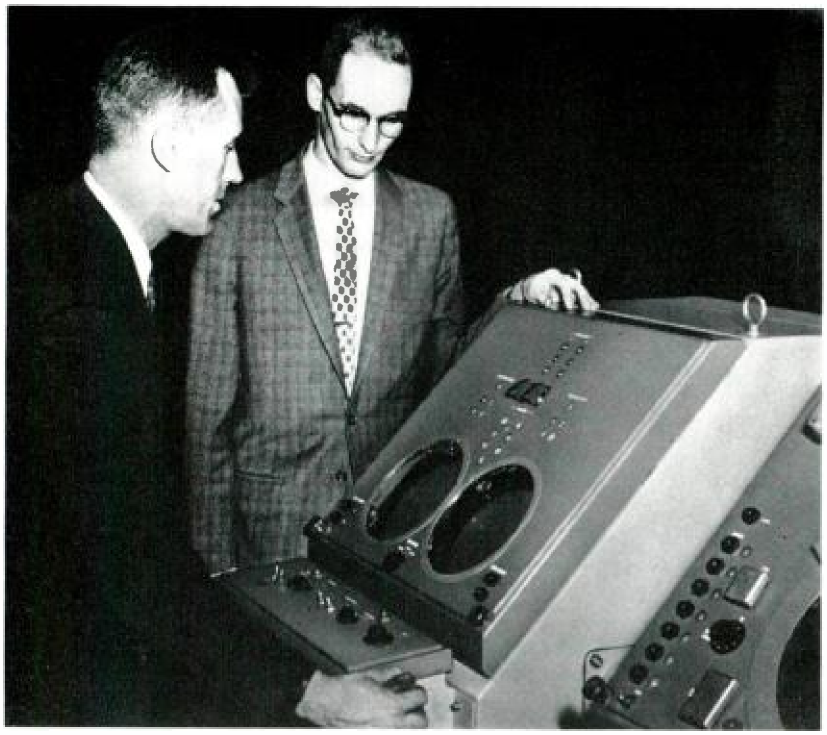
Considerable experimentation was required to adapt the blue-lighting system to the relatively low and irregular "overhead" (ceiling) typical of shipboard operating spaces. Installation of this system aboard ship has definitely improved operators' comfort and efficiency. The light can be made bright enough so that a man can enter the room, immediately after being in the bright sunlight, and recognize nearby people. It aids greatly in the rapid location of controls, and even, to a limited degree, permits brief messages to be written and read.

Visual displays are generally classified as either "pictorial" or "symbolic." The standard display for target data is a circular cathode-ray screen called a Plan Position Indicator (PPI). "Own ship" is usually at the center of the screen, and the targets appear as blips of light disposed about the center. Because it resembles a map, the PPI is classed as a pictorial display.

In symbolic displays, the information is encoded in some manner. Speedometers, thermometers and flashing or color-coded lights are in this class. In developing the symbolic displays for the Weapon Direction Equipment, designers used great care in selecting the lamp colors to be associated with various functions. For example, they adopted the following criteria for selection of colors: the total number should not exceed four; the colors should be widely dissimilar to minimize the chance of confusion; and, if possible, their use should agree with established habits of the United States population. The accompanying table shows the final choices of color and their associated meanings. Categories of information conveyed by green, amber and red lamps are similar to those associated with highway traffic lights. In shipboard equipments, these color-function relationships have stood the test of time, and the Navy's Bureau of Weapons now requests all contractors to use them as guides in the design of ordnance equipment.



Visible light spectrum is divided so that room lighting falls into shortwave portion, while CRT data is displayed in longwave portion of spectrum.



The author, left, operates firing key on weapon-assignment console while G. W. Bigelow observes subsequent action.

Perhaps the most interesting console in the Weapon Direction System is the one used in the "second stage" of processing. It is here that the ship's Gunnery Officer observes the progress of the antiaircraft battle, and it is here that his tactical decisions are executed. Engineers who developed this console were faced with a challenging problem. The display must enable the operator to evaluate the relative threat levels of a number of targets. His speed and accuracy of decision are of the greatest importance. Moreover, the operator must assess the ship's ability to engage the most threatening targets, and he must decide quickly the sequence in which the targets will be engaged.

Console Details

A product of extensive planning and experimentation, the main control panel of this console embodies a complex combination of pictorial and symbolic displays, giving a large amount of essential data within a small area. On the left of the panel for example, a PPI gives the operator a tactical picture of targets, including those being tracked by fire-control radars. The PPI also shows the heading of "own ship," and the locations and widths of sectors in which the target engagement is obscured by the ship's superstructure. The positions of the most threatening targets, as selected at the first-stage console from search-radar data, are depicted by single electronically-generated letters. Numerals on the screen reproduce the positions of the ship's fire-control radars.

A second cathode-ray display, on the console's right, aids the operator in evaluating the relative threats of the targets, and in determining the sequence in which the fire-control radars should be assigned to the most threatening targets. The display shows target threat in terms of "closing time" for each of the search-radar targets selected in the system's first stage. Also indicated are estimates of how much longer each fire-control radar will be occupied with its present target.

The right-hand cathode-ray screen has a vertical, electronically-generated, line for each selected search-radar target. Each vertical line shows the time interval during which a fire-control radar can be successfully assigned to the target. The distance from "zero time" on the display to the bottom of the vertical line represents the earliest time for assigning a target; the distance to the top of the line represents the latest time.

The rectangular display also has long horizontal lines associated with busy fire-control radars. Their distance from the bottom of the screen gives an estimate of how much longer the radar will be occupied with its present target. This aids the operator in planning the future phases of the battle, and permits using the available weapons with maximum effectiveness.

On each of the vertical lines is a small circle and a short horizontal line that move to indicate the target's speed and altitude, respectively.

In developing these displays, engineers constantly sought to reduce the probability of human error, and to display instantly the system reactions to orders. For example, in the execution of the more important decisions the operator is required to press two pushbuttons simultaneously. Moreover, the principles of feedback are used to show how other men or machines have responded to orders. The following description of second-stage console operation illustrates the application of these safeguards.

Suppose that after careful consideration of his displays, the operator decides that target A should be handled by fire-control radar number 2. He presses the A button in the "Designate From" column of the console, and simultaneously presses the 2 button in the "Designate to FCS" column. He holds these two buttons depressed until a lamp has lighted adjacent to each pushbutton, signifying that the desired connection has been made.

