Bell Laboratories

RECORD

November 1962

Contents

Cover   *W. M. Augustyniak prepares solid-state radiation detector for Telstar pre-flight tests. These detectors have now sent back important information on the radiation encountered during its flight through space. (See page 380)*

The Cap
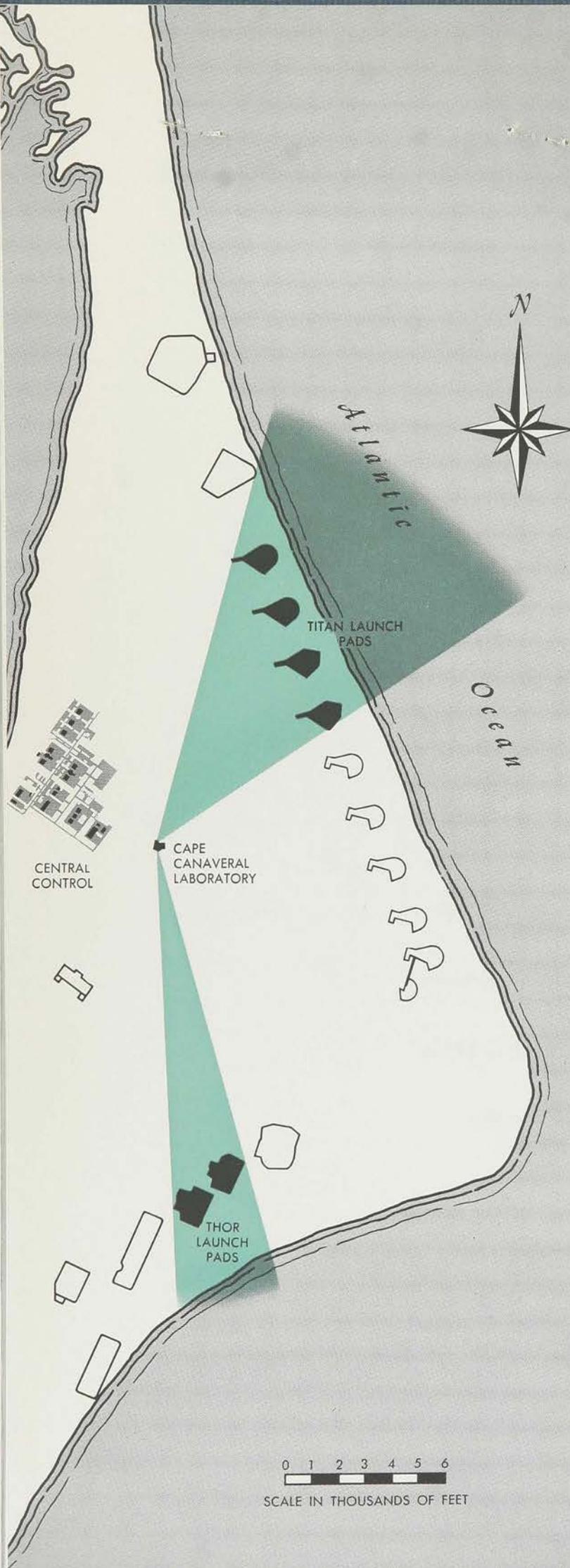
As the Delta launch vehicle carrying the Bell System's Telstar communications satellite lifted off the launching pad, thousands throughout the Bell System held their breath. The small group of Bell Laboratories people nearest to the event, however, were too busy doing their normal guidance job to even go outside and watch it. To these men, members of the Cape Canaveral Laboratory, this was in a sense only another in the series of over sixty successful guidance operations accomplished in the past 4 years at the Cape.

The highly successful guidance system, basically unchanged from its first use in 1958, was finally paying off in a big way for the Bell System, after having performed yeoman service in a variety of suborbital and orbital flights. These include many shots of the Titan I ICBM; experiments on re-entry vehicles; four Tiros weather satellites; Transit 4-B, the navigational satellite; Explorer XII, which probed the Van Allen belts; the orbiting solar observatory, OSO; Ariel I, the first International Satellite; and the earlier, passive communication satellite, Echo I.

The Laboratory at Canaveral is located about two miles back from the beach, within sight of the Military and Space Program launching pads which stretch from one end of the Cape to the other. This line-of-sight position is essential, since the Bell Laboratories Guidance System has been used to guide missiles launched from the Titan I pads to the north and the Thor-Delta pads to the south, as shown on the map at left and the photo on page 354. The men that make up the

Location of Bell Laboratories facilities and the launching pads involved in guidance operations.

Map labels:

Atlantic

Ocean

N

TITAN LAUNCH PADS

CENTRAL CONTROL

CAPE CANAVERAL LABORATORY

THOR LAUNCH PADS

0 1 2 3 4 5 6

SCALE IN THOUSANDS OF FEET
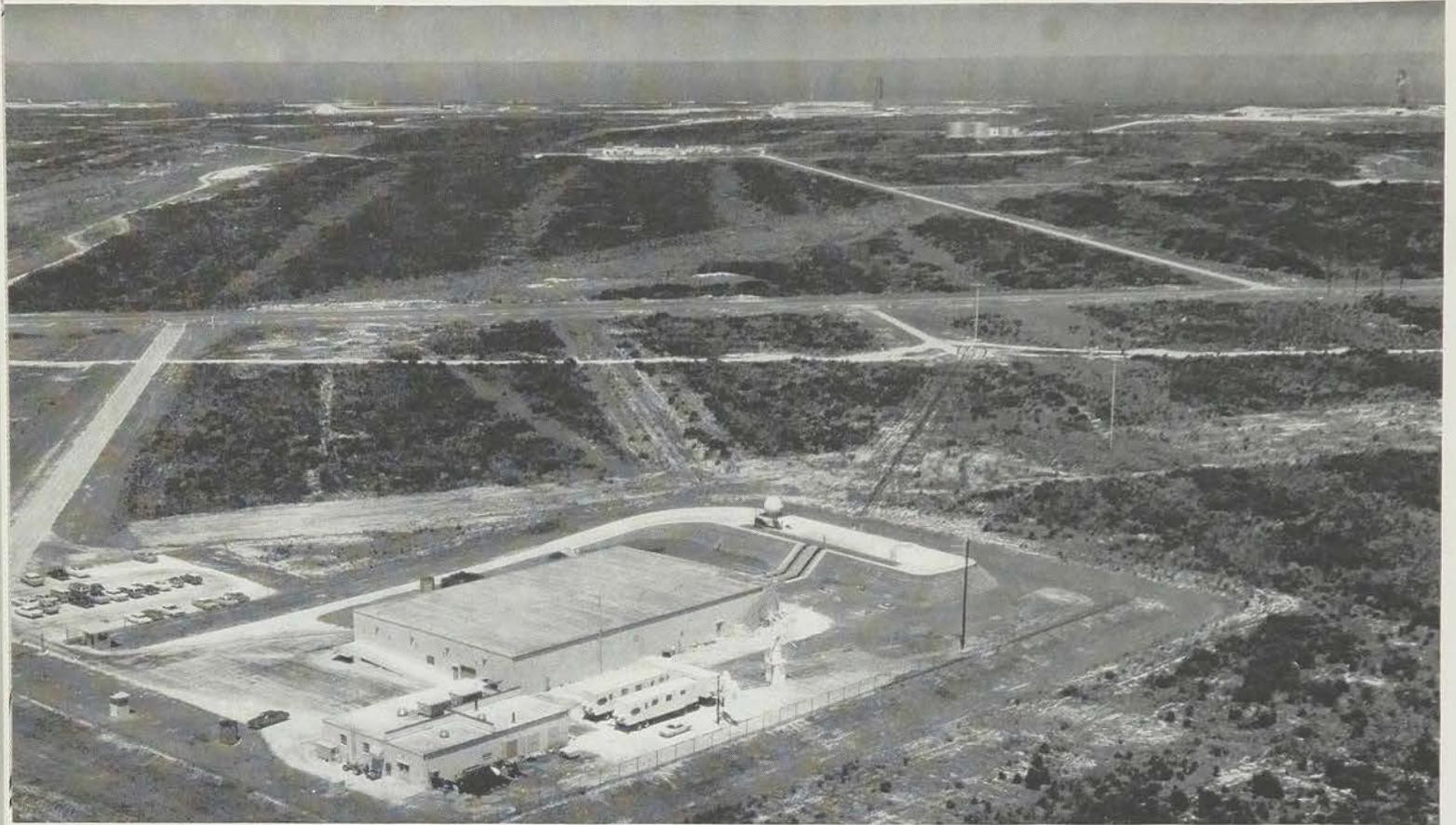
Canaveral Laboratory

J. B. D'Albora, Jr.

Cape Canaveral Laboratory are relatively few, and many of them have been stationed there since its beginning. The technical and administrative staff is made up of twenty-one Laboratories employees, twelve field engineers assigned to the Laboratories by Western Electric, and twenty-eight resident visitors who provide the basic plant, procurement, mechanical, electrical shops, and the clerical services. This group is swelled presently by engineering and administrative personnel concerned with the Telstar communications satellite project.

Historically, the Cape Canaveral Laboratory (CCL) was established to field test and evaluate the performance of the Command Guidance System designed by the Bell Telephone Laboratories for the Air Force and manufactured by the Western Electric Company. The Laboratory came into being in 1957 with the arrival of the first engineering model of the guidance equipment at its newly built facility on the Cape. The system was put through a comprehensive testing period from which a number of design improvements resulted. On January 22, 1959 the first "closed loop" guidance of a Thor-Able missile was accomplished. During this "closed loop" operation, all orders and commands were transmitted and received properly, and the missile was guided to the desired impact point. The precise impact prediction data obtained permitted the first recovery of a re-entry vehicle at ICBM ranges.

In November 1958, an improved pre-production model of the Guidance System, System No. 3, was shipped to the Cape from the Western Electric plant at Burlington, N. C. It was installed and checked out within two months. Initi-

ally, it was "slaved" to System No. 1 to provide duplicate or redundant data on each guidance operation so that its own operation could be studied and evaluated. Not until almost a year later, in March 1960, did System 3 guide its first missile, a Titan I ICBM. During these initial tests at the Cape, Bell Laboratories engineers at Whippany were completing the design of an operational version of the system and Western Electric was going into production. To field test and evaluate the operational concepts, reliability, and guidance accuracy of the production system with actual Titan missiles, one of the production systems was ear-marked for the Canaveral location. This system, No. 7, replaced System 1 and successfully guided twelve Titan I missiles into the MILS network downrange (RECORD, *July,* 1961). Having satisfactorily completed its evaluation tests, System 7 was removed from the Cape, returned to Burlington, N. C., for refurbishing, and delivered to the Air Force for reinstallation at an operational site.

The over-all responsibility for the Cape Canaveral Laboratory rests with the Resident Technical Director, J. B. D'Albora, Jr., who reports to E. P. Felch, Director of Guidance Systems Laboratory at Whippany. The technical staff is divided into a number of task groups, each of which is responsible for specific aspects of the guidance operation. The Ground Guidance Group, for instance, is responsible for the operation, maintenance, improvement, and field evaluation of the ground guidance system. Any modifications required in the guidance system are accomplished and documented by the mechanical and electrical personnel with the aid of the drafting group. The

Aerial view of Cape Canaveral Laboratory, with antenna ramp in foreground, launch pads in background.

Test Planning and Data Analysis Group performs the functions its name implies. Mr. R. G. Kimmell, the Western Electric Supervisor assigned to this location, heads three other groups concerned with checkout of the missile-borne equipment (MBE), reliability, quality control, and periodic maintenance procedures. All staff services are provided by G. J. Mihm, Resident Administrative Manager. Remington Rand UNIVAC has a resident staff to operate and maintain the "Athena" computer used in conjunction with the ground guidance system.

In principle, the Command Guidance System is quite simple. Missile position is continuously determined by a precise ground-based automatic tracking radar. A ground-based transistorized digital computer accepts the position data in suitable form and derives missile velocity (in a three rectangular coordinate system) by noting the change in position as a function of time. The missile position and velocity data so obtained are compared automatically with pre-calculated values (representing the desired trajectory) which have been stored in the computer prior to the flight. Coded steering commands based upon deviations between the actual and desired values are communicated to the missile over the radar beam. An engine cut-off command is sent to the missile when

the ground-based computer is satisfied that appropriate conditions for the desired free-flight trajectory have been met.

The accuracy of this Command Guidance System results primarily from the combination of precise radar tracking and a unique computation process involving Darlington's radio-inertial principles for determination of velocity.

Perhaps the flavor of activity at the Canaveral Laboratory may be derived from the highlights of a typical space vehicle guidance operation. Obviously, much preparation is needed both at Whippany and at the Cape to culminate in a five-minute period of guidance. Basic requirements are provided in a number of Air Force and NASA documents applicable to a specific operation. Whippany then generates guidance equations to satsify the trajectory requirements. These equations are implemented in the form of a program tape for the computer by UNIVAC headquarters at St. Paul, Minn.

Test plans are prepared at CCL which specify the operational requirements of the ground guidance system and the guidance equipment in the missile. Approximately one week before launch, the guidance program tape is checked out, using the ground guidance equipment, Athena com-

puter, and an analog computer to simulate the dynamic characteristics of the missile. These checks assure that the system and the program are compatible and operation is normal.

Checks of the missile-borne equipment installed in the vehicle are made in the hangar to insure proper operation. Similar tests are performed when the missile is erected on its launch pad. A number of tests are conducted between the missile equipment and the ground guidance station prior to launch. These tests include a "quick look," RF Interference test, T-minus-6-day acceptance test, T-minus-3-day combined systems test, T-minus-1-day pre-launch countdown, and T-minus-0 launch countdown.

During a launch countdown, one man, designated Radar Control, is responsible for the co-ordination of all checks performed at the Ground Station. Another, designated Guidance Control, is responsible for coordinating tests between the ground station and missile-borne equipment as well as providing liaison with the test conductor in the block-house.

All areas in the system have been carefully checked and adjusted beforehand to provide the best possible equipment performance. In the antenna area, where adjustments of level and bore-sighting are critical for accuracy of guidance, extreme care is exercised. Optical and RF alignment of the antenna and boresight telescope are accomplished by using a test mast located 750 feet in front of the antenna mound.

After the boresight telescope optical alignment is completed, the antenna is rotated to a monolith, another optical target located close to the test mast. The location of this monolith has been accurately surveyed by the U. S. Coast and Geodetic Survey Group, and its azimuth relative to true north is used by the computer as the standard azimuth reference. The monolith is also used to align optically the boresight movie camera used for photographing all flights and the "monitoring" TV camera mounted on the elevation shaft of the antenna.

During the guidance system terminal count, final checks are made on the entire guidance system. After the MBE is turned on, a standard program of pitch and yaw orders is transmitted from the Ground Station to insure proper operation of the missile equipment. Responses to these orders are monitored at the RIME (Radio Inertial Missile Equipment) Monitor, located in the block-house, via leads in the umbilical cable connected to the missile.

If all tests indicate that the systems are "Go," the guidance program is started and the com-

R. G. Kimmel, Western Electric (left), and Larry Gant, Bell Laboratories, watch as the Delta vehicle track is traced automatically on plotting board.