The numeral 2 now appears on the plan plot, and its motion exactly reproduces the motion of the fire-control radar as it seeks out and commences tracking the target automatically. In this case, the numeral 2 should come to rest adjacent to the letter A. If it were to stop at some other place on the screen the operator would know that the radar had acquired the wrong target and he would then take quick corrective action.

Having assigned fire-control radar number 2 to target A, the operator can change the radar's assignment merely by pressing the 2 button, as before, the button representing the new target.

Fail Safe Design

One further illustration of the designer's efforts to minimize human error is the requirement that to release a radar from its assignment, the operator must press the button in the "Designate to FCS" column together with a "Release" button. This assures that accidental pressure on a single button will not disturb an important connection.

Pressure on a single button, however, provides various indications that were designed as aids to the operator. As an example, there may be times when several target and radar symbols are clustered in the same small area of a cathode-ray screen. Pressing a single button, pertaining to a target or to a radar, greatly increases the brightness of the corresponding symbol on the screen, and makes it easy to read that symbol.

In summary, this console presents a detailed, running picture of the antiaircraft battle, and makes possible swift and accurate execution of tactical decisions. Before this equipment was introduced to the fleet, the Gunnery Officer traditionally stationed himself at a point high on the ship. Here, he would attempt to watch the action directly and to direct his forces by telephone or rudimentary control panels. Experience with the second-stage console has shown that it presents a comprehensive picture of actions covering thousands of square miles. Therefore, the Gunnery Officer has moved from his exposed station, and now is never far from this display.

COLOR	FUNCTION
RED	*Stop* Danger (e.g., safety interlocks shorted). Blown fuse alarm (power OFF). Emergency, urgency, alerting, warning. Complete casualty (to a major function).
GREEN	Go Power ON OK Last event in an important sequence
AMBER	Conditions intermediate between red and green Power in STANDBY condition (vacuum tube heaters energized). Partial casualty (having relatively minor effect).
WHITE	Routine Operating Data Locating captions

Whenever new display and control practices were considered, engineers gave them careful examination in the laboratory. But they knew that no laboratory evaluations, however detailed they may be, can substitute for field experience. The reactions and responses of designers do not necessarily agree with those of military operators. And, of course, it is not possible to duplicate in the laboratory the emotional stress and tension to be found under real or even simulated combat conditions. For these reasons, the opinions of operating personnel and their supervisors were solicited, and the equipment was given thorough tests aboard ship.

Naval personnel have operated these display and control positions extensively, under conditions of simulated combat. Their expressed satisfaction with the equipment indicates that the design efforts and concepts evolved at Bell Laboratories have been successful.

As automatic communications becomes more and more complex, so does the equipment needed to test and maintain it. For this reason, Bell Laboratories has developed for the 82B1 Teletypewriter Switching System a unique testing facility, ideally suited for a customer-housed system.

R. K. Bates

Test Equipment for the 82B1 Teletypewriter Switching System

One of the most important features of a communications system is its dependability. Therefore, many Bell System services incorporate elaborate ways to assure that they are working properly. This manifests itself in testing equipment for checking devices and circuits both before and after they are installed.

This philosophy of dependability was very much in evidence during development of the 82B1 Teletypewriter Switching System (RECORD, *May*, 1960). Evolved by Bell Laboratories for the U. S. Navy, this system serves teletypewriter switching centers located throughout the United States. Unlike many other Bell System services, however, this one operates for the most part on the premises of the customer. This calls for careful arrangement of the equipment, especially for in-service maintenance and repair.

Basically, a teletypewriter switching center is made up of a number of incoming and outgoing cabinets which receive and transmit messages. Two teletypewriter lines are assigned to each incoming-line cabinet and from one to four are assigned to each outgoing-line cabinet. The incoming cabinets receive messages in teletypewriter form on "reperforator-transmitter" machines which store them in the form of holes perforated in paper tape. Here, the "precedence prosign" of each message is checked to determine its priority, and destination address is decoded by special contacts. Also, certain parts of the address are checked for accuracy. The address of a message determines which outgoing cabinet should be used. When a connection across the office has been established, the reperforator-transmitter sends the message across the office to the proper outgoing cabinet at 200 words per minute.

As it is received in the outgoing cabinet, the message is again stored on perforated tape. A continuity check is made to assure that there is a cross-office path. Then, a new number is inserted into the message and it is sent on to its destination.