E. A. Baker checks out the missile-borne guidance equipment installed in the missile prior to launch.
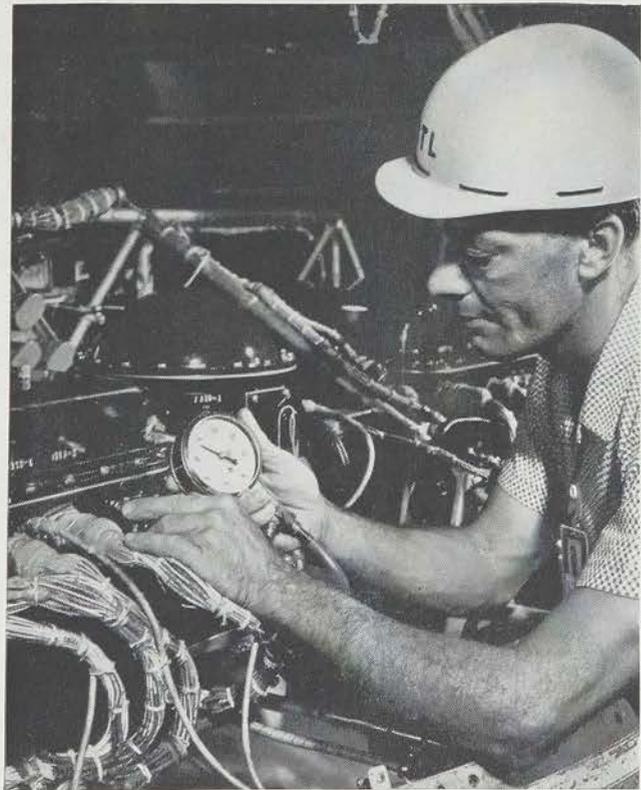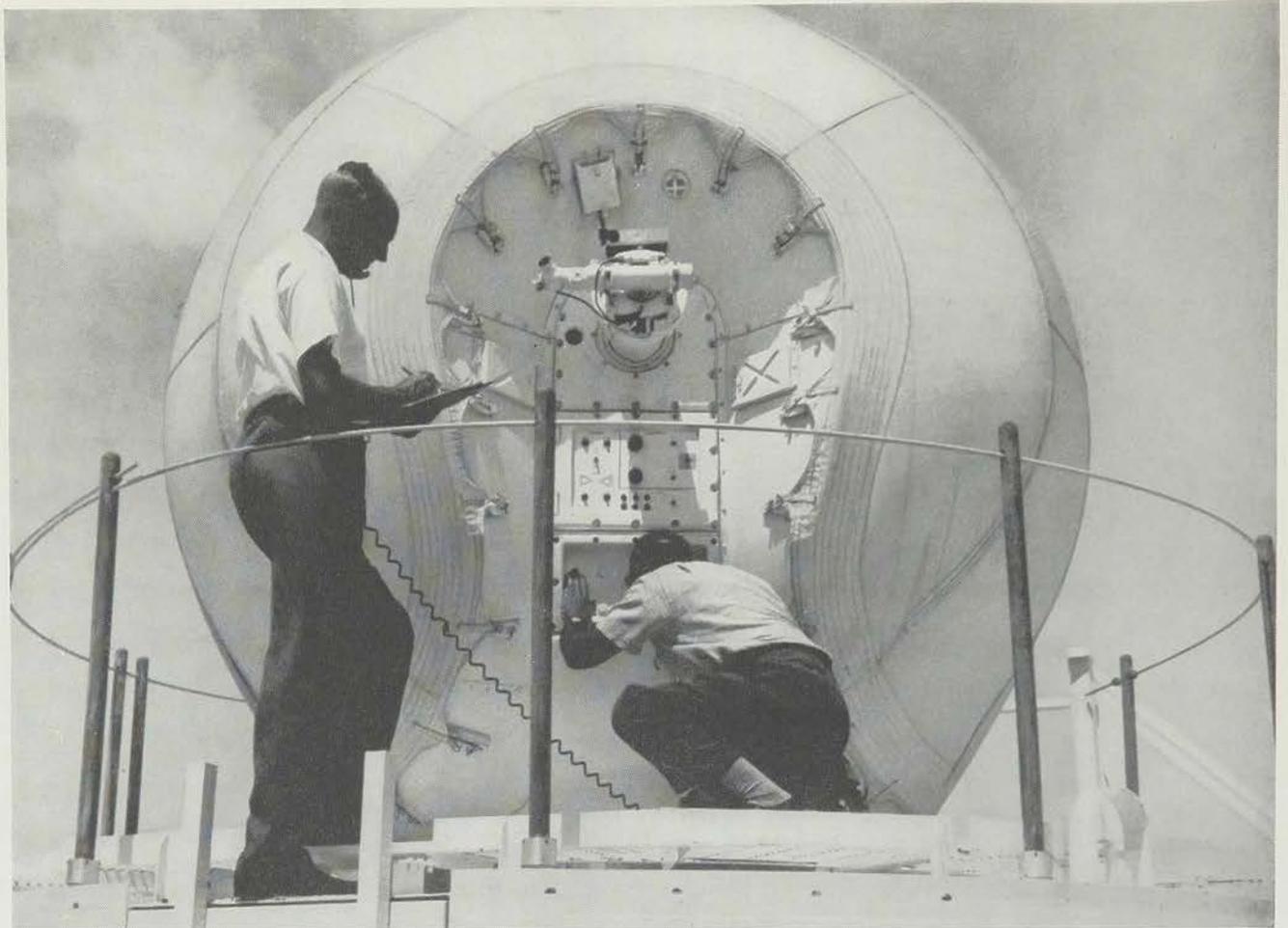
J. C. Crowley and R. J. Tellman check level indicators inside the tracking antenna at Cape Canaveral.

puter is ready to guide—the test phase is over and the pre-guidance phase begins. In this phase, Guidance Control, Radar Control and the console operators constantly monitor the status of their equipment. As the count proceeds towards zero, all subsystems are placed in a state of final readiness and are so indicated on the status board.

The status board includes the block-house and missile guidance equipment status as well as ground station status. When the missile is transferred from ground power to airborne power all lights must be green, indicating a "Go" condition. Word of this "Guidance Go" condition is transmitted to the Test Conductor's status board. If, after this time, any subsystem goes out of the "ready" state, and is not restored quickly, an automatic engine shutdown will result when the count reaches "zero."

As the missile lifts off its launching pad, the plotting board in the control room comes to life. The actual elevation and range of the missile derived from the radar tracking data are continuously plotted on a chart and visually compared with a pre-traced programmed trajectory.

Deviations from the programmed path are an indication of missile performance. A second pen on the plotting board simultaneously plots deviations from the desired launch azimuth. In addition to the traces of trajectory and launch azimuth on the plotting board, indications of pitch and yaw orders and command signals which are transmitted to the MBE are also displayed. Such signals include orders to gimbal the engines in the yaw or pitch plane, and discrete commands for engine cut-off.

The missile position information supplied to the plotting board at Bell Laboratories Guidance Center is simultaneously transmitted to the Range Safety Officer (RSO). The RSO has the responsibility of determining that the missile is within established safety limits and, if not, determining at what point it should be destroyed. In addition to the plotting board positional information, the guidance system also furnishes data to the IBM 7090 Impact Predictor computer which supplies information to the RSO regarding where the missile would fall if the engines were cut off at any given time. The data sup-

plied to the RSO by Bell Laboratories is used as a back-up for information normally supplied by tracking radars under the direct control of the Range Safety Officer.

The initial period of flight is controlled by a programmer installed in the missile. As the space vehicle leaves the atmosphere, the ground guidance system starts guiding the first stage. If the missile position and velocity are not those desired, corrective orders are issued. No attempt is made to return the vehicle exactly to the original trajectory, but rather computations are made to choose the trajectory closest to it which will still insure that the satellite will arrive at a desired insertion point for the designed orbit. The time of sustainer engine cut-off is as vital as the attitude of the vehicle, since this determines the terminal velocity. The need for accuracy in a ballistic missile system can be appreciated if one realizes that a variation of one foot per second from the desired velocity (approximately 18,000 feet per second) would result in an error in range of one mile at ICBM ranges. Once the sustainer engine cut-off is commanded, the guidance function is completed.

After the flight, but before sending all data to Whippany for reduction, study and analysis, the local Data Analysis Group reviews the data to determine if anomalies exist which would require further explanation. Some of these data include a strip chart recording from a twenty-four channel "Events Recorder" of signals and data indicating system performance during the flight. This recording includes automatic gain control level, range errors, azimuth and elevation errors, magnetron current, transmitted pulses, the time and duration of orders and commands, as well as a record of pulses received from the MBE. Also included are coded Atlantic Missile Range timing pulses, so that these records can be compared with those recorded by others during the flight. The computer records on magnetic tape all data supplied to it from the radar as well as information on orders and commands transmitted to the missile. Whippany processes the magnetic tape and returns a printed copy to the Data Analysis Group at Cape Canaveral for their information and additional study.

Although far removed from the metropolitan headquarters of Bell Telephone Laboratories, and even from the Western Electric Company manufacturing plants, the Cape Canaveral Branch Laboratory is performing an essential mission in support of the national military and scientific space exploration program.

Thor-Able, first vehicle to be guided by Command Guidance System, blasts off from the Cape.

*A new exchange area carrier system
has promise of great economic importance.
By taking advantage of modern solid-
state digital circuit techniques, it provides
high-quality transmission at low cost.*

The T1 Carrier System

D. F. Hoth

THE T1 CARRIER SYSTEM, which went into production this year, is a new departure in telephone communications. It is the first widespread application of time division multiplexing and pulse code modulation in commercial telephony. The new system will carry 24 telephone conversations over two ordinary cable pairs. Customers' voices are multiplexed by interleaving them in time rather than by the usual technique of modulating them into separate frequency bands. The signals are then encoded into a train of binary pulses which are transmitted over the cable at the rate of 1,544,000 bits per second.

Pulse code modulation of telephone signals was invented in France before World War II. It was immediately recognized as having two important advantages. First, because it transmitted information in the form of binary pulses it was able to tolerate very large amounts of noise, interference and distortion without impairing the signal being transmitted. Second, regenerative repeaters, similar to those which had been used for many years in telegraphy, could almost completely remove these effects, thus preventing their accumulation in long repeatered systems.

As a result, PCM very soon became a subject of research at Bell Laboratories and elsewhere. During World War II, the Laboratories developed an experimental PCM radio system for military use. It came too late in the war to be significantly applied, but it was the basis of later military exploitation of PCM. After the war, research in PCM continued at the Laboratories. New knowledge was gained and several experimental systems were built.

During the late forties and early fifties, several systems engineering studies of PCM were made. It was considered as a possible modulation method for the TD-2 microwave system. However, it had two strikes against it for commercial telephone applications. First, it required complex high speed logic circuits and with only electron tubes available at that time practical systems would have been too expensive. Second, it required around ten times the bandwidth of conventional analog systems.

The invention of the transistor and the subsequent development of efficient high speed transistor logic removed the first objection. The second still prevents its use in most commercial radio applications, but does not apply with the same force to cable transmission. In microwave radio, PCM requires much more bandwidth than the usual FM without providing sufficient compensating advantages. In cables, the lower frequencies are the best for communications. As fre-

quency increases, attenuation, crosstalk, and noise gradually increase, placing a limit on *useful* bandwidth. PCM is relatively tolerant to crosstalk and noise and can utilize higher frequencies, and thus wider bandwidths, than analog transmission. The bandwidth penalty is not so important since frequencies not previously useful can be employed.

Origin of the T1 System

During this period, the Bell System telephone operating companies were expressing an interest in obtaining a new facility for exchange trunks —the circuits interconnecting switching centers in and around cities. The Bell System uses about 2 million of these trunks. Their average length is about 6 miles and very few of them are longer than 25 miles. In addition to speech, the trunks must carry signals to control the switching equipment.

The operating companies needed the new facility to provide more cheaply for the rapid growth of the plant and at the same time to provide for transmission improvements. This need had been partly met by 1955 with type E repeaters which permit low loss trunks with small, and thus relatively cheap, cable conductors. Type N carrier (RECORD, *July* 1952) had also been used to a limited extent on some of the longer trunks. During

Repeaters between T1 terminals installed in a manhole near Skokie, Illinois. Two repeater cases are installed here; the one behind the craftsman is shown with its cover in place.

this time, systems engineering studies were made to find new ways to further economies. Several different carrier techniques were studied and PCM was found to be the most attractive.

Fundamentally carrier saves money by transmitting several telephone channels over a single pair of wires and thus making more efficient use of cables in which a great deal of money is invested. However, terminal equipment is needed to combine the voice channels and to convert switching signals for carrier transmission. Because of the terminal equipment, carrier systems tend to be more expensive than voice frequency circuits for short distances but much cheaper for long distances. Since exchange trunks are short, the problem in achieving an attractive carrier system was primarily to devise one with low cost terminals.

This factor led to the selection of PCM rather than more conventional techniques. In a PCM system most of the equipment is common to all channels and relatively little individual channel equipment is needed. The cost of common equipment is shared between all channels and terminal costs tend to be low if the system transmits a sufficiently large group of channels. Also, many of the expensive channel filters needed for conventional analog systems are eliminated. These advantages apply to signaling as well as to speech; built-in signaling can be provided very economically with PCM.

As a result of the systems engineering studies, exploratory development of a PCM system was started in 1955. An experimental system was tried out on a cable between Summit and South Orange, N. J. in 1958. This test turned up a number of deficiencies which led to further development. In 1961 and early 1962 a very successful field trial of prototype equipment was carried out on a route between Newark and Passaic, N. J. (RECORD, *August,* 1961). Regular production was started by Western Electric early this year and a number of operating telephone companies are now installing commercial systems.

General Principles and Features

The drawing on page 360 is a very much simplified block diagram of the T1 system. Only the voice channel features of the terminal are shown. Voice signals from the central office switching equipment enter the T1 terminal through a hybrid which isolates the transmitting and receiving parts of the terminal. The signal is then passed through a low-pass filter which eliminates frequency components above 4000 cps, and into a sampling gate which is operated 8000 times
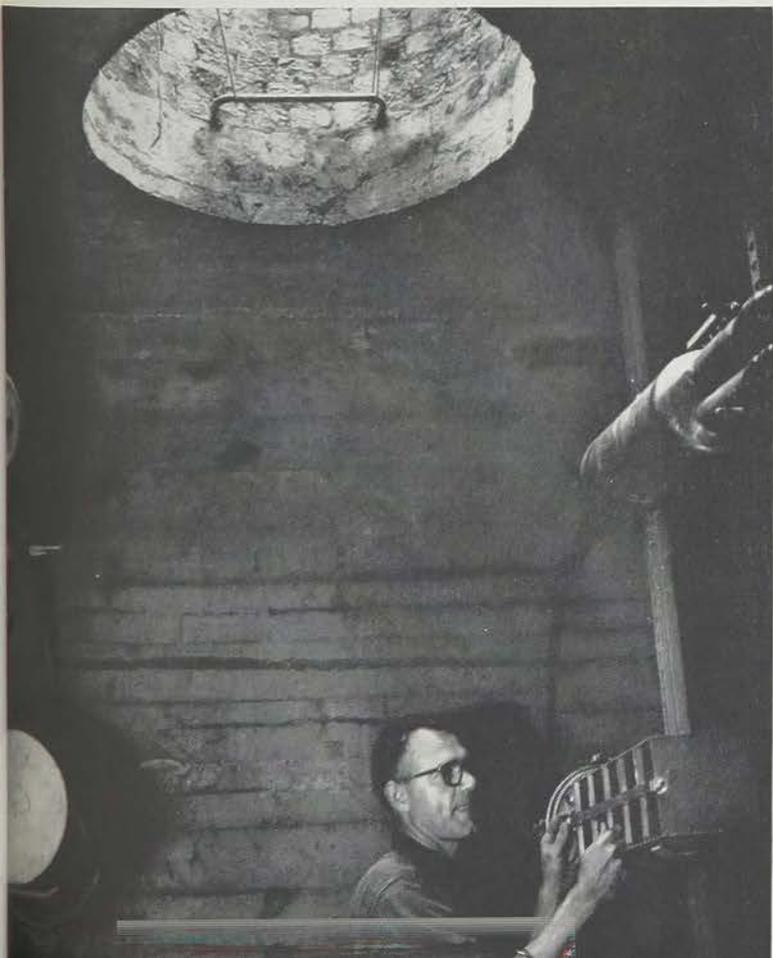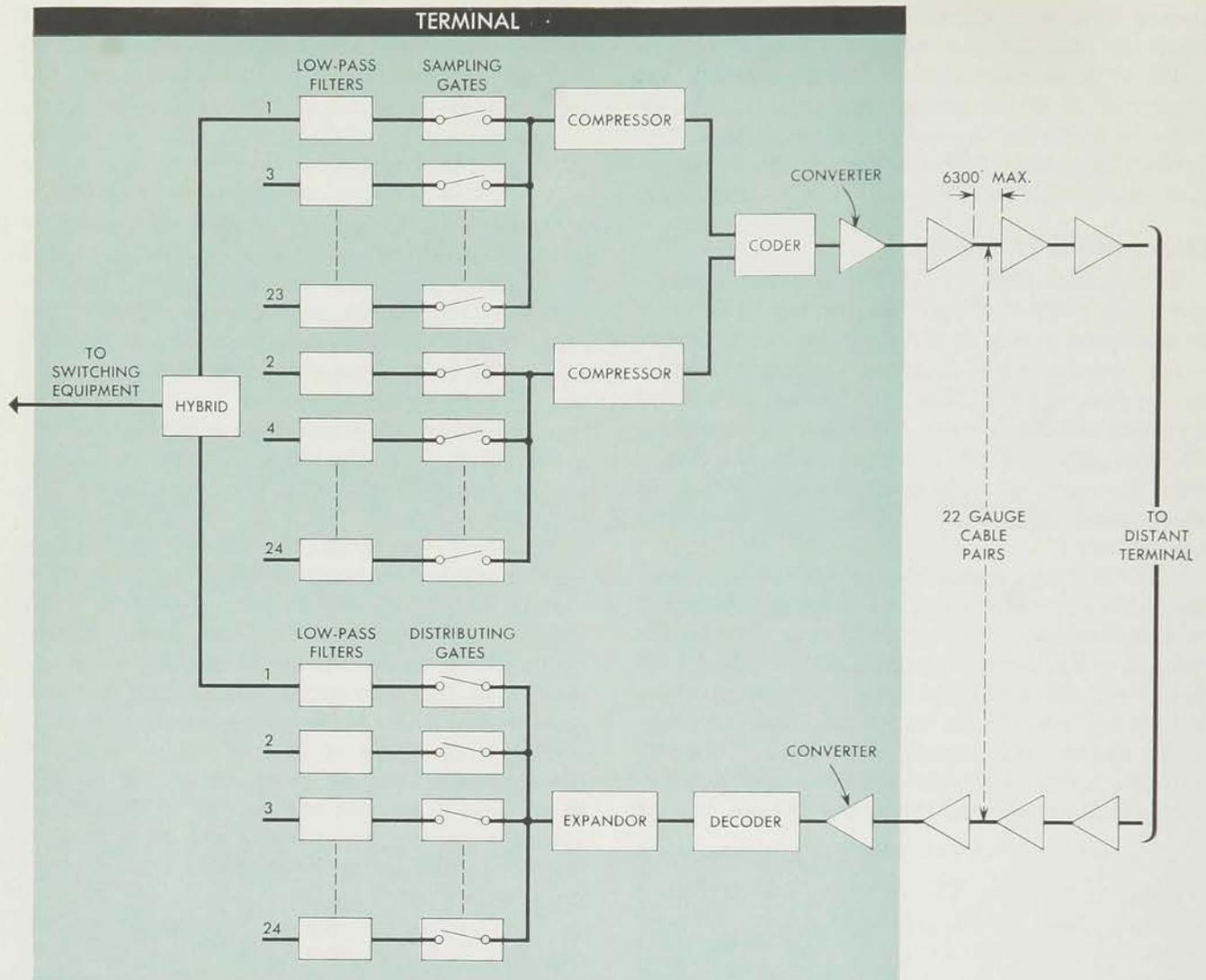
A simplified block diagram of the T1 Carrier System showing only the voice channel features. From the coder, outgoing signals pass through *a number of regenerative repeaters on their way to the distant terminal. Repeaters amplify the signal, retime it, reshape it, and send it on.*

per second under control of a timing wave generator. The gate's output is a train of pulses whose amplitudes are proportional to the amplitudes of the input speech signal. According to sampling theory, this output completely represents the input signal.