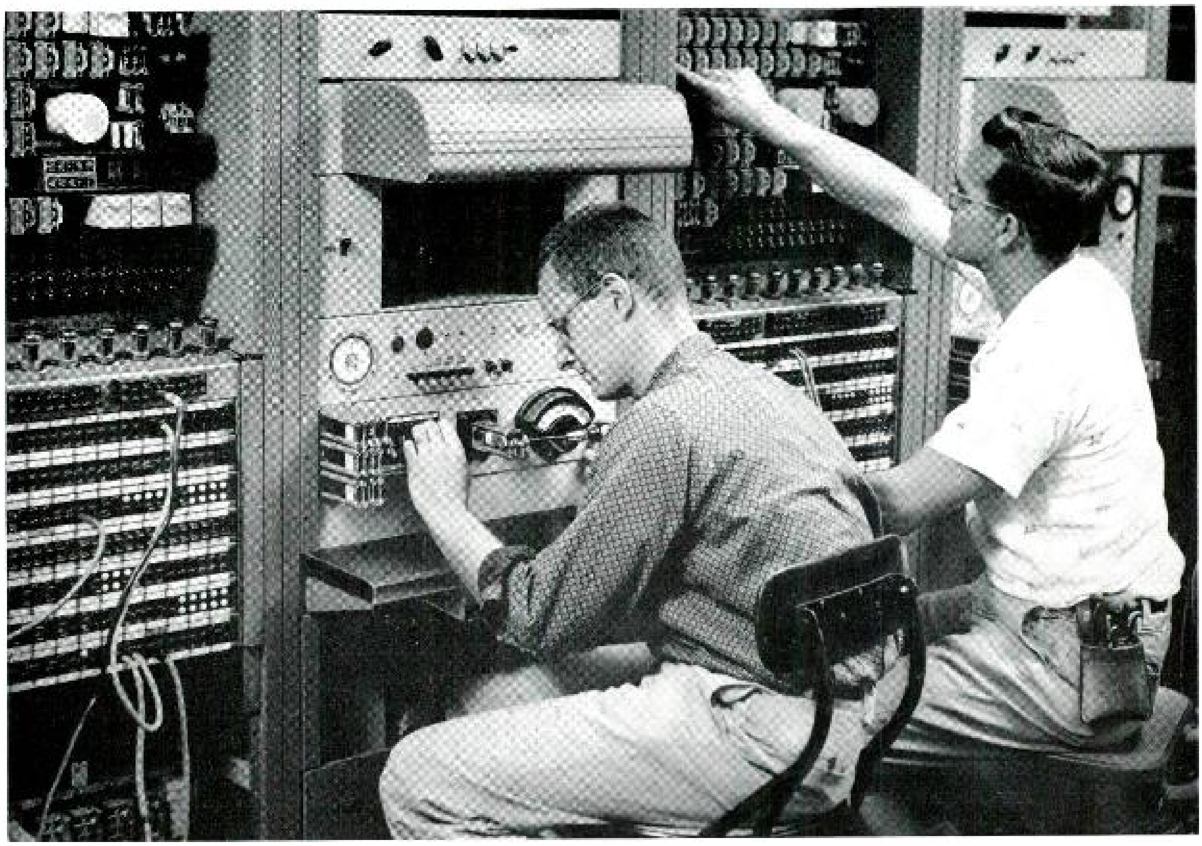
The testing facilities for the 82B1 system consist of two cabinets, two work and test benches, and one or more cable-storage wall boxes and miscellaneous portable testing apparatus. One of the cabinets contains power supplies and a telegraph distortion set that introduces, for test purposes, specific amounts of a given type of distortion into teletypewriter signals. This cabinet also contains an electron-tube tester, a relay-test unit and a portable set for measuring telegraph transmission.

The other cabinet has jack and key-panel equipment and relay equipment to simulate switching-cabinet circuitry. It also houses an "electronic distributor," a coding circuit for determining the characters to be sent by the electronic distributor, and electron-tube repeaters used to supply test signals to the reperforator-transmitters. The work and test benches furnish working space and contain relay equipment for testing the contacts of the reperforator-transmitters.

This equipment, in addition to miscellaneous teletypewriter equipment is located in a maintenance area separated from the switching center. The only part of the test facilities in the switching center itself are the wall boxes that store cables. These boxes contain the connectors and jacks that extend the test circuitry to the switching-center cabinets. This arrangement helps reduce congestion, noise, and general interference with switching-center personnel.

Three fundamental groups of tests may be performed by the testing facilities. One group consists of those tests made during installation of a switching center, or thereafter, on units that can be taken out of service. A second group consists of those tests performed on a cabinet in service with no disruption of traffic. The last group consists of tests made in the testing area on plug-in units removed from the system. These units may be replaced by others during tests so that the switching system may continue to function in a satisfactory manner.

When an 82B1 system goes into service, installers must be able to determine the working condition of each cabinet before inter-connecting it with other cabinets. For this purpose, the testing facilities provide simulated circuitry for both incoming and outgoing cabinets of the switching center. By operating keys and "patches," installers can test the inter-cabinet function of each. A cabinet in the switching center can be connected to the testing facilities by way of multi-contact plugs in the wall box.



O. F. Martin, left, and W. H. Topley, both of New Jersey Bell Telephone Company, operate test equipment in the United States Navy's teletypewriter switching center in Trenton, New Jersey.

Here, the testing circuitry can represent the balance of the system and test the functions required. In this manner, troubles within a single cabinet may be eliminated before it is inserted into the over-all system.

Special Circuit

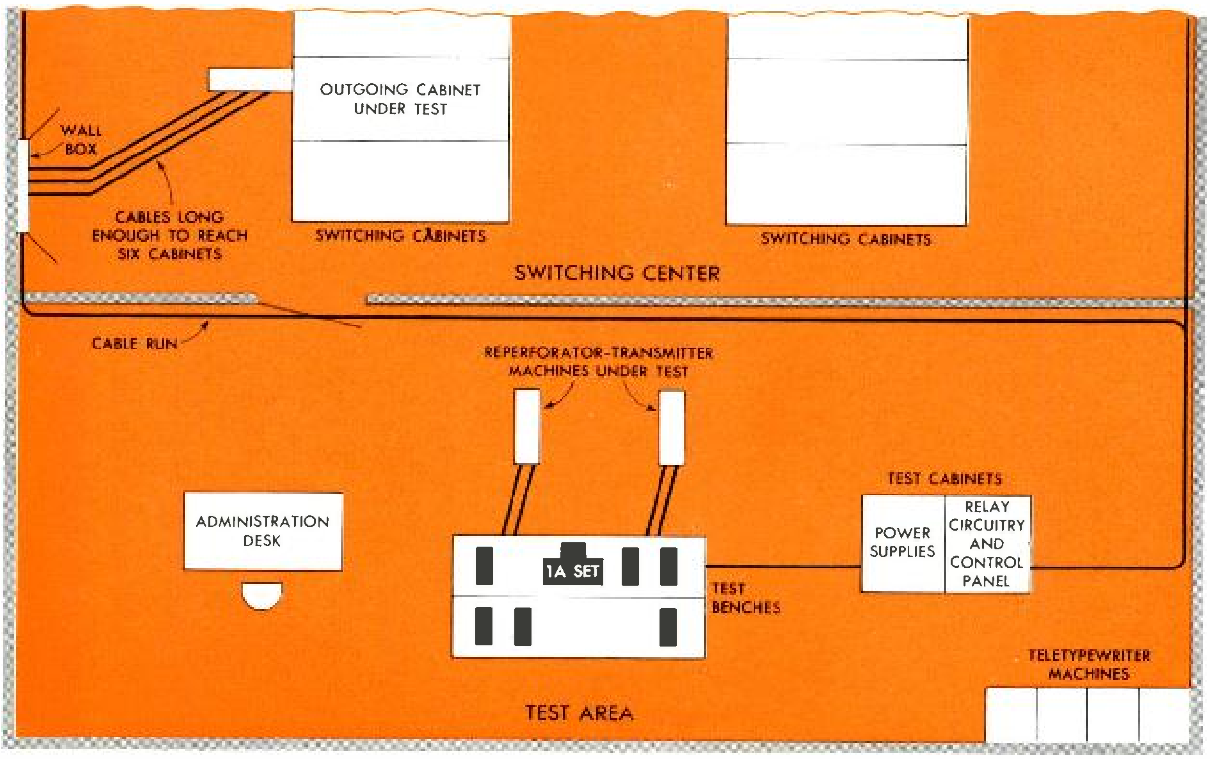
The testing facilities provide another feature called the "one-at-a-time" circuit. This is an excellent tool for locating trouble in the high-speed circuits of the reperforator-transmitter. By patching from the cabinet to the test facilities, installers may insert the one-at-a-time circuit into the control circuit for any of the reperforator-transmitters in any cabinet. This circuit permits only one character to be sent at a time by pushbutton operation, thus permitting high-speed sequences to be slowed down and carefully observed. Any time after installation, these same tests may be used to isolate trouble in the system if the cabinet to be tested is taken out of service.