By operating the gates of each of the 24 channels in turn at a combined rate of 192,000 times per second (8000 × 24), samples from the various channels are interleaved in time to produce a time division multiplexed signal. This signal is fed into an instantaneous compressor which amplifies the weak pulses more than it does the strong ones. The reason for this will be discussed later.

From the compressor, the pulses are transmitted into the coder, a logic circuit whose output is a series of seven binary digits for each input

pulse. By the laws of binary arithmetic, there are $2^7 = 128$ possible codes. Thus, a unique code can be assigned for each of 128 discrete input amplitudes. In between values of input amplitudes are approximated by assigning the nearest codes. This process, known as quantization, is equivalent to the rounding process of arithmetic where a limited number of digits represents a value.

Voice signals leaving the coder are in binary form, and are completely represented by the presence or absence of pulses in particular time slots. The only thing significant about the pulses is whether they are there or not; their exact amplitudes and shapes are not important. Considerable noise and distortion can be tolerated before the information the pulses contain is lost.

An eighth binary digit is added to each group of seven voice digits at the coder output. This

digit carries the signaling for its associated voice channel.

The output signal from the T1 terminal is illustrated in the drawing on this page. It consists of a train of pulses in which the binary digit "zero" is represented by a space (or no-pulse) and the binary digit "one" is represented by a positive or a negative pulse. (The rule is that pulses always alternate in polarity.)

A bipolar pulse train has several advantages. First, the dc component is eliminated from the pulse signal, thus simplifying repeater design and improving repeatered line performance. Secondly, a bipolar pulse train contains less energy at high frequencies. The bulk of the energy is centered at 772 kilocycles (one-half the pulse repetition rate). If pulses of only one polarity were transmitted, the energy would be distributed over a broader frequency spectrum with important components extending to above 1.5 mc. Hence, crosstalk interference is less for a bipolar pulse train then it would be for a unipolar train. Finally, the unique characteristic of this bipolar pulse train is useful for maintenance because errors caused by trouble in a repeatered line tend to cause violations of the rule of alternating polarity. A simple logic circuit which will give a measure of performance can be bridged across the line at any point.

As the diagram below shows, a frame which represents one sample from each speech channel, together with a signaling digit for each channel, consists of 192 bits. One bit is added for framing to enable the receiving terminal to identify the beginning of the frame and to correctly sort out the received pulses. This bit is alternately present and absent in successive

frames, a situation which will not occur for sustained periods in the other time slots. The complete frame lasts 125 microseconds (1/8,000 second) and thus the signal transmitted to the cable contains 1,544,000 bits per second.

The binary signal is transmitted over ordinary paper or plastic insulated cable pairs. Regenerative repeaters at intervals on the cable pairs receive the pulses, amplify them and equalize them for cable distortion. A timing wave is derived by converting the incoming bipolar pulse train to a unipolar pulse train by full-wave rectification. The unipolar pulse train has a strong discrete frequency component at the pulse repetition rate (1.544 megacycles) which is filtered out, amplified, and shaped into sharp timing pulses. This timing wave is smoothed with respect to the pulse train; short term time variations have been removed.

The main signal and the timing wave pulses are applied to a pair of regenerators—one for positive and one for negative pulses. When an input pulse of corresponding polarity that exceeds a preset value is applied to its input, the regenerator puts out a clean pulse whose time is controlled by the timing wave. Thus, the effects of noise, crosstalk, and distortion are virtually eliminated from the signal. Some time jitter does accumulate in the pulse train (i.e. pulses may be displaced from their correct time positions) which will eventually cause signal impairment for very long lines. However, lines with as many as 150 repeaters have been operated with low error rates and no detectable impairment in the speech signals.

In the receiving terminal, the framing pulse is detected and used as a reference in sorting out the pulse train. Signaling pulses are stripped off,
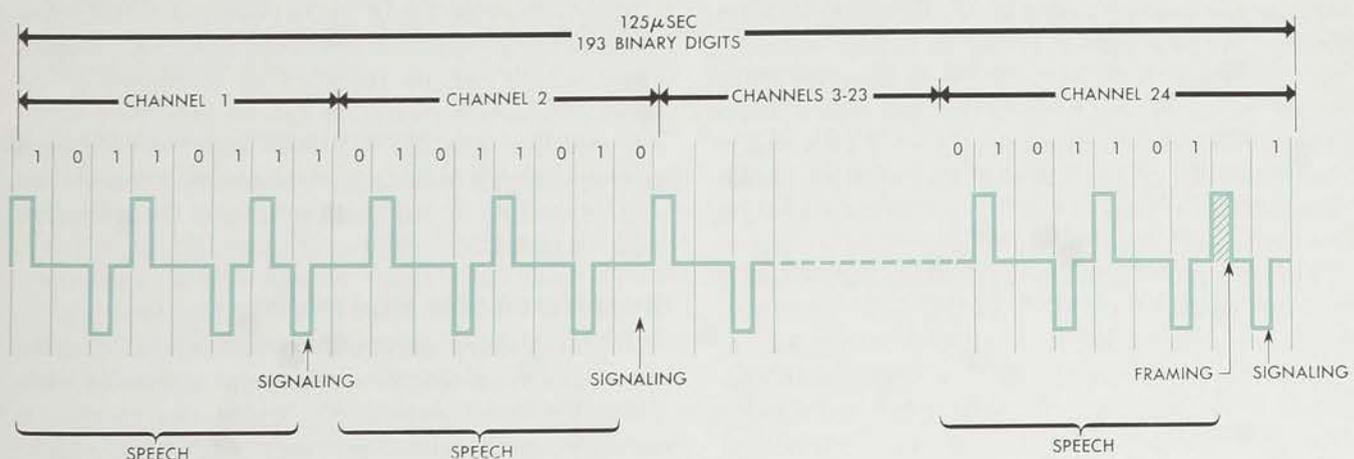
Configuration of the binary output signal from a T1 terminal. A frame, consisting of 193 bits, contains seven voice digits and a signaling digit for each channel, and one framing digit.
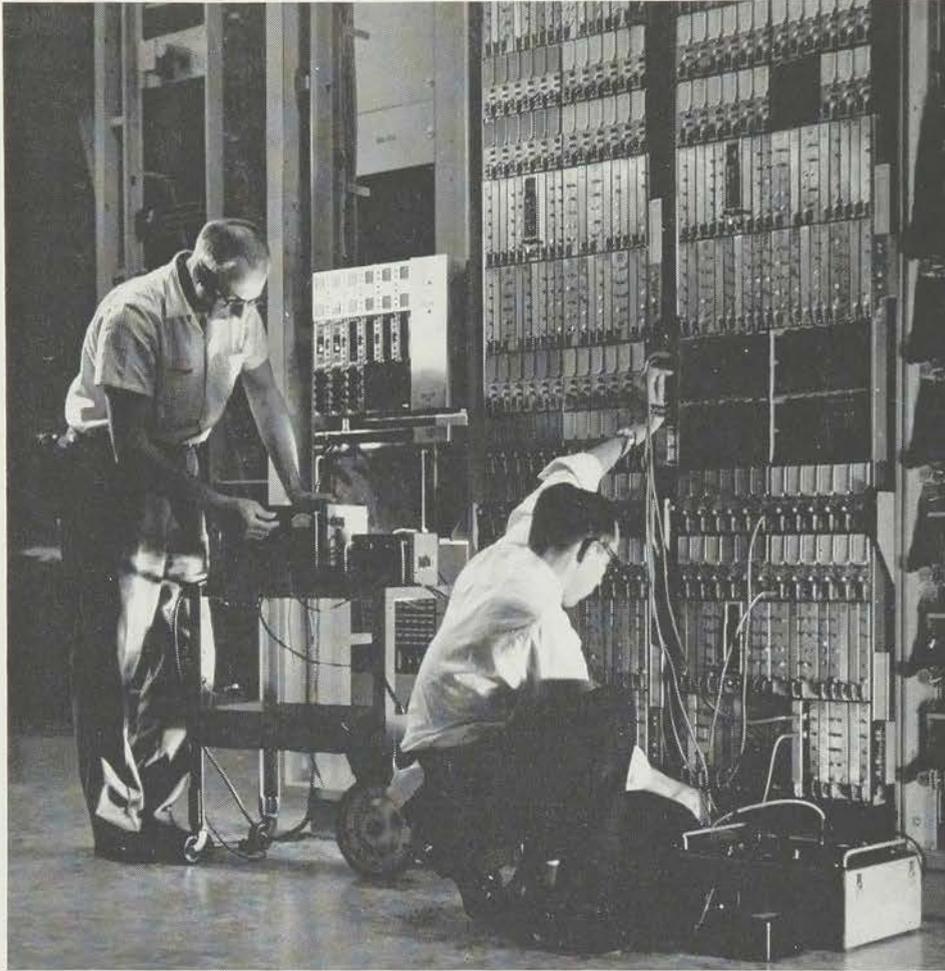
W. Whistler (left) and F. Martzell of Illinois Bell performing installation tests on T1 equipment. Repeaters are in the bay at the far left; the other bays contain terminal equipment for six systems.

signaling information is converted to dc form and applied to each of the two-wire outputs. The remaining pulses are transmitted into the decoder whose output is a train of pulses with amplitudes in accordance with the received codes. The pulses pass through the expandor which complements the compressor mentioned previously, thus preserving the overall linearity of the system. Gates distribute these pulses to the individual channel outputs. Each channel contains a low-pass filter which removes components in the pulse train above 4000 cps. The resultant signal, which closely resembles the original speech signal, then passes through the hybrid to the two-wire line and on to the switching equipment.

The T1 system is designed so that, for its major applications, it can directly replace voice frequency trunks without auxiliary equipment or modifications of the switching equipment. Because it is completely transistorized, equipment size and power requirements are minimized. Three complete T1 terminals—a total of 72 channels—can be mounted on a standard 11½ foot bay. They operate on 48-volt office batteries and

require only 220 watts per system terminal.

A selection of different types of plug-in channel units have been developed to meet a number of different signaling and voice channel terminating conditions. Additional channel units are being considered to meet other conditions and will be developed if there is enough need for them.

Repeaters are small transistorized units. Repeaters for 25 systems are contained in apparatus cases which can be installed in manholes or on poles. Defective repeaters can be identified without visiting repeater locations by a fault location arrangement which is part of the system. Power for repeaters is supplied over the transmission cable pairs.

Repeatered Line Engineering

Two ordinary plastic or paper insulated cable pairs are required for a T1 system, one for each direction of transmission. While the system is intended primarily for use on 22-gauge high-capacity cable, almost any type or gauge of staggered twist cable (which has been standard for about forty years) can be used. The type of cable

determines the spacing of the repeaters. For example, the normal spacing for 22-gauge high-capacity cable is 6000 ft; for 19-gauge low-capacity cable it is 10,300 ft; and for 24-gauge high-capacity cable it is 4500 ft. Build-out networks are available to permit shorter spacings. Adjacent to central offices, the spacing must be shortened to reduce the effects of impulse noise arising in switching equipment.

The principal transmission limitation on T1 repeatered lines is crosstalk interference between systems operating in the same cable. Because of the nature of the signal, this crosstalk is not intelligible but it can produce digit errors in the transmitted pulse train and appear as noise in the disturbed system.

Crosstalk places limitations on the number of systems which can be operated in a single cable. The exact limitations depend on the type of cable and the degree to which it is practical to maintain separation between oppositely directed pairs within the cable. Under favorable conditions, it is possible to operate up to 200 systems (4800 channels) in a single cable with full repeater spacings. Under less favorable conditions, fewer systems can be installed or shorter repeater spacings can be used. For large installations, it will often be desirable to use separate cables for the opposite directions. In this case there is no limitation due to crosstalk.

The widespread use of T1 is expected to result in a complex network of repeatered lines. For flexibility, to simplify maintenance and administration, and to minimize the number of fault location pairs and spare repeatered lines, it is planned to install the lines in groups between central offices which may become nodes in the network, although they need not contain terminals. Repeaters will be powered from these points. Lines in various spans can be connected together to build up lines between terminals as they are needed. Spare lines can be patched in when working lines fail.

Transmission Performance

The T1 system is designed to provide low loss trunks of high quality. It will handle satisfactorily all signals found on switched telephone circuits. It will also be useful for many private line applications. However, because of the use of PCM, it has certain characteristics that differ from analog type carrier systems.

For one thing, unlike conventional analog carrier systems, the attenuation of the repeatered line has no effect on the loss of a voice channel. Thus, channel loss varies less in the T1 system than in analog systems. Noise is low and tends to be independent of system length.

Noise and crosstalk picked up on the cable pairs do not appear directly in the voice channels. In fact, up to fairly high levels, noise and crosstalk have no effect at all. Above these levels, digit errors start to occur which will appear as faint clicks in the telephone channels. An occasional sustained noise burst may cause the system to lose synchronism, which it recovers after a brief period. During the field trial in New Jersey such interruptions were rare, and when they did occur they ordinarily lasted for only a small fraction of a second.

Another effect peculiar to PCM is due to quantization. In a PCM system, the output signal is not an exact replica of the input; there is a small amount of distortion. Compressing the signal before coding, however, which makes the quantization steps smaller for weak signal components than for strong ones, keeps this effect minimal. Roughly, the percentage error, and thus the signal-to-distortion ratio, remains constant over the important levels of speech signals. Subjective tests have shown that, for telephone speech, distortion in the T1 system is undetectable by acute observers over the normal range of the speech volumes.

Field of Use

The T1 System, then, is an economical, high quality transmission system for the expansion of exchange area telephone service. Primarily, it will be used to interconnect central office trunks in major metropolitan areas, but it should also be quite useful for such special services as foreign exchange lines, PBX tie lines, and WATS access lines. At present, 50 miles is considered the maximum limit for which it should be used although experience may show that this limit can be increased.

T1 is most economical on routes where from perhaps 10 to several hundreds of carrier systems are required or where growth rates are high. All systems need not interconnect the same pair of central office buildings; in general they will not. On such routes, T1 will generally prove more economical than other carrier systems and, in a large number of situations it will prove-in over voice frequency circuits for distances longer than 10 to 12 miles. In some situations it will be attractive for "thinner" routes or shorter distances. Since it exploits new techniques, it opens the door to the development of still newer digital transmission systems. Bell Laboratories engineers are now exploring a number of such possibilities.

A new concept in printed circuitry
promises increased flexibility in
the field of equipment packaging,
economy, and an over-all simplification
of the manufacturing processes involved.

Sintered Circuits

P. R. White and R. F. Jack

IN RECENT YEARS, there have been several different approaches to the manufacture of printed-wiring boards. Of course, the basic objective remains the same: to form a conducting circuit pattern on an insulating base which holds the conductors in place and acts as a supporting member for other circuits and components. Conductors have been made by chemical etching of copper foil, and by "dinking," or punching, the circuits from metal foil and bonding them to the substrate with adhesives. Other methods for making conductors include sprayed metal techniques, electroplating, and high-temperature firing.

There are, however, several practical difficulties inherent in each of these processes. For example, attempts to bond only the desired conductors to the substrate have had limited success because of die problems. Furthermore, the adhesives used in these processes deteriorate with exposure to elevated temperatures such as those required for soldering. Since the practical limit for heating the adhesives is approximately 20 seconds at 500 degrees F, such bonding techniques impose severe limitations on the amount of soldering and repair work that can be done. In addition, there is a long-term degradation of the adhesive bond if the assembly is operated near 175 degrees F.

Now, a new technique, in which sintered copper conductors are mechanically bonded to a plastic substrate, holds the promise of making highly durable and reliable circuits that can be econom-ically manufactured. Conductors are formed in flat metal dies in which the circuit configuration has been machined. These circuit grooves hold powdered copper for pressing and sintering operations. Then, the circuit die with the sintered copper in the grooves is placed as an insert in a plastic molding die. During molding, the sintered circuit is mechanically bonded to the plastic base and is subsequently released from the circuit die.

As illustrated on the right, the sintered-circuit process consists of these basic steps:

1. The circuit grooves machined in the die are filled with copper powder.
2. A thin rubber mat is placed over the metal die.
3. The copper powder is compressed at approximately 50,000 psi.
4. The pressed powder circuit is sintered in place in the metal die in a furnace for approximately 15 minutes at 930 degrees F in a reducing atmosphere.
5. The molded assembly is formed by pressure-molding an insulating material, such as plastic, to the sintered-copper circuit.

This technique does not involve photographic processing, chemical etches, or grinding off of unwanted conductor material from the individual boards. The entire process consists of steps that are simple mechanical, metallurgical, and plastic-molding operations.
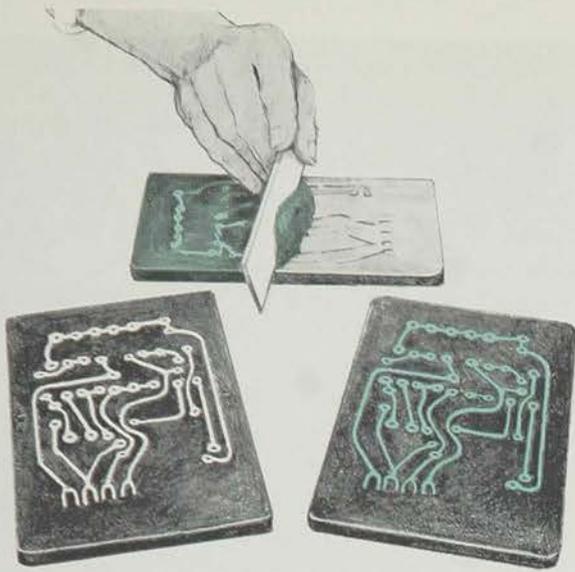
1. *Placing powdered copper in circuit die plate.*
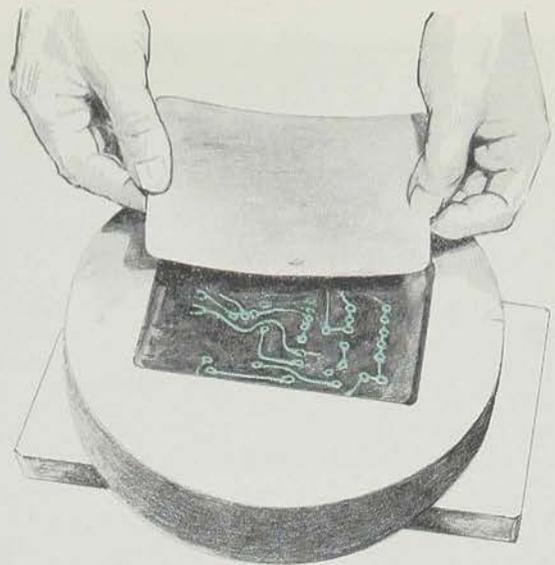
2. *Rubber mat is placed directly over circuit die.*

3. *Powdered copper is compressed at 50,000 psi.*

4. *Circuit is sintered in a reducing atmosphere.*

GUIDE PIN

MOLD CAVITY

UPPER PLATEN

RAM

PLASTIC

CIRCUIT DIE PLATE

LOWER PLATEN

COPPER CIRCUITRY

GATE
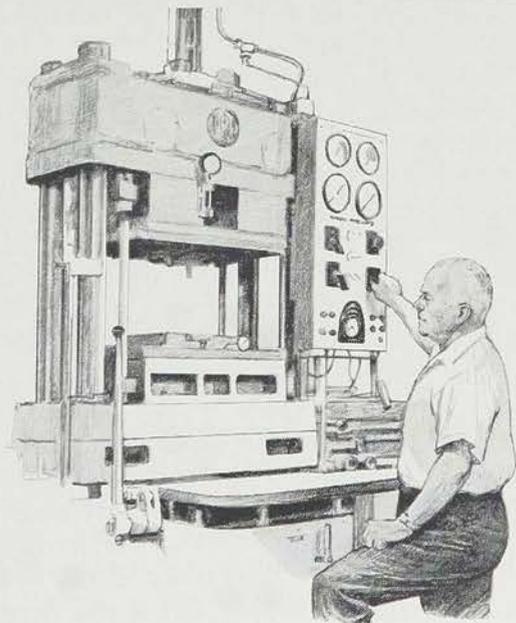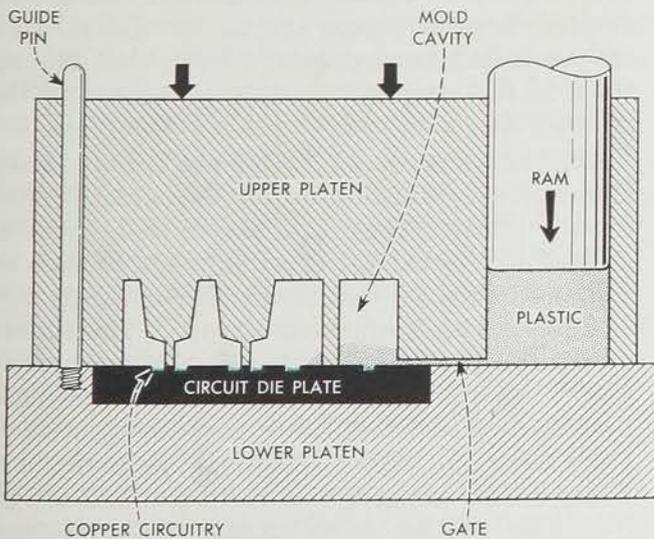
5. *Plastic substrate is molded to sintered circuit; schematic drawing (left) shows section of molding die.*

STRIKE OFF EXCESS
COPPER POWDER — COPPER POWDER
— CIRCUIT DIE

PLUNGER
RUBBER PAD — RETAINING RING
DIE
COMPACTING COPPER POWDER

— CONDUCTORS
— DIE
COPPER SINTERED IN DIE

MOLDING DIE — MOLDING COMPOUND
DIE
MOLDING

PLASTIC SUBSTRATE
SINTERED CONDUCTOR
FINISHED PRODUCT
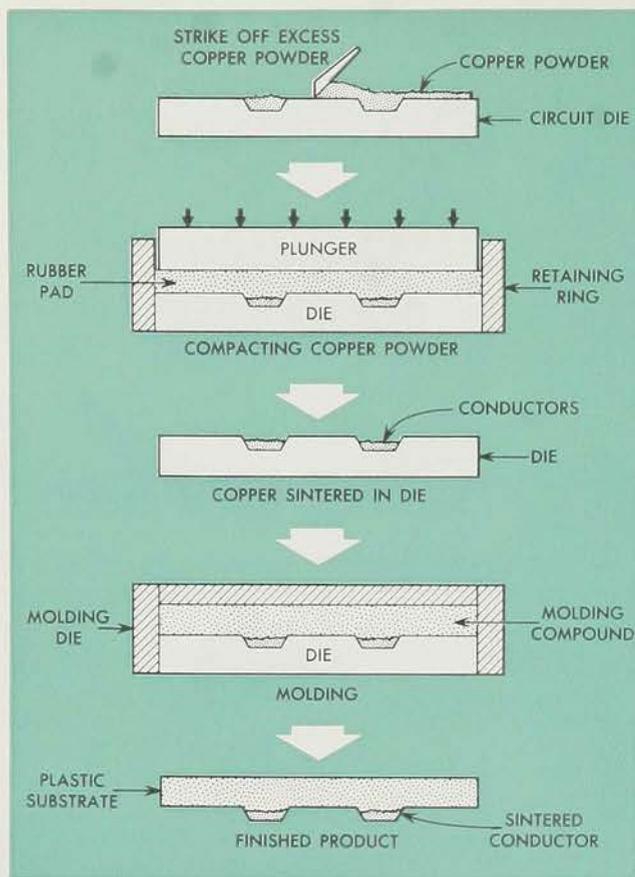
With these simple mechanical, metallurgical, and plastic-molding operations, copper circuits 0.025-inch high can be bonded to insulating boards.

The grooves in the average circuit die should preferably be no less than 0.025-inch deep. The cross-section of the conductor groove, although not a critical factor, should have a draft angle of about 5 degrees to help release the circuit from the die after molding. The bottom corners of the grooves can be sharp or rounded, but there should not be any undercuts.

During the pressing step, the copper powder is compacted to almost one-half of its original thickness in the grooves. The way the rubber mat deforms under pressure results in some of the copper powder being left on the walls of the groove. The copper powder, which is forced against the polished circuit grooves under high unit pressures, forms smooth conductor surfaces while the back of the copper powder (which is in contact with the rubber mat) is left rough and slightly porous. This rough surface is the basis for the strong mechanical bond between the sintered conductors and the molded plastic base. Thus, the plastic during the first stage of the molding step is quite fluid and—under pressure—penetrates into the interstices of the rough surfaces of sintered copper. Since the bond is me-

chanical, the back of these conductors can be oxidized during the molding operation without having any detrimental effect on the bond. With certain plastics, an oxidized copper surface may actually increase the bond strength. Thermoplastic as well as thermosetting molding compounds can be used for the insulating substrate.

Compacting pressures of 50,000 psi are necessary to produce dense conductors having high conductivity and ductility. Although conductors could be made by using much lower pressures, they would not be as strong nor as conductive as desired. The conductivity of the sintered conductors is equivalent to that of 2 oz. copper foil.

The pressed copper is sintered in a furnace containing a heat-resistant alloy muffle through which hydrogen is passed. Circuit dies are pulled through the muffle on a nickel sheet. After 15 minutes in the high heat zone (930 degrees F) the die is pulled into a water-cooled chamber until it reaches room temperature.

While this is the way the experimental work was done, actual production could be done in other atmospheres and furnaces. Any atmosphere that will reduce the copper oxides at 930 degrees F should be satisfactory. Forming gas and various commercially-produced atmospheres are suitable.

Sintering action takes place when the copper circuit gets above 750 degrees F. However, a large part of the total furnace heating time is used in getting the mass of the die up to this temperature. Cycle time may be reduced, if necessary, by induction heating or by using a high-temperature preheat zone. The longer the copper is sintered and the higher the temperature, the more dense and more ductile the conductors become. If the temperature is too high, however, the metal die may soften. Since the cost of dies is not usually very high, the simplest arrangement would be a continuous belt furnace taking the dies through the controlled atmosphere furnace, then cooling them to the temperature desired for use in the molding die.

Conductors produced by this process are raised approximately 0.025 inch from the surface of the molded plastic. They can therefore be readily cleaned by mechanical cleaning methods such as rubbing with steel wool, glass fiber brushes, wire or rubber wheels or abrasive paper. The rubber wheel appears to be the most feasible method. They should not be cleaned by chemical methods because ionic contaminants may be trapped in the conductors. After cleaning, the boards are fluxed with a noncorrosive rosin flux and solder-coated by floating them on top of a 60:40 tin-lead solder bath at 475 degrees F. The excess mol-
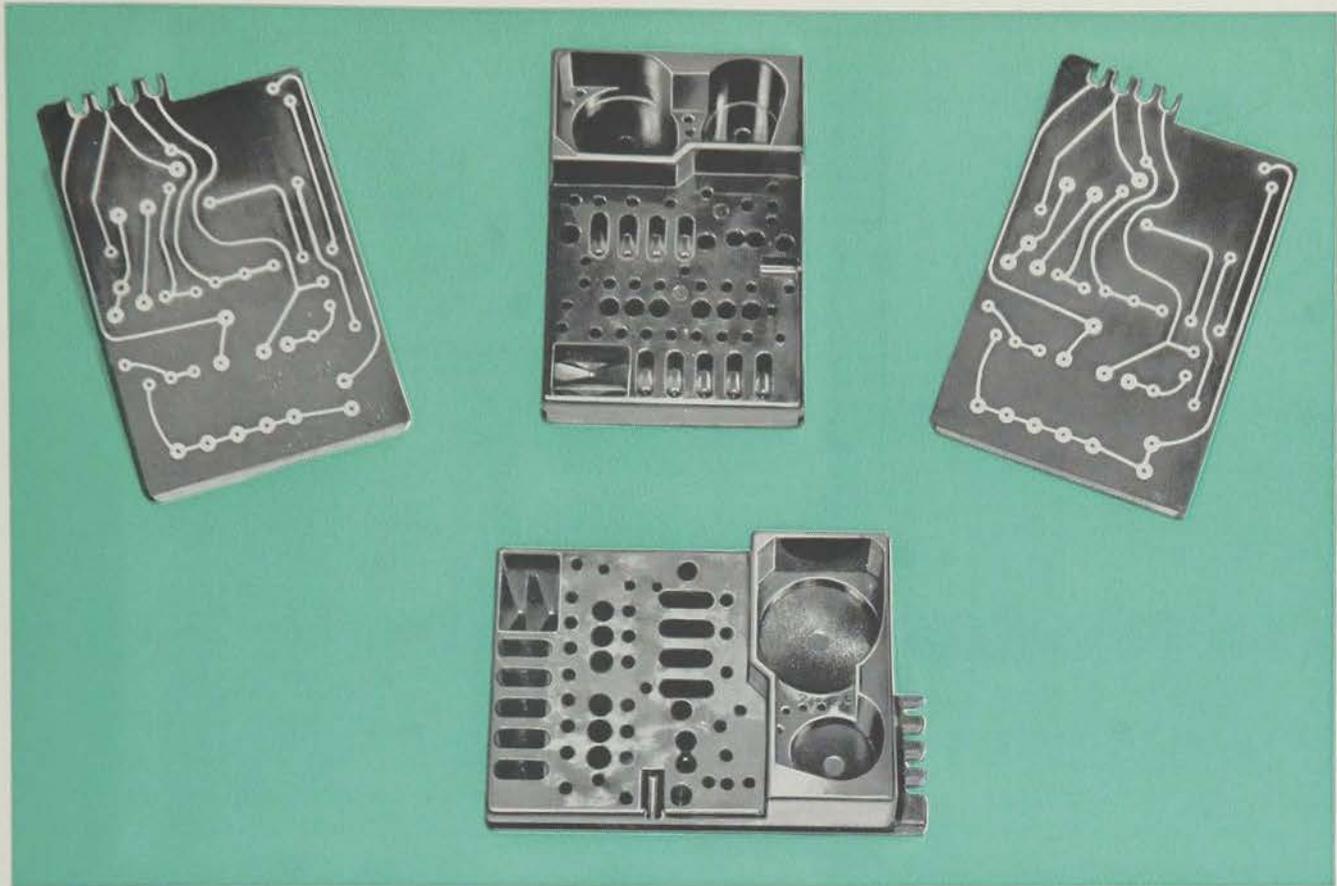
Completed molding with raised sintered-copper conductor for the E6 telephone repeater. This is the first full-scale trial of sintered circuits and results indicate that this process can be easily automated and that it has many advantages over conventional printed-wiring techniques.

ten solder can then be readily shaken off. Since the bond is mechanical and the thermosetting plastic is not very susceptible to degradation during the short time at this soldering temperature, the boards can be soldered and resoldered several times without affecting the circuit or the bond. This is a distinct advantage over conventional adhesive-bonded printed-wiring boards.

A further advantage over conventional methods is that the circuit dies can be designed so that all the component lead wire holes will be automatically molded into the assembly. No drilling or punching will be required. This can be done by having a small pin in the center of the land area contact a tapered pin in the plastic-molding die as shown on page 365. Any small amount of flashing can be removed when the assemblies are cleaned.

The sintered-circuit process can be readily automated. Furthermore, only the desired copper circuit is bonded to the insulating base. No unwanted material has to be removed by chemical etches or machining. This means that the high-resin content on the surface of the molded plastic base is retained and that this surface is not contaminated by any chemical etchants.

Sintered circuits will be particularly effective where assemblies may have to be repeatedly resoldered and subjected to high mechanical stresses and high operating temperatures. In addition, the sintering process is adaptable for designs requiring conductors or other parts of the circuit at different elevations. By placing special inserts in the grooves prior to filling with copper powder it is possible to obtain wear resistant contacts and even permit the conductors to go around corners. Where mechanical details such as cavities to hold components, guides for attachment to other apparatus or identification markings are desired in addition to the circuitry, this process will find extensive application.

The first Bell System application of this process is shown above. The E6 repeater network part for field trials was produced by an outside supplier working closely with the Laboratories Metallurgical Research Department and W. C. Schmidt of the Laboratories branch location in Merrimack Valley, Mass. The sintered-circuit process has proven its feasibility and is available for exploitation by the designer.

The world's largest capacity communication system—the TH System—is now in service. The design and development of the TH terminals represents a major contribution to the over-all efficiency of the system.

TH Radio Terminals

H. Maunsell and J. Schill

To SUPPLEMENT existing telephone and television transmission facilities across the United States, Laboratories engineers have designed and developed a new microwave radio system. This is the TH System—now in operation between Denver and Salt Lake City. The TH System has nearly three times the communication capacity of any previous microwave system (RECORD, *February*, 1961). This article describes two very important parts of the system: the terminal transmitter and the terminal receiver.

When you speak on the telephone, your voice travels over the same circuits as hundreds of other conversations. With the TH System, your voice is combined with as many as 1860 other telephone callers and assigned to one of the eight radio channels of the system as shown in the drawing on page 369. Multiplexing equipment combines all these calls and transmits them simultaneously. The composite signal might be envisioned as a long array of voiceband signals stretching from 0.3 to 8.25 mc. This composite signal is called the baseband frequency. At this point, although 1860 individual circuits may exist on one pair of wires, each circuit occupies a slightly different part of the frequency spectrum. The telephone signals are combined on a two-wire transmission line connected to the terminal transmitter.