Once the switching center is in operation, the equipment can be maintained either while "in service" or when removed and replaced by a working unit. One group of tests may be made with the equipment working thus causing no loss of service time to the customer. Another group of tests must be made on replaced equipment, causing a loss of time, but only during the actual process of replacement.

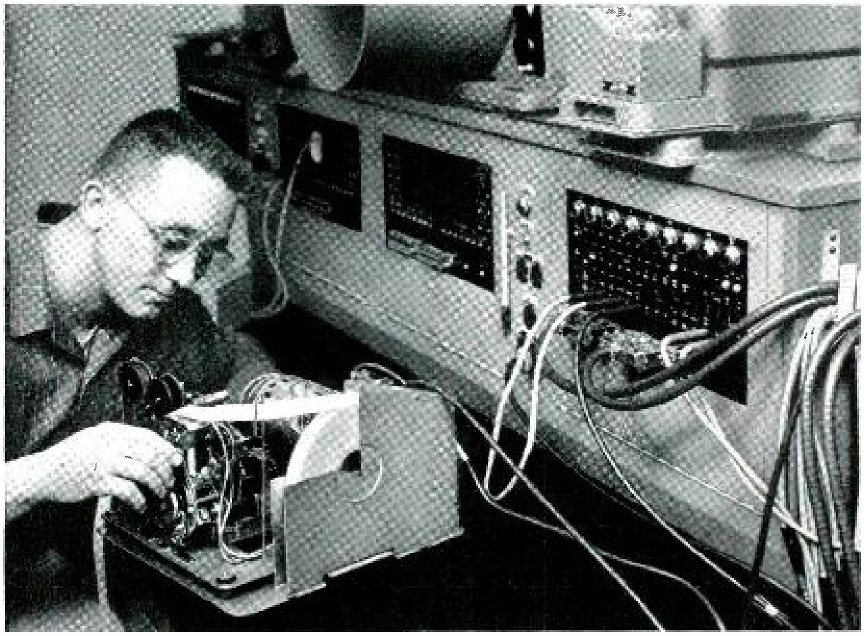
One important in-service test involves a high impedance input circuit that monitors or measures cross-office paths for distortion during normal traffic. Routine measurements of distortion can indicate the condition of a machine, so that it can be removed and re-adjusted before trouble conditions arise.

Tests made on replacement equipment comprise the bulk of routine examinations. Electron tubes and certain relays, for example, receive checks on panels installed as part of the test cabinet. These tests are performed periodically and as part of the normal maintenance of the system. The remaining tests performed on replacement equipment are those made on the electronic distributors and the reperforator-transmitters.

The electronic distributor is a device that uses diode logic and electron tube circuits to convert parallel fed data to teletypewriter-signal sequences. It is tested by connection to a receptacle on the test bench by a suitable patch cord. This receptacle provides the power sources re-



Typical testing room layout for an 82B1 Teletypewriter Switching System. Cabinets include distortion simulating equipment; benches contain equipment for testing reperforator-transmitters.



L. C. Nowakowski at test bench facilities checks out operation of typical teletypewriter machine.

quired, a way to code signals, and a relay to "step" the coding device. The coding device can be used to code any one character, or alternate two characters, or a test sentence. The output of the electronic distributor is fed through an electron-tube repeater and may be used to actuate a teletypewriter machine for monitoring. This provides an over-all test of the distributor—coding the input signal and observing the output. Further tests for trouble conditions may be made by observing the various wave shapes within the unit on an oscilloscope furnished as a part of the test facilities.

The other major function of the test bench is testing the reperforator-transmitters. These machines are connected to receptacles on the test bench which furnish all power required as well as connect the machine to the circuitry of the bench. Teletypewriter signals at any of the standard operating speeds may be fed into the machine to perforate tape. The contacts actuated by these signals may be observed in one of three ways: (1) on a group of neon lamps, (2) on the face of a teletypewriter test set, or (3) on an oscilloscope screen.

These observations can detect any irregularity in operation. The perforated tape may be transmitted from the machine being tested, and operation of the proper keys will switch the displays to the contacts involved. Further observation is possible with a monitoring teletypewriter that prints the actual transmitted characters. All auxiliary and supplemental contacts of the machine may be displayed for checking operation.

In addition to the display of contact closure there is an "RY read" test. The RY read test permits a test of the line reading contacts of the receiver or the sensing contacts of the transmitter. With the key panel arranged for this test, the characters "R" and "Y" are alternately sent into the machine by the coding circuit and the receiving contacts recognize these characters. R and Y characters are used because the letter R checks "reading" contacts 2 and 4 and the letter Y checks contacts 1, 3 and 5.

Since the machine contacts change position only when the pulses of the character "see" a change, all pulses of each character must change to check the contacts fully. The RY sequence does this. As long as R's and Y's are received and read, or transmitted and read on the outgoing side, the RY test circuit remains normal. If the machine reads incorrectly, that is, indicates a character other than an R or a Y, the machine automatically stops and a lamp lights. This visual indication attracts personnel to locate the trouble.

Switching center personnel will use the test bench and the equipment for testing the reperforator-transmitters most often for routine maintenance and to locate and clear troubles in them. The other portion of the equipment will be used less often but nevertheless will be extremely helpful in locating difficult troubles. On a whole, the test equipment provides a wide range of tests and can perform all necessary maintenance and trouble-locating functions required by a system installed on a customer's premises.