At the output of the terminal transmitter, the last remnant of a signal's individuality is lost. The entire composite signal exists as an FM signal centered at an intermediate frequency of 74 mc. The signal consists of highly complicated groups of sideband frequencies, and it would be impossible to identify any particular telephone conversation. The output signal is amplified and sent along on a coaxial cable to the input of the radio transmitter. The radio transmitter shifts this IF signal to a specific frequency in one of the eight channels in the 6000-mc common-carrier band. After amplification, the signal is trans-
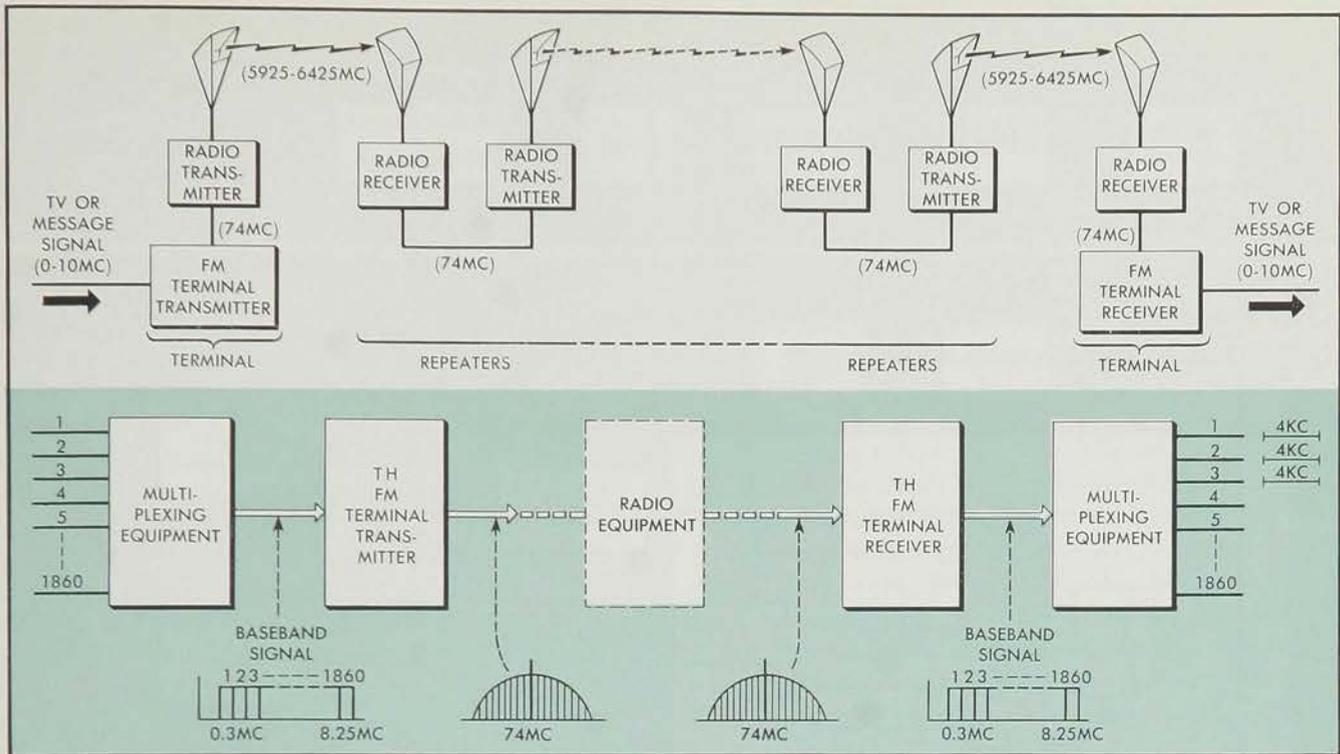
Diagrams illustrate importance of the FM terminals in TH System. Terminal connections to radio system are shown above; lower diagram depicts multiplex connections to TH terminal equipment.

mitted with the signals from the seven other TH radio transmitters.

At the far end of the system, a radio receiver shifts the 6000-mc signal back to an intermediate frequency of 74 mc and then amplifies it. This IF signal is sent to the terminal receiver where it is amplified and demodulated. At the output of the FM terminal receiver, there now exists a baseband signal identical to that which appeared at the input of the FM terminal transmitter. Multiplexing equipment sorts out the individual voice signals and routes them to the called-party's telephone.

Increased message-carrying capacity and high-quality transmission have both been achieved with the TH System. Since as many as 16 FM terminals may be used in tandem, the permissible distortion for one set of FM terminals must be extremely low. This exceptional performance is basically attributable to the design of the terminal equipment.

At the FM transmitter terminal, the multiplexed signals pass through a video amplifier consisting of two balanced amplifier stages. These stages, which contain specially designed, high-performance tubes must meet stringent specifications of linearity and frequency response. Good linearity is necessary to prevent crosstalk from one telephone channel to another. The amplitude-frequency characteristic of the amplifier is essentially flat out to 10 mc. This avoids distortion of the input signals and helps insure that all the frequencies at the input of the video amplifier are faithfully reproduced at the output.

The output of the video amplifier is connected to the repeller of a klystron oscillator. This klystron is designated the deviation oscillator. The klystron rest frequency is tuned to 6174mc but, since the frequency of the klystron is a function of the repeller voltage, the output of the klystron is a frequency-modulated signal of 6174 mc. A second klystron oscillator of the same type operates at 6100 mc. It is designated the beat oscillator because when its output is combined with the output of the deviation oscillator in a mixer circuit, a low level "beat" frequency of 74 mc is generated. This heterodyne signal still carries all the original telephone signals in frequency-modulated form.

The 74-mc signal passes through an IF amplifier to bring it to a higher power level; this completes the prime function of the terminal transmitter. The IF signal is sent through a radio transmitter where it is shifted up to a frequency of 6000 mc and transmitted to the antenna. Two remaining functions must be performed in the transmitter terminal: it must hold the 74-mc carrier to within ±0.1 mc, and provide adequate

TRANSMISSION PATH

VIDEO AMPLIFIER — 0–10 MC
KLYSTRON — DEVIATION OSCILLATOR
ISOLATOR — 6174.1 MC
MIXER
TRANSMITTING IF AMPLIFIER — 74.1 MC
TO RADIO TRANSMITTER

AFC CORRECTION VOLTAGE
BEAT OSCILLATOR — KLYSTRON
ATTEN-UATOR — 6100 MC
AFC LOOP

FREQUENCY COMPARATOR
AMPLIFIER
276K RELAY
276K RELAY
30 CPS SQUARE WAVE
LIMITER DISCRIMINATOR
IF AMPLIFIER
74.1 MC CRYSTAL OSCILLATOR — REFERENCE OSCILLATOR

Block diagram of the FM terminal transmitter for the TH microwave radio system showing the transmission path and the circuits which keep the 74-mc intermediate frequency closely controlled.

alarm facilities to report any malfunctions in the equipment. The former strict requirement is necessary to keep interchannel interference within acceptable limits. This type of frequency control, however, is complicated by several problems.

For example, the klystron frequency is subject to change with variations in temperature and applied voltage. In addition, the automatic frequency-control system must not distort the intentional modulation in any manner. To prevent this from happening, Laboratories engineers designed an automatic frequency control that can correct as much as a 10-mc drift in the klystron oscillator frequency.

In the automatic frequency-control system, a sample of the IF output signal of the FM terminal transmitter is sent through an IF amplifier which is switched on and off at a 30-cps rate. Simultaneously, a crystal-controlled 74-mc reference oscillator is alternately switched off and on at a 30-cps rate. These signals are sent alternately through a limiter-discriminator circuit, thus providing a comparison of the two frequencies.

If the average frequency of the transmitter output is exactly the same as that of the reference oscillator, there will be no output from the discriminator. Let us suppose, however, that the average frequency of the output is not exactly that of the reference oscillator; the output of the discriminator during one-half of the 30-cps period will differ slightly from the output during the alternate half period. In this case, there is a square wave at the output of the discriminator. A frequency-comparator circuit senses and amplifies this square wave.

The sensing device consists of a relay which acts in synchronism with the relay that alternately switches the AFC-IF and the reference oscillator signals on and off. The dc voltage at the output of the frequency-comparator circuit changes the bias voltage on the repeller of the beat oscillator klystron, shifting its frequency to compensate for the original frequency error. In this way, the automatic frequency control reduces all frequency errors by a factor of 100.

The signal at the output of the radio receiver is sent to the FM terminal receiver which is shown above. Circuits in the FM terminal re-
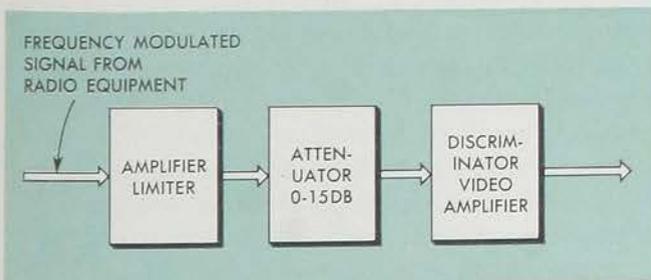
ceiver recover the original multiplex information from the 74-mc signal. First, the signal passes through a limiter which eliminates variations in signal amplitude caused primarily by imperfections in the radio paths and in the repeaters. The limiter employs new and improved circuits in which solid-state diodes are used in combination with electron-tube amplifiers. The output of the limiter, a pure frequency-modulated signal free from variations in amplitude level, passes through a variable attenuator to the input circuit of the discriminator.

A discriminator with a wide bandwidth and low distortion was needed for satisfactory transmission. Laboratories engineers determined that its performance could best be achieved by very careful control of three separate circuits isolated from one another by electron tubes. These circuits, the IF buffer stage, the high-frequency discriminator, and the low-frequency discriminator, are individually very simple. Together, they make an FM receiver having the high-quality performance demanded by the TH System. The outputs of the discriminator circuits feed a final balanced video amplifer where the power level is increased. This amplifier has been designed with local feedback to ensure low distortion, low hum, and low susceptibility to power-supply variations.

Alarm-indicating devices have been designed for the FM terminal equipment. These alarms will operate if there is a malfunction in the automatic frequency-control system, the transmitter or the receiver video amplifiers, or if there is a loss of IF input to the FM terminal receiver.

The performance of the terminals has been kept so close to the ideal that on each radio path, many more high-quality telephone circuits can be carried across the continent than ever before. The extremely stringent requirements on each terminal ensure that the over-all system, which may include as many as 16 terminals in tandem, has a minimum of over-all distortion.

FREQUENCY MODULATED
SIGNAL FROM
RADIO EQUIPMENT

AMPLIFIER LIMITER → ATTEN-UATOR 0-15DB → DISCRIM-INATOR VIDEO AMPLIFIER →

Simplified diagram of the FM terminal receiver which demodulates and amplifies incoming signals.

Canadian 'Alouette' Satellite Guided Into Orbit By Command Guidance System

The "Alouette" Topside Sounder satellite, built by Canada's Defense Research Board, was launched on September 22 from Pt. Arguello, Calif., by the National Aeronautics and Space Administration in NASA's first West Coast orbital launch. The satellite was guided into its near-circular earth orbit by the Bell Laboratories Radio Command Guidance System. The 320 pound, almost spherical "Alouette" will probe the ionosphere to measure electron distribution and density.

Major guidance system elements—radar and computer — were ground based; missile-borne guidance equipment was carried in the first stage of the Thor-Agena-B launch vehicle. Prior NASA launches with the BTL Guidance System used a Thor booster first stage and Delta or Able-Star upper stages.

The Thor booster's main and vernier engines burned for some 2½ minutes following liftoff. During this time, the entire vehicle was under control from the ground, with the guidance system feeding the vehicle commands on yaw, pitch, and, at the appropriate time, engine cutoff. After main and vernier engine cutoff, the vehicle coasted for approximately 30 seconds. Then, through a sequence of events initiated by the ground-based computer, retrorockets slowed the Thor booster and the Agena-B stage separated. From that point on, the Agena engines functioned automatically, burning twice: for 2½ minutes shortly after booster separation, and for several seconds some 48 minutes later for insertion into its orbit.

The Laboratories Command Guidance System has been used in over 100 U.S. missile and space launches with only one failure, as discussed in the article on page 352 of this issue.

The "Alouette" launch marks one part of NASA's Topside Sounder Program to investigate electron density distribution and variation in the ionosphere, that portion of the atmosphere from about 50 to 250 miles above sea level. The ionosphere is, in effect, an electrical conductor which, because of its shape and composition, has the properties of a spherical reflecting mirror for radio waves. The Sounder Program is under the management and technical direction of NASA's Goddard Space Flight Center at Greenbelt, Maryland.

*For thousands of years, plowing
has been an "art" performed by farmers.
Now, Laboratories engineers are
turning this art into a science.*

Evolution of
Cable-Laying Plows

J. C. Maclay

Buried telephone cable is becoming an increasingly important part of the communications facilities installed by the Bell System. For example, the sheath miles of cable buried yearly increased from 2000 in 1955 to 13,000 in 1961; additionally, the annual installation rate of buried facilities to residences has nearly doubled every year, from less than 4,000 in 1955 to over 185,000 in 1961.

Cable is buried by one of two methods—trenching or plowing. Trenching is time-consuming and relatively expensive because it involves three separate operations—digging a ditch, placing the cable, and filling the ditch. Operating telephone companies use this method when special conditions exist, such as a need for more than one wire or cable in the same trench. Plowing, on the other hand, is one operation and reduces both time and cost. Here, a motive force pulls a cable plow through the soil without disturbing the soil excessively, and a cable runs through a feed tube on the plow into the soil.

In 1957, Laboratories engineers made a study of the commercially available plow equipment for burying cable. The study showed that very little was known about plowing from a scientific point of view, and that most of the plows available were "rippers," normally used for breaking up the soil, with cable feed tubes attached. The basic assumptions used in designing the plows often differed from one manufacturer to another. Some manufacturers believed that the relationship between drawbar pull and disturbed soil depth was directly proportional, while others thought the relationship to be exponential. It also appeared that very little consideration was ever given to making the plows easy to pull. Rather the intent was to make the blade of the plow strong enough to withstand the largest force ever to be imposed on it. Because of these findings and the growing trend to greater use of buried cable, the Laboratories started development of a more suitable cable-laying plow.

At that time, it was estimated that cable sizes up to 1 inch would fulfill 90 percent of the expected needs of the Bell System for buried plant. Also the investigations showed that most of such cable would be placed at soil depths of cover from 16 to 30 inches. From this information the Laboratories was able to limit the initial testing to relatively small equipment.

The development included measuring the effects on a plow share cutting through soil and the effects on cable as it passed through the feed tube. A typical cable plow share is shown on the opposite page. Some of the design features investigated were the point, the leading edge (shin), the share's cross-sectional shape, the share's width (front to back), and the shape and length of the

feed tube. The engineers also tested the necessary tractive force to move plows through different types of soil at different depths. This information facilitated the selection of tractors having adequate drawbar pull for various plowing conditions. Finally, they hoped to evaluate any other factors which might affect the plowing operation. This included testing for the advantages, if any, of attaching the plow directly to the prime-mover or trailing it behind, and checking the effects of the prime-mover condition, operator skill and cable reel handling methods.

The tests started with model plow shares of approximately one-eighth scale. The models were pulled through moist clay to find what forces were required to move each share. With the data thus obtained, the testing went on to full scale shares, attached to a 4-wheel trailer and drawn by a winch. A winch line dynamometer measured the horizontal forces, providing the drawbar-pull measurements for each of the different share configurations.

However, this equipment did not provide information about the vertical forces imposed on the plow share by the soil. To obtain this information, the engineers constructed a special test frame with instruments to measure not only drawbar pull but also the downdraft and moments on the shares. The test frame was attached directly to a tractor as shown on page 374.

From the tests run with this equipment, they collected a great deal of valuable information. The engineers found that the angle of attack of the share's leading edge has a significant effect on the drawbar pull required. Three different angles, as shown at the top of page 375, were tested. Angles A and B required much less drawbar pull than C and tended to stay in the ground better than C. Because angle B was only slightly inferior to A in the tests and also simplified the feed tube design, B was used throughout the rest of the tests. The engineers found that as long as the leading edge was not blunt, the cross-section of the share made very little difference in the plow's performance. They then adopted the simplest shape, a broad V with the altitude of the triangular-shaped leading edge equal to the share's thickness.

The tests showed that two factors—the proportions and the angle of attack of the point—have the greatest effect on reducing drawbar-pull and increasing downdraft. It also showed that the resultant of all the forces on the share was at a point very nearly at the bottom of the share and that the line of action of the resultant force intersected the ground about three to four feet in
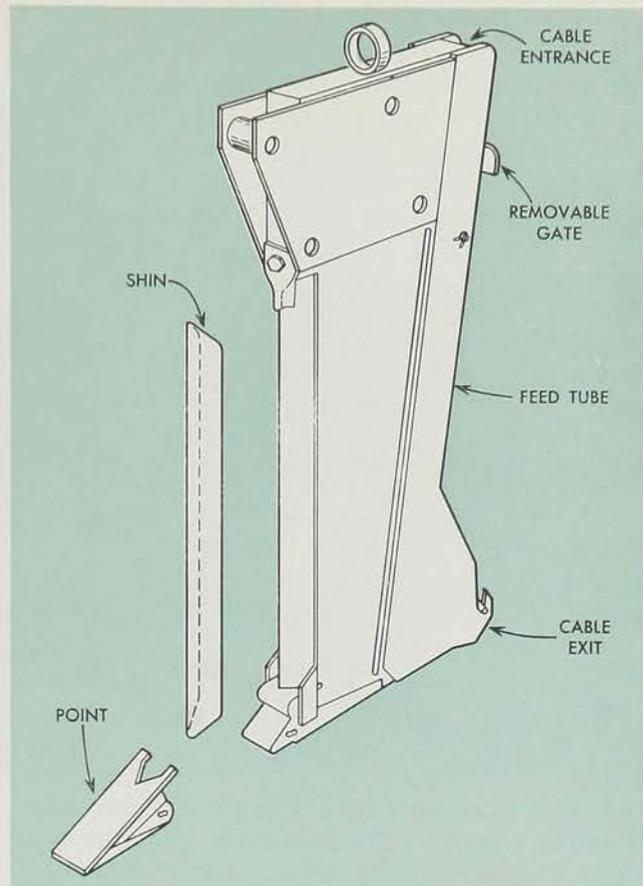
The above drawing of a typical cable-plow share shows the design features affecting its operation.

front of the plow. This meant that rather than lifting the wheels of the tractor a properly designed plow actually pulled the wheels down, thus increasing the tractor's effective weight and available traction. These tests also indicated that crawler tractors are much more suited to cable plowing than the rubber tire farm type, because the crawlers translate their weight into drawbar pull more efficiently.

The next series of tests was run to obtain complete information on how variations of the point configuration affect drawbar pull and downdraft. A trailed-type plow arrangement was used in all the remaining tests because directly-coupled plows had produced problems in controlling the depth of the plow when the tractor went over bumpy or irregular ground. The engineers tested each of five different plow shares, varying in thickness from 1⅜ to 4 inches, with 37 different points. The tests ran at soil depths of 18, 24 and 30 inches in three different type soils. The data received conclusively defined the best point dimensions for shares up to 2 inches thick—three inches wide, 14 inches long and mounted 25 to 30 degrees from the horizontal. This point re-

This test equipment was constructed by Laboratories engineers to measure drawbar-pull, downdraft, and moments on various plowshare configurations during the extended test program.

quired the minimum drawbar pull and produced the maximum downdraft in all three soils under all moisture conditions. The principal advantage of this point was that no compromise was necessary in its design to favor either drawbar pull or downdraft. The limited data obtained thus far about the 3 and 4 inch shares did not provide conclusive information.

All the tests up to this point had been on rather small plows. But since the operating telephone companies were rapidly increasing the amount of larger buried cable, there was a great deal of interest in equipment capable of laying larger cable at deeper depths. Therefore, tests were begun to obtain more information on plow shares between 2 and 4 inches thick.

A large trailed plow, bottom of page 375, on which 2, 3, and 4 inch shares could be mounted was used. Each share was tested with 30 different points at soil depths up to 42 inches. More than 450 separate tests were made, requiring almost 21 acres of land at the Chester Laboratory. Each test run was approximately 100 feet in length so as to reduce the effects of soil variations from test to test. In brief, the results of the tests substantiated the earlier data taken on 2 inch shares. It also established the best point configurations for 3 and 4 inch shares, which are respectively 5 inches wide, 14 inches long with a 30 degree angle of attack, and 6 inches wide, 14 inches long and 30 degree angle of attack.

As an integral part of the plow tests, different types of feed tube designs were investigated. Cable was passed through the feed tubes and buried under actual plowing conditions. Tests were made to find the best diameter and position for the guide rollers in the tubes, the proper radius of the cable as it bends from the vertical to the horizontal, and the amount of tension placed on the cable. Air dielectric coaxial cable, used for closed circuit television, was used in tests to evaluate each of the feed tubes. This cable is relatively fragile and any deformations occurring in its outer tube were easily detected by the resulting changes in the electrical characteristics of the cable.

When the testing was completed, the engineers knew a great deal about many other factors affecting plowing operations. The data showed that both directly-coupled and trailed plows transferred downdraft to the tractor. This increased the tractor's effective weight and, therefore, increased the drawbar-pull obtainable from the tractor. Thus, a cable-laying plow is one earth moving tool which helps its prime mover develop more pulling effort. The discovery that the trailed-plow transfers weight to the tractor eliminated one of the presupposed disadvantages for it.
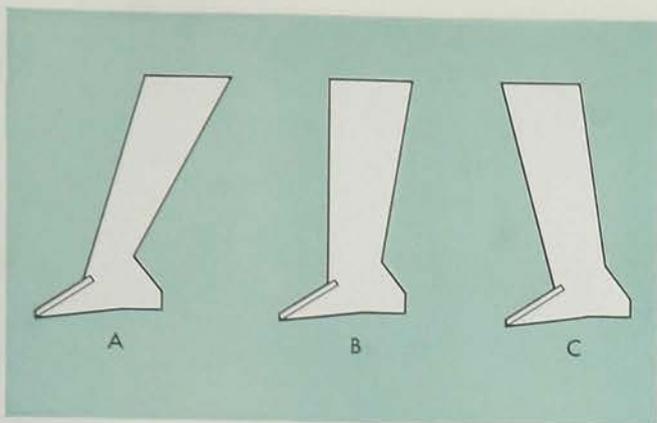
Three angles were tested to find the best over-all angle of attack for cable plows; B was adopted.

Therefore, the same size tractor could be used to pull either a directly-coupled or trailer-type plow. Consequently the only advantage of a directly-coupled plow is its compactness. On the other hand the trailed-type plow offers the following advantages:

▶Lower investment cost—no need for an expensive tractor to stand idle when not placing buried cable and wire.

▶Less tension in the cable (or wire).

▶Less likely to damage the cable (or wire).

▶More uniform depth of cable (or wire) in rolling terrain.

▶Can be winched through streams, swamps, etc.

▶Requires less detailed design.

▶Need not be restricted to any particular prime mover.

The many inherent advantages of trailed-type

plows coupled with the newly proven fact that they could be pulled by the same size tractor as a directly-coupled unit, resulted in a decision to concentrate on the development of trailed plows.

The first plow designed is now available to the operating telephone companies. Basically, the unit is a modified commercial plow chassis with a Laboratories designed share attached. It has all the features already found to be important from the tests, and should reduce the tractive effort required for pulling by at least 25 per cent of the amount required by commercially available plow shares. The back of the feed tube can be opened for removal of the cable. Three share sizes are provided to accommodate cable up to 3.1 inches and place the cable at a maximum depth of 36 inches. This plow had extensive field trials during 1961 and was well received by the field forces. The Laboratories is now designing a smaller trailed plow for cable up to 1.5 inches.

What then has been accomplished by the Laboratories investigation of cable plowing? This field, an art for so long, now has a solid base of technical information. No theories on soil mechanics of plowing have been proposed because it was felt that this was not the prime function of the study. Rather, its intent was to remove major uncertainties in a scientific, experimental manner so that cable or wire could be placed in the ground undamaged. This has been done, and the prompt translation of these efforts into usable, efficient tools will allow the telephone companies to reap significant cost savings in construction and maintenance, and the public-relations benefits of buried cable.

The later version of the instrumented test frame was trailed behind the tractor to reduce the problems of depth control encountered when plows were directly attached to their "prime mover."

Mrs. M. R. Arlitz, New York Telephone Company, demonstrates the new supervisor's console as it would be used in a typical operating room.

R. M. Kriegel

Centralized Supervisor Facilities

IT has been said that if the Bell System had not gone over to dial switching systems, and we had the same number of operators per 10,000 telephones that we had forty years ago, we would need about 1,000,000 operators to make all of today's connections by hand! As a result of this conversion, however, the routine duties of the operator have decreased, and her duties now entail special assistance to a customer in completing his call. This, coupled with an expansion of direct distance dialing and the use of local and centralized automatic message accounting, has resulted in an extension of the duties of the supervisor, and development of new equipment for her use.

Today, supervisors are assigned for switchboard operators at a ratio of one supervisor for each nine to fifteen switchboard positions and desk positions. Since operators now handle an increased number of situations without assistance, a new centralized supervisory system has been developed which permits a supervisor to work with as many as seventy operators from one operating console.

At present, the supervisor performs her functions at the switchboard or desk position and uses the facilities at these locations for receiving or originating calls. The newly designed facilities permit her to be seated at a console with telephone trunks to each position that she supervises; thus, she will be able to function with much greater efficiency than by moving up and down a long line of switchboards or desks, as shown in the frontispiece photo.

The supervisory functions which are provided in the new centralized facilities permit the supervisor to:

▶ Receive incoming calls from operators who, for example, need some information to help them complete an unusual type of call or to assist in the completion of a call in which difficulty has been encountered along the line.

▶ Receive incoming calls from customers who may not be satisfied with the answers received from the operator.

▶ Receive incoming calls from maintenance men who may wish to obtain more information about a particular case of trouble they are working on, or to give the supervisor an "OK" on a previous case of trouble they have cleared.

▶ Make calls to the operators whom she supervises to pass on new instructions and pertinent information relative to the day-to-day job.

▶ Make outgoing calls to customers in response to their earlier calls for information after she has obtained the desired answers.

▶ Make outgoing calls to plant craftsmen to report trouble conditions on circuits or to request information on new lines or circuits.

▶ Monitor on the operators she supervises to check the quality of service rendered to the customer.

These new arrangements replace the existing supervisory circuits found in the large variety of existing switchboards and desks, including Switchboards Nos. 1, 3, 3C, 3CF and 3CL, Switchboards Nos. 13C, 13D, 14C, 14D, 15C and 15D, Operating Room Desks Nos. 2, 3, 6, 7 and 23 and the new 100A Traffic Service Position.

The supervisor at her centralized console can originate connections to a maximum of seventy positions by depressing one of seventy nonlocking push buttons. She answers calls from the positions over a maximum of six trunks by pressing
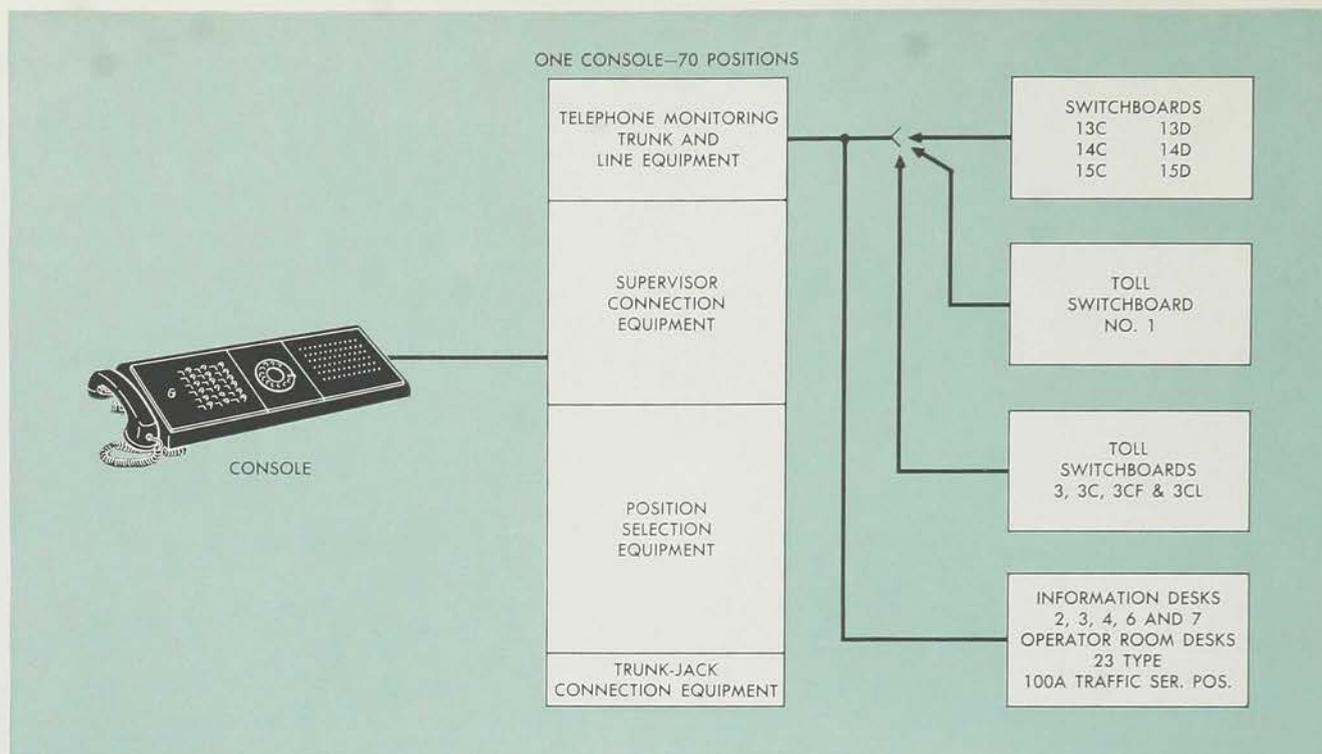
Schematic drawing shows typical equipment configuration, using one console with 70 positions.

a nonlocking illuminated key associated with each trunk. The console is equipped with a dial, a handset, and a pilot lamp for calling the supervisor's attention to incoming calls at the console. It is also equipped with headset telephone jacks for a 52 type headset for use during extended periods at the console when the handset would be cumbersome. In addition, it has illuminated nonlocking keys for holding calls at the console, for initiating calls to a dial office for local or DDD completion, for connection to a toll office for nondialable toll calls, and for recalling the operators on transferred calls (except for the Nos. 2, 7 and 23 type desks, whose operators can not be recalled on transferred calls). Two sets of auxiliary telephone jacks multipled at the console can be provided at the supervisor's desk if required, for simultaneous headset monitoring.

Facilities are also provided at the switchboard or desk so that the supervisor may answer and hold calls at that location. These facilities are provided at a maximum of four positions in the switchboard or desk lineup. The flashing signal lamps at the switchboard or desk lineups are arranged to call the supervisor's attention to incoming calls at that lineup or other lineups under her supervision when she is on the floor and not at the console.

Two centralized supervisory consoles may be provided for large installations when required,

and may be associated in several patterns. When there are no more than seventy positions in the supervised unit, the consoles may be wired for joint access to and from the positions over the same originating and incoming paths. When there are more than seventy positions in the supervised unit, the originating paths are divided between the consoles. The incoming paths, however, can be multipled partially or completely by providing an extra six button illuminated key unit at either or both consoles. With complete multipling of the maximum number of positions, each console can have originating access to seventy positions and can answer calls from one hundred forty positions. Typical equipment configurations are shown above.

The associated relay rack equipment contains the units for the telephone monitoring trunk and line equipment, supervisor's connection equipment, position selection equipment, and trunk to jack connecting equipment.

The new centralized supervisory plan and facilities results in improved operator training and development, permitting the supervisor to give sufficient uninterrupted time to the operator, thus improving the quality of service through better trained and motivated operators. It will also materially fill the need in operating rooms for efficient, attractive and comfortable equipment for supervisors.

NEW SURFACE ANALYZER

A simple and inexpensive method of detecting extremely
small variations in the surfaces of polished flat semiconduc-
tor materials has been devised by Miles V. Sullivan of the
Metallurgical Research Laboratories. Making use of principles
known in the field of optics for over 1000 years, he is
able to discern surface roughness and small defects more
readily with the new analyzer than with normally-used inter-
ferometers and high-powered microscopes.

Light from a small tungsten-filament lamp is made to
shine on the surface of the material and is reflected onto a
screen or ground glass. Ripples or defects in the surface
are enlarged and accentuated in the image on the screen. For
example, a defect about 0.25-mm wide may easily be magnified
to 6.3 mm when projected onto a screen 20 mm away. The rela-
tive position of any defects on the specimen can easily be
determined because the entire surface can be viewed at one
time. No lenses are needed for forming, examining or photo-
graphing the image.

The new surface analyzer has been particularly useful
in the development of new chemical and electrochemical semi-
conductor polishing techniques.

HIGH-SPEED X-RAY SPECTROGRAPH

Bell System telephone poles are normally protected from the
ravages of decay or termite attack by pentachlorophenol preserva-
tive used either alone or with creosote, and tested periodically
for preservative loss. Up to now, Bell Laboratories has used
conventional X-ray machines to analyze small borings from test
poles in these tests. One sample every three minutes could be
analyzed this way.

Now, the Laboratories has developed a new X-ray spectograph
attachment that analyzes one sample every 43 seconds. The unit,
designed by Stephen De Bala with Thomas Loomis and Keith H. Storks,
all of the Chemical Research Laboratory, bombards the chlorine
atoms in the preservative. These atoms fluoresce, giving off X-rays
of a characteristic wave length. These X-rays enter an analyzing
crystal and then a tube where they are converted into electrical
pulses. The pulses are amplified, counted, and the
result is tabulated on a printer.

Data on the radiation encountered by Telstar are now being processed by Laboratories scientists, and will be made available to others. One important fact: damage to solar cells is within the range expected.

Telstar Provides
High-Altitude Radiation Data

The Bell System's experimental communications satellite, Telstar, has encountered a large amount of high-energy electrons in space. Whether the amount represents an unusually high concentration of Van Allen belt electrons or results from the United States' high-altitude nuclear bomb test of July 9 is still being debated, according to a recent report by Laboratories scientists.

They said also that radiation damage to Telstar's power plant—caused by both electrons and protons—is within the range originally expected in the Van Allen belt without any nuclear tests.
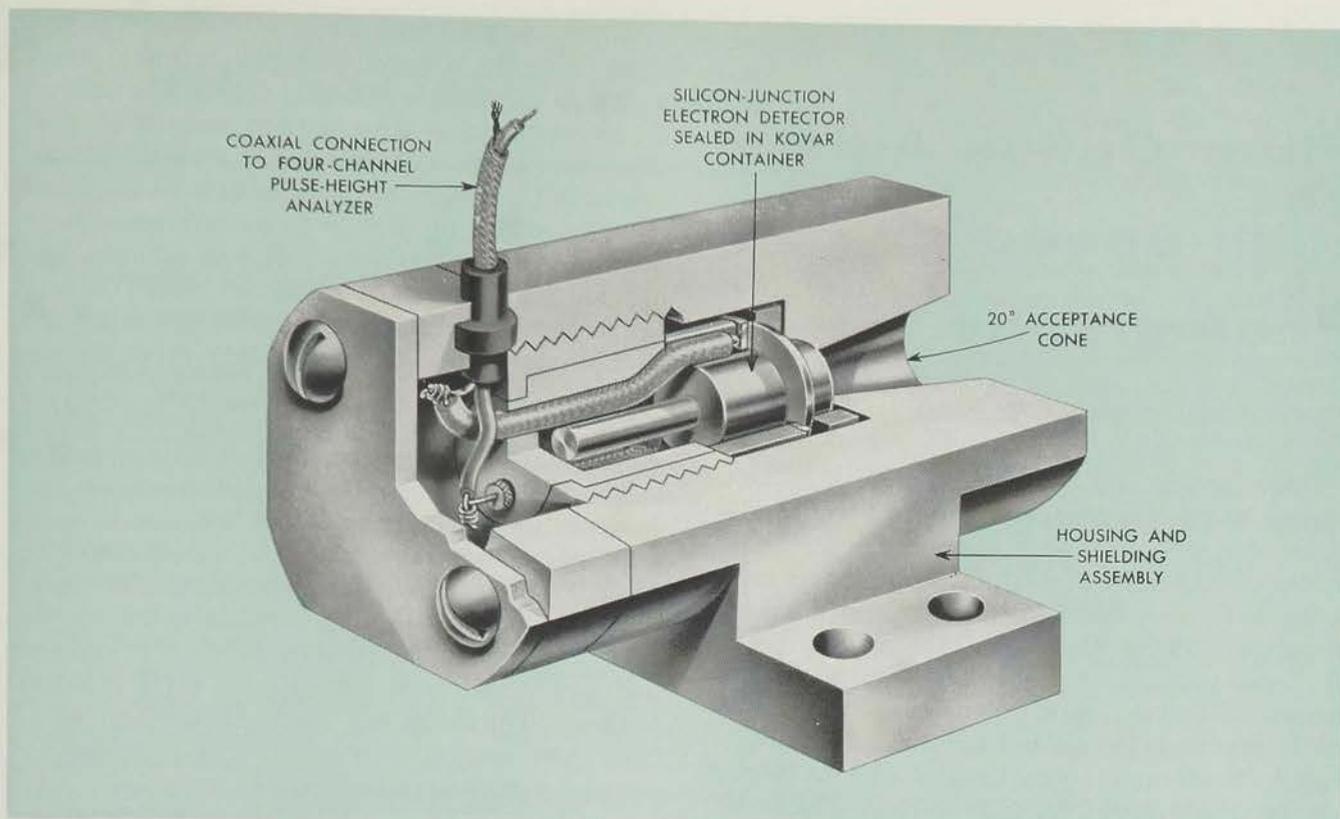
Telstar, launched on July 10 by the National Aeronautics and Space Administration, is reporting a wealth of information on radiation in its high orbit—from 600 to 3500 statute miles above earth. The orbit passes through the heart of the Van Allen belt, a natural band of radiation extending upward from the earth's atmosphere for thousands of miles. The belt is made up of energetic electrons and protons trapped by the earth's magnetic field.