Command Guidance Plays Role In Titan Hardened-Complex Launch

News of Missile Guidance

The Air Force's mighty TITAN I ICBM took another stride toward becoming operational last month when it was successfully launched and guided from operational-type, "hardened" facilities for the first time.

After being elevated from its 146-foot deep underground silo and launched, the huge missile was accurately guided to a preselected target area down the Pacific Missile Range, near Wake Island, by the Laboratories Command Guidance System. Operational versions of the ground guidance units, manufactured for the TITAN I weapon system by the Western Electric Company were used in the shot and were also situated in the experimental hardened site. The guidance radar was elevated from its 42-foot deep silo just prior to launching.

Last month's initial test of the launching and guiding of the TITAN I missile was the first of a series of tests pointing toward operational status for the TITAN I weapon system later this year. The tests are being carried out under the direction of the Air Force's Ballistic Systems Division. When the missile system is declared operational, it will be turned over to the Strategic Air Command for deployment as an important part of SAC's aerospace deterrent force.

For these important tests of the Vandenberg facility, operational conditions were simulated as nearly as possible. An operational TITAN I launch complex is an underground system of shelters designed to protect equipment and personnel against the effects of nuclear weapons. These shelters, which are linked together by underground passageways, house all of the elements of the missile system — the missile, its guidance equipment, including guidance-radar antennas, a control center, and power equipment.

Just prior to launch, the missile and the guidance radar antenna are raised to the surface. The guidance computer, another vital element of the Command Guidance System, is located underground in the control center. By comparing tracking information from the guidance radar with a previously determined trajectory, the computer generates steering orders that are transmitted to the missile-borne guidance equipment via a communication link in the radar beam.

The TITAN I guidance system evolved from the command guidance philosophy pioneered by Bell Laboratories in the Army's NIKE family of air-defense missiles. This guidance philosophy has been thoroughly tested and proven in the NIKE AJAX and NIKE HERCULES missile systems. In its progress toward operational status, the guidance system has been tested many times with the TITAN I weapon system in developmental firings at Cape Canaveral and at Vandenberg AFB.

In its evolution, the Command Guidance System has been greatly refined. For example, an early model of the equipment weighed 380 pounds. A recent version for space applications is approximately one-tenth this weight. The reduction was achieved with smaller and lighter components, new materials and packaging techniques, and improved and simplified circuits.

Developed at the Whippany, N. J., location of Bell Telephone Laboratories for the TITAN I ICBM, this versatile guidance system has also been used successfully in the Air Force's Thor-Able re-entry test vehicle program and in the first stage of the Thor-Agena vehicles for the Air Force's Discoverer satellite program.

Command Guidance is also used in the Thor-Delta rockets that injected the National Aeronautics and Space Administration's Echo I, Tiros II and III, and Explorer X and XII satellites into their precise orbits.

The missile-borne guidance equipment is manufactured by the Western Electric Company at its Winston-Salem, N. C., plant; the Burlington, N. C., plant makes the ground guidance equipment. Remington Rand Univac manufactures "Athena," the guidance computer.

Solid-State Device Directly Amplifies Ultrasonic Waves

News of Solid-State Device Development

Ultrasonic waves have been amplified directly in a piezoelectric semiconductor crystal by Bell Telephone Laboratories scientists. The sound waves are amplified by interaction with electrons drifting in the crystal, in much the same way that electromagnetic waves are amplified in a traveling-wave tube. A new class of solid-state electronic devices such as amplifiers, oscillators, delay lines and isolators now appears possible based on the combination of piezoelectricity and semiconduction in certain crystals.

This new method of amplification was first proposed by D. L. White of the Solid-State Device Development Department while investigating ultrasonic attenuation in piezoelectric semiconductors with A. R. Hutson, a member of the Semiconductor Research Department. The principle and the first experimental verification of it are announced in the September 15, 1961 issue of *Physical Review Letters* by A. R. Hutson, J. H. McFee of the Electronics and Radio Research Department and D. L. White. They report that they have amplified an ultrasonic wave traveling through a crystal of cadmium sulfide (CdS) by applying a dc electric field in the direction of wave propagation. They observed gains of 18 db in a 15 megacycle wave and 38 db in a 45 megacycle wave traveling through a 7-millimeter length of CdS.

The amount of amplification obtained depends on the applied voltage and the conductivity of the material. CdS was used in the experiment because large single crystals are available which are strongly piezoelectric and have the required semiconducting properties. Since CdS is also photoconductive, the conductivity can be adjusted to just the right value for amplification by shining light on the crystal.

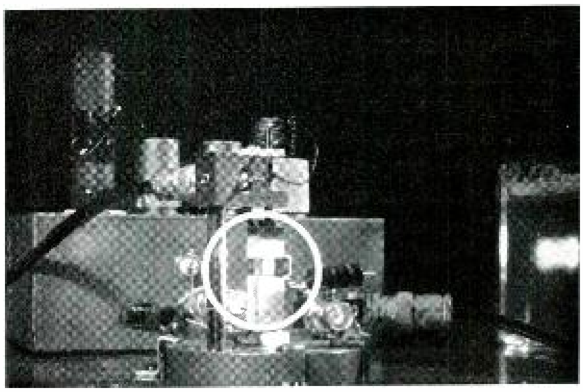
Direct amplification of high-frequency sound waves is possible because a sound wave traveling in a piezoelectric material produces a longitudinal electric field which travels along with the wave. If the material is also conductive, the electric field will cause currents to flow in the material. Because the piezoelectric field is periodic the electrons bunch together in parts of the ultrasonic wave. The bunched electrons tend to interact with the piezoelectric field and consequently react back on the material changing the velocity and amplitude of the sound wave.

Mr. White conceived the idea that if a dc electric field is impressed on the material, so that the bunched carriers are made to drift in the direction of wave propagation faster than the speed of sound, the sound wave will be amplified similarly to the way electromagnetic waves are amplified in a traveling-wave tube.

Messrs. Hutson and McFee experimented with a crystal of CdS with quartz transducers on both ends. An RF pulse applied to the transducer produced an ultrasonic wave which was propagated through the CdS crystal. It was converted by the transducer at the other end to an RF signal which was measured under various conditions of electric field and photoconductivity.