Telstar's radiation test package counts particles in several energy levels to provide one of the most thorough radiation measurements by any satellite at these altitudes. The measurements are virtually the only ones now being reported from the higher altitudes. Bell Laboratories is processing the abundant data and making an analysis available to the nation's scientists.

An increase in radiation resulting from the government's nuclear test is fairly well established for the lower altitudes. But just what happened in the higher region covered by Telstar's orbit is still being debated—because of the uncertainty as to just what radiation intensity existed in the region before the nuclear test.

Post-test conditions reported by Telstar's solid-state detectors show that the number of protons is about the same as expected, but the number of energetic electrons is about ten times as large as had been anticipated.

Total radiation damage to the vital solar cells (which convert the sun's energy into electric

COAXIAL CONNECTION
TO FOUR-CHANNEL
PULSE-HEIGHT
ANALYZER

SILICON-JUNCTION
ELECTRON DETECTOR
SEALED IN KOVAR
CONTAINER

20° ACCEPTANCE
CONE

HOUSING AND
SHIELDING
ASSEMBLY

Drawing of radiation detector shows detail of external structure and shielding of active elements.

power for the satellite) is within the range of damage anticipated from natural conditions. Up to now, output of the solar cells has been reduced by radiation and other effects to 85 per cent of the initial power. The rate of damage to solar cells by radiation decreases with time, and it is estimated that at the end of two years the solar cell output will still be about 68 per cent of the initial amount. Because Telstar was designed to operate with a 50 per cent degradation in its power supply, the power level will still be sufficient to permit Telstar to perform its role.

Telstar owes its good solar-power condition to heavy shielding of the cells by windows of clear, artificial sapphire and especially to a new kind of solar cell, used in a satellite for the first time. Negative-type silicon is on top instead of underneath positive-type silicon as in other satellites. The lower sensitivity to radiation damage in this type of cell was first demonstrated by the Army Signal Corps Research and Development Laboratory. Had these developments not been used in Telstar, the satellite's power output would have been reduced within two weeks to the level now expected after two years.

A conservative power-plant design, which provides a large margin for solar-cell decay before threatening the power needs of the satellite, was used in an effort to point toward development of

operational communications satellites with an economical long life.

Telstar continues also to perform well its primary function—the experimental relay of communications signals. It was used this summer for the first experimental transmission by way of satellite of overseas telephony, data and facsimile pictures, and the first transoceanic transmission through any medium of live black-and-white and color television.

All transmission measurements planned originally have been carried out with results close to those predicted, yet one of Telstar's important scientific tasks will not be fulfilled until it fails. The discovery of component failures as they occur will be of great value in the design and development of components and circuits for future operational communications satellites.

One small malfunction has occurred in the satellite. Command receivers and decoders translate coded radio messages into action in the satellite. Two receivers and decoders are used as a precaution against the failure of one. A special circuit in the satellite tests the individual decoders on command from the ground. This test command has failed. The failure does not affect the operation of Telstar but simply means that now no one can confirm that both of the decoders are still operating.

Fiber Optics Aids
High-Speed
Photography

Fiber optics and the motion-picture camera have joined forces in a new way to produce pictures of rapidly changing phenomena. Scientists in the Mechanics Research Laboratory recently completed experiments with a fiber optics image-dissection camera which can take a sequence of 75 X-ray pictures at a speed of 400,000 frames per second and still produce good resolution.

At the 6th International Conference on High-Speed Photography, recently held at The Hague in the Netherlands, J. S. Courtney-Pratt described the camera, which uses an assembly of glass fibers embedded in a matrix to conduct light to a photographic plate. The fibers are coated at one end with a phosphor that converts the X-rays to visible light. The matrix and the rapidly moving plate beneath it act as a high-speed recorder.

High-speed cinematography is an important tool for research into many physical phenomena. X-ray pictures are particularly needed for studying actions like that of a melting fuse or of an electrical contact inside a sealed relay system. In rocket propulsion, X-ray pictures are useful for determining the mass and velocity distribution of particles in the combustion process.

Conventional high-speed cameras are limited by the speed of their mechanical shutters. A way to overcome this barrier is to use some form of image-dissection plus a continuous movement of the film plate.

Basically, the arrangement consists of the phosphor as a light source, the object to be photographed, the fiber-filled matrix and the movable photographic plate. The matrix is approximately three inches square and one inch thick. Each fiber consists of an inch-long, 0.001 inch-diameter, rod of flintglass surrounded by a thin sheath of crown glass whose lower index of refraction provides total internal reflection. This sheath is coated with a second sheath of opaque glass and the closely packed array of 32,000 fibers is held in the matrix by an opaque epoxy resin.

Thus arranged, the fibers efficiently transmit light from the image to the photographic emulsion held close to the opposite side of the matrix. Under continuous illumination, each fiber produces a line whose density varies with the illumination on the image. The film needs to be displaced only the width of a fiber to permit subsequent exposure of entirely new patterns of light and dark areas. This short distance (about 1 mil) combined with rapid movement of the film plate (a maximum of 36 ft. per second) gives the extremely high-speed action.

The film plate is mounted on a trolley which moves in a track by a compressed-air arrangement. Despite acceleration and deceleration exceeding 100 g, the plates do not break.

To get recognizable photos it is necessary to "decode" the pictures from the composite plate. This is done by re-aligning the plate in accordance with a recognizable pattern originally exposed and slowly pulling it through the same physical sequence. The result is a "slow motion" reproduction which can be observed directly or copied by conventional camera techniques.
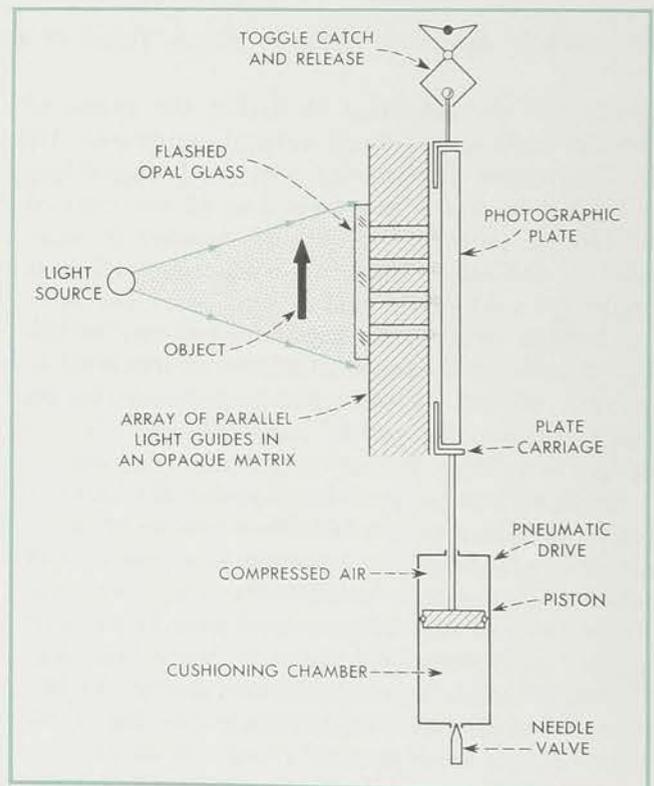
Optical analog of fiber optics image dissection camera developed at Bell Laboratories to study high-speed X-ray phenomena. Camera proved feasibility of using fiber optics cinematography for high-speed exposures over entire visible spectrum. Apparatus for moving film plate incorporates cushioning device to avoid plate breakage.

news in brief

Whippany Laboratory To Be Expanded

Bell Laboratories has announced that the Whippany Laboratory will be expanded by $1 million in new construction. The project will include a 90,000-square-foot, two-story extension to Building 1, and a 10,000-square-foot boiler house to consolidate heating facilities for the entire location.

The boiler house also will be used for additional office and laboratory space for the staff and technical organizations and for machine, coil and printed circuit shops. The building will be designated 1D. The existing shipping and receiving facilities will be renovated as part of the over-all project. The new buildings will enable the Laboratories to abandon and remove several temporary structures which were built during World War II.

Occupancy installations in the new building are expected to start in March, 1963; full occupancy will be completed by the end of June.

President Appoints Satellite Company Incorporators

President Kennedy named 13 prominent Americans to set up this country's new satellite communications corporation. His choices, who must be confirmed by the Senate, were drawn from business, labor, and professional groups.

The incorporators will set up the private corporation, which will be under government regulation, and make plans for the initial public stock offering.

The first Board of Directors will be named after the organization has been incorporated and charter and bylaws have been drawn up.

Two Labs Men Receive ASTM Award

Two Laboratories men were among twenty leaders in the field of engineering materials recently honored by the American Society for Testing and Materials. The Award of Merit was presented to W. Babington, of the Metallurgical Engineering Department, and W. A. Evans, who retired from the Laboratories in 1945.

The awards were made at the 65th Annual Meeting of the ASTM held in New York City on June 27. This award is given to men who have rendered outstanding service to ASTM, particularly in the Society's technical committee work.

Mr. Babington received the award in recognition of his "long and constructive participation in the work . . . on Die-Cast Metals and Alloys." Mr. Evans award was for recognition "of active productive service and leadership in the standardization of test methods and specifications . . . on electrical insulating materials and . . . on plastics."

AT&T To Spend $3 Billion For Construction

AT&T will spend $3 billion for construction during 1962, F. R. Kappel, Chairman of the Board, announced recently. The figure is the largest sum any company has ever spent on expansion in a single year.

This will mark the seventh consecutive year in which the Bell System will have spent more than $2 billion in a single year. No other company has even approached this figure. The previous high of $2.7 billion was set by the Bell System in 1961.

Mr. Kappel announced the construction figures at the meeting of the Telephone Pioneers of America in Dallas, Texas. He pointed out that the record sum would be spent despite the fact that 1962 would not be the biggest growth year for the System. He told the Pioneers that AT&T was able to undertake such a program "because we are in good shape financially . . . and by so doing can make an important contribution to the country's over-all economic welfare right now."

Telstar Relays Tape Schirra's Launch to Europe

Telstar relayed to Europe a tape of Commander Walter M. Schirra, Jr.'s lift-off from Cape Canaveral. The tape was transmitted 45 minutes after the launch.

The Eurovision network, which serves 17 nations outside the Soviet block, carried the TV scenes throughout the area it services. News agencies reported the tape also was seen in nine eastern European countries, including part of the U.S.S.R.

Reports from England are that the Telstar picture was "clear". There was some interference caused by a ground loop in the U.S. It blocked out the picture between Schirra's entering the van which carried him to the rocket and his arrival at the rocket. The tape was sent twice via two separate passes of Telstar.

Commander Schirra's flight is —like earlier space trips by astronauts Sheppard, Grissom, Glenn, and Carpenter—part of the National Aeronautic and Space Administration's Project Mercury. Western Electric Company led the industrial team that engineered and built the original network for tracking and providing communication with the astronaut. Three stations recently have been added to the network.

Design and installation of the operations control room at Cape Canaveral were headed by Bell Telephone Laboratories.

PATENTS

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

Albersheim, W. J.—*Scanning Antenna System*—3,056,129.

Ashkin, A. and Gordon, E. I.—*Low Noise Electron Beam*—3,054,964.

Bjornson, B. G.—*Optical Pulse Echo System*—3,053,134.

Bobeck, A. H.—*Magnetic Memory Circuits*—3,052,873.

Boyd, G. D., Fox, A. G. and Li, T.—*Optical Maser Cavity*—3,055,-257.

Braun, H. J., Mallina, R. F. and McKenzie, R. W. *Modifying the Terminations of Electrical Components*—3,054,165.

Chynoweth, A. G., Feldman, W. L. and Pearson, G. L.—*Three Stable State Semiconductive Device*—3,053,998.

Cook, J. S. and Louisell, W. H.—*Low Noise Superconductive Ferromagnetic Parametric Amplifier*—3,056,092.

Cutler, C. C.—*Horn Radiator For Spherical Reflector*—3,055,004.

Feldmann, W. L.—see Chynoweth, A. G.

Fox, A. G.—see Boyd, G. D.

Gordon, E. I.—see Ashkin, A.

Hagelbarger, D. W.—*Accumulator*—3,052,413.

Hagelbarger, D. W.—*Telephone Handset*—D-193,662.

Hagelbarger, D. W.—*Telephone Handset*—D-193,663.

James, D. B. and Wolfe, R. M.—*Communication System Employing Pulse Code Modulation*—3,056,085.

King, B. G.—*Negative Resistance Pulse Regenerator with Unidirectional Reflector*—3,054,906.

Lee, C. A.—*Negative Resistance Semiconductive Device*—3,054,-972.

Li, T.—see Boyd, G. D.

Louisell, W. H.—see Cook, J. S.

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McKenzie, R. W.—see Braun, H. J.

Meyers, S. T.—*Binary Counter Employing Multiregion Bistable Semiconductive Devices*—3,054,-000.

O'Brien, W. D. and Pollard, C. E. Jr.—*Liquid-Contact Switch*—3,054,873.

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Pferd, W.—*Card Holder For Card Dialer*—3,055,679.

Pollard, C. E., Jr.—see O'Brien, W. D.

Seidel, H.—*Traveling Wave Maser*—3,056,091.

Tendick, F. H.—*Logic Circuit*—3,054,002.

Warner, R. M., Jr.—*Temperature Compensated Field Effect Resistor*—3,056,100.

Weiss, M. T.—*Gyromagnetic Harmonic Generator*—3,054,042.

Wight, F. P.—*Private Branch Exchange Console*—D-193,513.

Wolfe, R. M.—see James, D. B.

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Young, T. F.*, see Walrafen, G. E.

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* Not a Laboratories employee.

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

Anderson, E. W., see McCall, D. W.

Andreatch, P., see Sikorski, M. E.

Averbach, E., *Short-Term Visual Memory*, Penna. Sci. Teachers Assoc., and the Penna. Acad. Sci., California, Penna.

Bakanowski, A. E., *Physics of Varactor Diodes*, MIT, Cambridge, Mass.

Barns, R. L., *Imperfections in Ruby for Maser Applications*, AIME Conf. on Advanced Electronic Materials, Philadelphia.

Benes, V. E., *Frequency Modulation, Feedback Demodulation, and Fixed Points in Function Space, Part-1*, Intern. Symp. on Inform. Theory, Brussels.

Benes, V. E., *On Rearrangeable Three-Stage Connecting Networks*, 2nd Intern. Conf. on Inform. Processing, Munich.

Bennett, W. R., see Patel, C. K. N.

Brattain, W. H., *Comments on the Role of Research in the Navy Program*, Pacific Northwest Navy Res. and Develop. Clinic, Seattle.

Brugger, K., see Mason, W. P.

Chruney, M., see Uenohara, M.

Coke, E. U., see Rothkopf, E. Z.

Cottingham, W. B., *Surface Recombination and Heat Transfer in a Dissociated Diatomic Gas, Part-1 and Part-2*, 5th Natl. Heat Transfer Conf., Houston, Tex.

Cowan, R. A., *A Digital Non-Linear Function Generator*, Assoc. Computing Machinery Natl. Conf., Syracuse, N. Y.

Dammont, F. R., see Salovey, R.

David, E. E., *Computer-Catalyzed Speech Research*, 4th Intern. Cong. on Acoustics, Copenhagen.

David, E. E., and Hanson, R. L., *Binaural Hearing and Free-Field Effects*, 4th Intern. Cong. on Acoustics, Copenhagen.

David, E. E., Mathews, M. V., and Pfafflin, S. M., *An Energy Detector Model for Monaural Auditory Detection*, 4th Intern.

Cong. on Acoustics, Copenhagen.

David, E. E., Schroeder, M. R., Logan, B. F., and Prestigiacomo, A. J., *New Applications of Voice-Excitation to Vocoders*, Speech Commun. Seminar, Stockholm.