They found that if a dc field is impressed on the crystal while it is in the dark, there is no effect on the output signal. Also, if the crystal is illuminated without a drift field, conductivity increases and the sound wave is attenuated. However, if the crystal is illuminated and sufficient voltage is impressed on the crystal to make the carriers drift faster than the velocity of the sound wave, the wave is substantially amplified. This verified Mr. White's prediction.

Messrs. Hutson and McFee also observed that when no signal is put into the device and the drift field is applied for a comparatively long time, RF acoustic energy builds up from thermal noise. Ultrasonic waves propagating through the crystal in the direction of the drift field are amplified. Gain in this direction more than compensates for energy lost by reflection at the ends of the crystal and for energy lost as the waves traverse the crystal in the reverse direction. Thus the crystal becomes an oscillator.



In this experimental device, light is focused through filter (right) on CdS crystal (circled) to modify the photoconductivity of the material.

news in brief

H. E. D. Scovil Honored For Maser Development

H. E. D. Scovil of the Solid-State Device Development Department will be awarded a Stuart Ballantine medal by the Franklin Institute for "the invention of the three-level solid-state maser and its subsequent development for practical use." Dr. Nicolaas Bloembergen, Harvard University Professor of Applied Physics, will be a co-recipient of the award. The medals will be presented at formal Franklin Institute ceremonies, October 18.

Mr. Scovil, who joined the Laboratories in 1955, has been engaged primarily in the development of solid-state devices at microwave frequencies. He took part in designing the maser amplifier used in the Project Echo receiving equipment at Holmdel. The Stuart Ballantine medal is awarded for outstanding achievement in fields of communications which employ electromagnetic radiation.

J. L. Merrill, Jr., Cited By Franklin Institute

J. L. Merrill, Jr. of the Transmission Studies Department will be awarded the Edward Longstreth Medal by the Franklin Institute "for his analysis of problems associated with losses and distortion in telephone transmission systems; for his synthesis of the negative-impedance booster; and particularly for his successful development of a negative-impedance booster system that has proved to be highly effective and economical." The medal will be awarded at the Institute's Medal Day ceremonies, October 18. It is awarded annually by the Institute for "inventions of high order and for particularly meritorious improvements and developments in machines and mechanical processes."

Mr. Merrill joined the development and research department of the A.T.&T. Co. in 1930 and transferred to the Laboratories in 1934. His work has always been closely connected with telephone transmission problems. The negative-impedance repeater went into commercial use in 1949 and is now used in domestic and foreign telephone networks. Over 1.5 million are used in exchange circuits in the United States. Mr. Merrill holds eight patents, including four on negative-impedance repeaters.

G. C. Dacey Elected Sandia Vice President

G. C. Dacey, Director of the Solid-State Electronics Research Laboratory has been elected Vice President, Research of the Sandia Corporation. His new assignment will begin this month.

Mr. Dacey has been a member of the Laboratories since 1951. After spending his first years on transistor feasibility studies, he supervised a group engaged in development work on silicon transistors and cross-points. He was named Assistant Director of Solid-State Electronics Research in 1958 and was appointed Director in 1960.

Du Pont Medal Awarded To J. S. Courtney-Pratt

J. S. Courtney-Pratt, a member of the Mathematics and Mechanics Research Department, has been awarded the E. I. Du Pont Gold Medal of the Society of Motion Picture and Television Engineers for his work on high speed photography.

Since joining the Laboratories in 1958, Mr. Courtney-Pratt has been doing research in methods of high-speed photographic recording, optics, optical instrumentation, as well as other fields of applied physics. He has received a number of other awards for his work, among them the Sir Charles Vernon Boys Prize for experimental physics.

The Du Pont Medal is awarded annually for outstanding contributions to the development of techniques and equipment in the fields of instrumentation and high-speed photography.

BTL Co-Authors Awarded Medal for Paper

D. E. Koontz, C. O. Thomas and D. O. Feder, of the Transistor Development Department, were awarded the American Electroplaters Society Silver Medal for 1960 for their paper "Cleaning in the Electronics Industry." The medal was awarded at the AES National Convention in Boston in June. The paper had been presented at the 1960 National Convention in Los Angeles.

The society presents three medals—gold, silver and bronze—for the three best papers published during the year in the society's monthly magazine, *Plating* or in the Technical Proceedings of the National Convention.

A.I.E.E. Honors Former Labs Members

Major awards will be presented to one retired and one former member of the Laboratories by the A.I.E.E. at their Fall General Meeting in Detroit this month. Harry Nyquist, a member of the Laboratories for 20 years before his retirement in 1954, will be given the Mervin J. Kelly Award "for his fundamental role in the evolution of modern communication and control theories." C. H. Townes, a former member of the Laboratories and now provost of the Massachusetts Institute of Technology will receive the David Sarnoff Award "for research in resonance physics leading to major advances in communication technology."

TALKS

Following is a list of speakers, titles and places of presentation for recent talks presented by members of Bell Laboratories.

Benes, V. E., *Ultimately Periodic Behavior in a Class of Non-Linear Servomechanisms*, Symposium on Differential Equations in Non-linear Mechanics, Air Force Academy, Colo.

Benkert, R. C., *Education in Industry*, Montclair State Teachers College, Montclair, N. J.

Bird, Mrs. C. M., see Flanagan, J. L.

Black, H. S., *Satellite Communications*, Rotary Club of Summit, Summit, N. J.

Bray, A. R., see Iwerson, J. E.

Brown, W. L., see Smits, F. M.

Chirba, V. G., see Gibbons, D. F.

David, E. E., Jr., *Theory and Application of Speech Production and Coding*, I.R.E. Lehigh Valley Subsection Meeting, Allentown, Pa.

Ellis, W. C., see Treuting, R. G.

Flanagan, J. L., and Bird, Mrs. C. M., *Minimum Phase Responses for the Basilar Membrane*, Sixty-First Meeting of Acous. Soc. Am., Philadelphia, Pa.

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PATENTS

Following is a list of the inventors, titles and patent numbers of patents recently issued to members of the Laboratories.

Abbott, G. F., Jr.—*Supervisory System for an Electronic Counter*—2,996,248.

Andrews, F. T., Jr. — *Bipolar Pulse Transmission and Regeneration*—2,996,578.

Bozorth, R. M.—*Magnetic Field Detector*—2,997,648.

Buhrendorf, F. G. — *Electrical Connection and Tool and Method of Making Same*—2,998,590.

Chruney, M. Ericsson, H. W., Sr., and McCarthy, J. A. — *Beam Positioning Tube*—2,997,619.

Dickieson, A. C.—*Control System for Torpedo Steering* — 2,997,970.

Dickieson, A. C.—*Torpedo Steering System*—2,997,971.

Dimond, T. L., Pruden, H. M., and Vogt, C. O. — *Method of and Apparatus for Generating Coded Signals*—2,996,704.

Edwards, P. G.—*Control System for Torpedo Steering*—2,995,100.

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

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THE AUTHORS

H. D. Irvin

H. D. Irvin, a native of Jacksonville, Fla., joined the Laboratories in 1956 after receiving a B.S. degree in physics from the University of North Carolina. From 1947 to 1952, he was with the Research Division of American Enka Corp., working on problems of instrumentation in studies of the physics of cellulose fibers. From 1952 to 1956, he was Chief Engineer of Radio Station WUNC at Chapel Hill, N. C. He was also a consultant in instrumentation to medical research and psychological testing laboratories.

In his initial assignments at Bell Laboratories, he was concerned with problems of simulation in the human factors studies of new communication services and devices in the Human Factors Engineering Department. He was recently transferred to Military Systems Research. He is a member of Phi Beta Kappa and a senior member of the IRE. Mr. Irvin is co-author of the article on simulation in the Project Mercury program in this issue.

William L. Cowperthwait joined the Bell Laboratories in 1928 in the Toll Systems Laboratory where he tests and developed a variety of dialing, switching, and signaling circuits. Transferred to the Whippany Radio Laboratory early in 1942, he worked in the design of microwave components and the development and flight testing of intercept and bombing radar systems. After World War II, he engaged in military systems research, the development of advanced radar techniques and the flight testing of experimental high resolution radar systems. The co-author of "Around the World by Simulation" in this issue, he has recently completed his work on the project Mercury simulation system and is currently participating in the active satellite repeater project. Mr. Cowperthwait, a resident of Watchung, N. J., received his B.E.E. degree from New York University in 1939. He is a member of Eta Kappa Nu, the A.I.E.E. and the I.R.E.

W. L. Cowperthwait

William Pferd, who describes the automatic card dialer in this issue, was born in Elizabeth, New Jersey. After undergraduate training at Union Junior College and Purdue University, he entered the Armed Services in 1943. As an intelligence officer in the Air Force he served with the 98th Bomb Group in Italy and subsequently received a B.S. in M.E. from Rutgers University in 1947 and his M.S. in mechanical engineering from Newark College of Engineering in 1951. He joined the Laboratories in 1947 and was first engaged in the development of the ringer and dial for the 500-type telephone. He was appointed a supervisor in charge of development of a new coin telephone in 1955, and is presently in charge of a group engaged in exploratory development of station apparatus including public telephones, signaling apparatus and station connectors.

W. Pferd

Harold J. Hershey was born in Harrisburg, Pa., and grew up in Pittsburgh. His education at Penn State University was interrupted during World War II when he served as pilot, bombardier, and instructor in the U. S. Army Air Corps.

He returned to Penn State to receive his B.S. degree in 1948. He joined Bell Laboratories in 1952 in the Station Apparatus Department, working on a mechanical reperatory dialer. Since then Mr. Hershey has been concerned with both mechanical and magnetic reperatories, special rotary dials for Princess sets, and various experimental Dial-in-Handsets. More recently, he has designed for production the Card Dialer at the Indianapolis Branch Laboratory, where he transferred in 1956.

Mr. Hershey is co-author of the Card-Dialer article in this issue.

H. J. Hershey

Kenneth B. McAfee, Jr. was born in Chicago, Illinois and raised in Wilmette, Illinois. He is now a resident of Chatham, N. J. He received his B.S. in electronic physics from Harvard in 1946 and an M.A. and Ph.D. from Harvard in chemical physics in 1947 and 1950. He joined the Laboratories in 1949 and conducted experiments on diffusion effects and avalanche breakdown in semiconductor junctions. Later, he studied atomic diffusion in glasses and developed experimental helium-separation processes. Mr. McAfee is now working on processes of electron attachment to molecules. During World War II, he served with the Navy as Lieutenant in the Pacific Theater of Operations. Author of "Helium and Diffusion Separation" in this issue, Mr. McAfee has several patents on an avalanche transistor and diffusion techniques. He is a member of the American Physical Society, Sigma Xi, and the Harvard Engineering Society.

K. B. McAfee, Jr.

J. M. Wier received the B.S. and M.S. degrees in electrical engineering from Iowa State College in 1949 and 1950, respectively. He was employed in the Digital Computer Laboratory of the University of Illinois from 1950 to 1956 while completing the requirements for the Ph.D. degree at that institution. In 1956, he joined the Laboratories, and since then has worked on problems involving the systems aspects of data communications and data processing, the subject of his article in this issue. Mr. Wier is a member of the Institute of Radio Engineers, Tau Beta Pi, Phi Kappa Phi, Pi Mu Epsilon, Eta Kappa Nu, and Sigma Xi.

J. M. Wier

W. J. Kopp was born in New York City and lived next door to the magician Harry Houdini, who in many ways was a scientist in his own right. Now a native of Queens, N. Y., Mr. Kopp joined the Laboratories in 1929. He was first concerned with transmission measuring apparatus related to studies on transmission standards and effective transmission rating systems. During World War II, he worked on wire and radio networks, and after the war on system aspects of early mobile radio telephone equipment. In 1947, he became involved with the early work on the first negative-impedance repeater, the E1, and he helped design the first combination series and shunt repeater, the E23. He is now working on the system aspects of a new repeater for mechanized TWX loops. Mr. Kopp received a B.S. E.E. from New York University. For the past two years he has been a judge at the North Nassau Science Congress. He is the author of "Applications for E6 Repeaters" in this issue.

W. J. Kopp

R. Hammell was born in New York City. He received the B.S.-E.E. degree in 1940 from Rutgers University, and the M.S. degree from Stevens Institute of Technology in 1950. He joined the Laboratories after World War II service in the Navy, which included studies at Bowdoin College and M.I.T., and duty in the Southwest Pacific area. His work at the Laboratories has included development of radar units, and design of switching circuits, display and control positions for weapon direction equipments.

For two years, Mr. Hammell was an instructor in the CDT Program. After work on project UNICOM, he transferred to the Military Component Reliability Department, where he supervises the passive components group. He is Commanding Officer of the Naval Reserve Electronic Battalion in Summit, New Jersey, and is a member of the IRE. Mr. Hammell is the author of "Displays for Weapon Direction Equipment" in this issue.

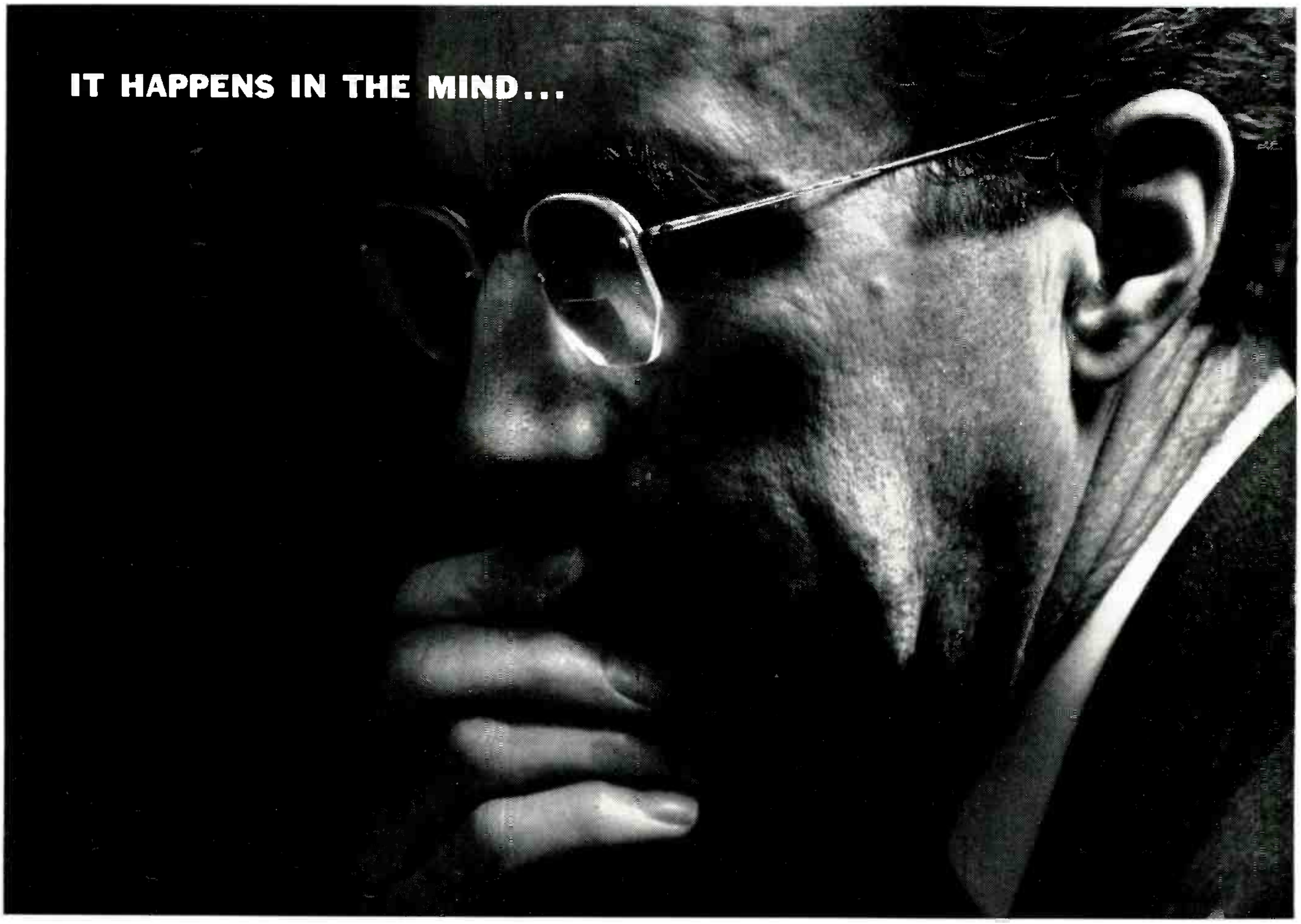
R. Hammell

Richard K. Bates began his Bell System service with the Long Lines Department in his home town of West Haven, Connecticut. During World War II he served aboard a destroyer in the South Pacific. Later he returned to duty aboard an aircraft carrier in the waters around Korea during the action there. He was an Electronic Technician Chief having received his training in radio, radar and underwater sound equipment at the Radio National School at the Navy Research Laboratories in Washington, D. C. In 1946 and 1947 he attended Brown University where he majored in engineering and physics.

R. K. Bates

Prior to coming to Bell Laboratories in 1954 to work on the development of the 82B1 Teletypewriter Switching System, Mr. Bates was working on the first Bell System microwave radio relay system installed between New York and Boston. He is currently with the Data Switching Development Department working on line switching systems for application to airlines customers. He now lives in Metuchen, New Jersey.

At Bell Telephone Laboratories, mathematician Sidney Darlington has contributed notably in developing the art of circuit analysis.



. . . It is essentially a thing of the mind for it works through concepts, symbols and relationships . . . it helps man to analyze and synthesize the complex phenomena of the universe and himself . . . it works in many ways to advance electrical communications:

IT IS CALLED MATHEMATICS

At Bell Telephone Laboratories mathematics works powerfully to solve problems involving complex data. For example, engineers must design and synthesize complex systems to process specific signals in precisely controlled ways. At the same time the technology provides a wide choice of circuits and components. Mathematical circuit analysis reveals the circuits which can do the job most efficiently and economically.

Intriguingly, too, the mathematical approach leads to basically new knowledge. For example, it led to the invention of the electric wave filter . . . disclosed a kind of wave transmission which may some day carry huge amounts of information in waveguide systems . . . foretold the feasibility of modern quality control . . . led to a scientific technique for determining how many circuits must be provided for good service without having costly equipment lie idle.

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