David, E. E., Schroeder, M. R., Logan, B. F., and Prestigiacomo, A. J., *Vocoders for Practical Bandwidth Reduction*, Intern. Symp. on Inform Theory, Brussels.

David, E. E., see Flanagan, J. L.

David, E. E., see Mathews, M. V.

Dewald, J. F., see Pearson, A. D.

Dodd, D. M., and Wood, D. L., *The Energy Levels of Praseodymium(III) in Calcium Tungstate*, Intern. Symp. on Mol. Structure and Spectroscopy, Tokyo.

Douglass, D. C., and Fratiello, A., *A Nuclear Magnetic Resonance Investigation of the Perfluoro-N-Heptane- iso-Octane System*, Am. Chem. Soc., Phys. Chem. Div., Atlantic City, N. J.

Eisele, K. M., see Uenohara, M.

Eisinger, J., *Paramagnetic and Endor Spectrum of Copper (III) in Aluminum Oxide*, 1st Intern. Conf. on Paramagnetic Resonance, Jerusalem.

Eisinger, J., *Proton Relaxation Enhancement*, 1st Intern. Conf. on Paramagnetic Resonance, Jerusalem.

Faust, W. L., see Patel, C. K. N.

Fawcett, E., see Reed, W. A.

Flanagan, J. L., *Perceptual Criteria in Speech Processing*, Speech Commun. Seminar, Stockholm.

Flanagan, J. L., *Computer Simulation of Basilar Membrane Displacement*, 4th Intern Cong. on Acoustics, Copenhagen.

Flanagan, J. L., David, E. E., and Watson, B. J., *Physiological Correlates of Binaural Lateralization*, 4th Intern Cong. on Acoustics, Copenhagen.

Fraser, D. B., *High-Temperature Internal Friction of Quartz*

Subjected to an Electric Field, Am. Phys. Soc., Seattle.

Fratiello, A., see Douglass, D. C.

Fuss, P. S., and Lauver, R. M., *Cause and Correction of Phase Distortion in Pulse Excited Long Ultrasonic Delay-Lines*, Western Electronics Show and Conv., Los Angeles.

Geballe, T. H., and Matthias, B. T., *The Isotope Effect in Superconducting Transition Metal Elements and Compounds*, 8th Intern. Conf. on Low Temp. Physics, London.

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

Geller, S., *Crystal Chemical and Magnetic Studies of Garnets*, Gordon Research Conf. on Inorganic Chem., New Hampton, N. H.

Gerstenberg, D., *The Effects of Nitrogen and Oxygen on Structure and Electrical Properties of Thin Tantalum Films*, Conf. on Thin Films, Glenwood Springs, Colo.

Gilbert, E. N., *Models of Polycrystalline Solids*, Intern. Cong. of Mathematicians, Djursholm, Sweden.

Gillette, D., *An Introduction to Guidance*, Univ. of Connecticut, Inst. of Missile and Rocket Technol., Storrs.

Giordmaine, J. A., *New Modes of Large Optical Resonators*, MIT, Physics Dept. Seminar, Cambridge, Mass.

Gordon, J. P., see Louisell, W. H.

Gossard, A. C., Jaccarino, V., and Wernick, J. H., *Ytterbium-171 NMR — Nuclear Moment and Ytterbium Metal Knight Shift*, Am. Phys. Soc., Seattle.

Hammock, J., *Educational Ills and Patent Medicines*, Conf. on Programmed Learning for Teachers, Univ. of Tennessee, Knoxville.

Hammock, J., *Machines—What Can They Teach Us?* Natl. Council of Teachers of Math., Univ. of Wisconsin, Madison.

Hanson, D. C., see Uenohara, M.

Hanson, R. L., see David, E. E.

Hawkins, W. L., and Sautter, H., *The Mechanism of Stabilization*

TALKS (CONTINUED)

with Organo-Sulfur Compounds, 11th Canadian High Polymer Forum, Windsor, Ont.

Haynes, J. R., *Recombination Radiation in Semiconductors,* Gordon Research Conf. on Phys. and Chem. Solids, Meriden, N. H.

Hempstead, C. F., Kim, Y. B., and Strand, A. R., *Stability of Critical Persistent Supercurrents,* Am. Phys. Soc., Seattle.

Hornung, G. T., *Producing Wiring Drawings from Circuit Drawings Using Data Processing Techniques,* Seminar on Design Automation, Chicago.

Imbusch, G. F., Schawlow, A. L., and Remeika, J. P., *Fluorescence Spectra of Chromium Ions in Gallium Oxide,* Am. Phys. Soc., Seattle.

Jaccarino, V., see Gossard, A. C.

Johnson, L. F., *Infrared Detectors and Optical Masers,* Infrared Inform Symp., Syracuse Univ.

Keith, H. D., *Mechanisms of Spherulitic Crystallization,* Am. Chem. Soc., Polymer Chem. Div., Atlantic City, N. J.

Kim, Y. B., see Hempstead, C. F.

Kluver, J. W., *A Low-Noise M-Type Parametric Amplifier,* 4th Intern. Cong. on Microwave Tubes, the Hague.

Kuebler, N. A., see Nelson, L. S.

Kurkjian, C. R., *Relaxation of Torsional Stress in the Transformation Range,* 6th Intern. Cong. on Glass, Washington, D. C.

Laue, R. V., *A Problem of Prediction in Production Engineering,* Rutgers Conf. on Qual. Control, New Brunswick, N. J.

Lauver, R. M., see Fuss, P. S.

LeCraw, R. C., see Matthews, H.

Lee, C. Y., *A Self-Describing Turing Machine—Its Role in Self-Reproduction,* Intern. Conf. of Mathematicians, Stockholm.

Levenbach, G. J., *Integrating Statistical Applications into a Reliability Program,* Am. Soc. Qual. Control Conf., Rutgers Univ.

Lewis, J. A., *Viscous Damping*

of Gravitationally Stabilized Satellites, 4th U.S. Nat. Congr. Appl. Mech., Berkeley, Calif.

Logan, B. F., see David, E. E.

Long, T. R., *A Discussion of Electrodeposited Cylindrical Thin Films,* IBM Seminar, Yorktown, N. Y.

Louisell, W. H., Walker, L. R., and Gordon, J. P., *Quantum Statistical Properties of Ideal Phase-Sensitive Receivers,* 4th Intern. Cong. on Microwave Tubes, The Hague.

Macrae, A. U., *Electron Diffraction Studies of Adsorbed Gas Atoms,* Gordon Research Conf., New Hampton, N. H.

Mallows, C. L., see Richter, D.

Mason, W. P., and Brugger, K., *Effect of Interstitials Due to Water on the Attenuation and Velocity of Ultrasonic Waves, and on the Thermal Resistance of Sodium Chloride Crystals,* 4th Intern. Cong. on Acoustics, Copenhagen.

Mathews, M. V., Miller, J. E., and David, E. E., *Strategies for Automatic Pole-Zero Analysis of Speech,* 1. 4th Intern. Cong. on Acoustics, Copenhagen. 2. Speech Commun. Seminar, Stockholm.

Mathews, M. V., see David, E. E.

Matsuoka, S., *Volume Viscosity,* Conf. on Nonideal Mech. Behavior of Solids and Liquids for College Teachers of Engrg., Appl. Math. and Appl. Phys., Princeton Univ., Princeton, N. J.

Matthews, H., and LeCraw, R. C., *Acoustic Wave Rotation in Gallium Substituted Yttrium Iron Garnet,* Am. Phys. Soc., Seattle.

Matthias, B. T., and Geballe, T. H., *Ferromagnetism Versus Superconductivity of the Transition Elements, Particularly Alloys of Chromium and Iridium,* 8th Intern. Conf. on Low Temp. Physics, London.

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

McCall, D. W., and Anderson, E. W., *Proton Magnetic Relaxation in Polyamides,* Am. Chem.

Soc., Atlantic City, N. J.

McFarlane, R. A., see Patel, C. K. N.

Miller, J. E., see Mathews, M. V.

Morrison, J. A., *The Effect of Radiation Pressure and Oblateness on the Equatorial Orbit of an Earth Satellite,* Am. Math. Soc., Vancouver, Brit. Columbia.

Nelson, L. S., and Kuebler, N. A., *The Kinetic Absorption Spectra of Flash-Heated Tungsten,* Am. Chem. Soc., Phys. Chem. Div., Atlantic City, N. J.

Neumann, P. G., *On a Class of Efficient Error-Limiting Variable-Length Codes,* Intern. Symp. on Inform. Theory, Brussels.

Northover, W. R., see Pearson, A. D.

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Patel, C. K. N., Bennett, W. R., Faust, W. L., and McFarlane R. A., *Optical Maser Oscillation in Pure Helium, Neon, Argon, Krypton and Xenon,* Am. Phys. Soc., Seattle.

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Pinkam, R. S., see Wilk, M. B.

Pinson, E. N., *Pitch Synchronous Time-Domain Estimation of Formant Frequencies and Bandwidths,* Acoust. Soc. Am., New York City.

Pollak, H. O., *The Content and Philosophy of the Ninth Grade S.M.S.G. Curriculum,* Bowling Green State Univ., Bowling Green, O.

Pollak, H. O., *On the Nature of Applied Mathematics*, 1. Fordham Univ., New York City, 2. Hamilton College, Clinton, N. Y., 3. Bowling Green State Univ., Bowling Green, O.

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Riesz, P. R., *Talking by Satellite*, Human Factors Soc., Metropolitan Chapt., Murray Hill, N. J.

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Rigden, J. D., see White, A. D.

Rogers, C. E., *Stress Cracking and Sorption in Polyethylene*, Am. Chem. Soc., Atlantic City, N. J.

Rosenberg, S., *Analysis of Two-Person Interactions with Individual Behavior Models*, Am. Psychol, Assoc., St. Louis.

Rosenzweig, W., Smits, F. M., and Brown, W. L., *The Energy Dependence of Proton Irradiation Damage in Silicon*, Am. Phys. Soc., Seattle.

Ross, I. M., *Highest Speed Semiconductor Components*, Intern. Fed. Inform. Process., Munich.

Rothkopf, E. Z., and Code, E. U., *Sequence of Repetition in Word Pair Learning*, Psychonomic Soc., St. Louis.

Russell, C. A., see Schard, M. P.

Salovey, R., and Dammont, F. R., *Molecular Weight Changes on Irradiation of Polyethylene Oxide and Polypropylene*, Am. Chem. Soc., Polymer Chem. Div., Atlantic City, N. J.

Sartori, E. F., *The Hybrid Trans-* former as a Transmission Device, AIEE, Denver.

Sautter, H., see Hawkins, W. L.

Scaff, J. H., *Space Age Demands on Materials and Ceramics*, Am. Soc. Metals Panel Discussion, Milwaukee.

Schard, M. P., and Russell, C. A., *Oxyluminescence of Polymers*, Am. Chem. Soc., Atlantic City, N. J.

Schawlow, A. L., see Imbusch, G. F.

Schroeder, M. R., see David, E. E.

Sharpe, L. H., *Further Studies of Surface Phenomena by Frustrated Total Internal Reflection*, Gordon Research Conf. on Adhesion, New Hampton, N. H.

Shepard, R. N., *Analysis of Proximities As a Technique for the Study of Information Processing in Man*, Human Factors Soc. and Univ. of Southern California Joint Symp., Los Angeles.

Sikorski, M. E., *Correlation of the Coefficient of Adhesion with Various Physical and Mechanical Properties of Metals*, Gordon Conf. on Friction, Lubrication and Wear, Tilton, N. H.

Sikorski, M. E., and Andreatch, P., *Pressure Effects on Transistors*, Am. Phys. Soc., Seattle.

Sinden, F. W., *A Canonical Form for Quadratic Programs*, Intern. Cong. of Mathematicians, Stockholm.

Slichter, W. P., *Nuclear Magnetic Resonance Relaxation in Elastomers*, Am. Chem. Soc., Atlantic City, N. J.

Sobel, M., See Richter, D.

Smits, F. M., see Rosenzwieg, W.

St. James, L. N., *The Economics of a Reliable System*, 7th Military-Industry Missile and Space Reliability Symp., San Diego.

Stillinger, F. H., *The Statistical Mechanical Theory of the Electrical Double Layer*, Am. Chem. Soc., Phys. Chem. Div., Atlantic City, N. J.

Strand, A. R., see Hempstead, C. F.

Traub, J. F., *On the Information-* al Efficiency of Iteration Functions, Intern. Cong. of Mathematicians, Stockholm.

Traub, J. F., *The Theory of Multipoint Iteration Functions*, Nat'l. Conf. Assoc. Computing Machinery, Syracuse, N. Y.

Tukey, J. W., *Reduction of Wasted Stringency in Ranking and Counting Procedures through the Use of Supplementary Criteria*, Inst. Math. Statist., Minneapolis, Minn.

Uenohara, M., Chruney, M., Eisele, K. M., Hanson, D. C., and Stillwell, A. L., *4GC Parametric Amplifier for Satellite Communication Ground Station Receiver*, Western Electronics Show and Conv., Los Angeles.

Walker, L. P., see Louisell, W. H.

Watson, B. J., see Flanagan, J. L.

Wernick, J. H., see Gossard, A. C.

White, A. D., and Rigden, J. D., *Continuous Gas Maser Operation in the Visible*, Conf. on Electron Device Research, Minneapolis.

Wilk, M. B., and Pinkham, R. S., *The Creasy-Fieller Paradox*, Joint Mtgs. Inst. Math Statist., Am. Statist. Assoc., and Biometric Soc., Minneapolis, Minn.

Williams, W. H., *Regression Analysis with Large Quantities of Data*, Gordon Research Conf., New Hampton, N. H.

Wilson, M. P., *Human Factors at the Whippany Laboratories*, Human Factors Soc., Metropolitan Chapt., Murray Hill, N. J.

Williams, W. H., *The Use of Multiple Regression in Time and Cost Index Studies*, Am. Statist, Assoc., Minneapolis.

Wolfe, R. M., *Ultrafast Thin Film Logic*, Workshop for Ultrafast Computers, Los Angeles.

Wood, D. L., see Dodd, D. M.

Yariv, A., *Recent Developments in Optical Masers*, 1. Hebrew Univ., Jerusalem. 2. Weizmann Institute of Science, Rehovot, Israel.

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* Not a Laboratories employee.

AUTHORS

John B. D'Albora, Jr., author of the article on the Cape Canaveral Branch Laboratory in this issue, is a native of Brooklyn, N. Y. He received his S.B. in E.E. from the Massachusetts Institute of Technology in 1934. Prior to joining the Bell System, he was a research assistant at MIT and senior radio inspector with the Inspector of Naval Material in New York. He joined the Western Electric Company field engineering force in 1941 and worked on installation and maintenance of Navy shipborne radar, with a field test group on new radar systems, and was a Section Chief assigned to the Charlestown Navy Yard. He transferred to the Laboratories in 1945 and worked on many phases of a number of Navy

J. B. D'Albora, Jr.

radar systems. After a two year assignment on the Dew Line Search Radar development program, he was appointed Supervisor in 1956 and assigned the responsibility of the ground guidance equipment at Cape Canaveral. In 1961, he was put in charge of the Cape Canaveral Laboratory. He has been a Senior Member of the IRE since 1948.

Daniel F. Hoth received the degree of M.E. from Stevens Institute of Technology in 1935. The following year he joined Bell Laboratories where he was initially

D. F. Hoth

concerned with various transmission studies. In 1942 Mr. Hoth joined the Signal Corps where he was responsible for planning military communications systems and attained the rank of captain. Since his return to the Laboratories in 1946 he has been responsible for studies and planning of development projects for wire and radio systems including mobile radio systems, microwave systems, PCM systems, and a number of others. In 1952 he supervised a group in the engineering planning of the initial DEW line installations.

At present Mr. Hoth is the director of the Transmission Studies Center and is responsible for planning a number of new kinds of communications systems. A senior member of the IRE and a member of the AIEE, Mr. Hoth is the author of the article on the T1 Carrier System in this issue.

P. R. White

P. R. White, a native of New York City, returned from Army service in World War II to attend Columbia University, where he received the B.S. degree in Metallurgical Engineering in 1948 and the M.S. degree in 1949. After employment at the General Motors Research Laboratories, where he was a research metallurgist on ferrous and non-ferrous alloy development problems, he joined Bell Laboratories in 1955. Since that time he has been engaged in research on low-melting alloys, soldering, welding and special metallurgical problems. Mr. White, co-author of "Sintered Circuits" in this issue, is a member of the American Society for Metals and the American Welding Society.

R. F. Jack

R. F. Jack, co-author of "Sintered Circuits" in this issue was born in Newark, N. J., and educated in that city's schools. After attending Cooper-Union, he was employed by the H. A. Wilson Company and conducted development work in their Precious Metals and Duplex Metals Contact Division. He later was concerned with the establishment of their Rolled Gold Plate Division. In 1946, he became associated with Majestic Metal Specialties, Inc. as superintendent to set up a complete new Precious Metals Processing Plant. Mr. Jack came to the Laboratories in 1950. He is

now supervisor in the Metals Processing Laboratory of the Metallurgical Research Laboratory engaged in a variety of projects. Among these are the development of straight, strain-free conductor substrates for plated memories, clad niobium-tin composite superconducting wires, and fine wires and ribbon for magnetic-memory applications.

Ian Maunsell, co-author of "TH Radio Terminals" in this issue, comes from Southern Rhodesia. When released from the R.A.F. at the end of the war, he attended the University of the Witwatersrand in Johannesburg, South Africa, where he earned the degree of B.S. (Eng.) in

Ian Maunsell

1950. He then completed a postgraduate course under the auspices of Marconi College in Chelmsford, England. Since that time he has been engaged in the development of broadband microwave communication systems, first in England and more recently in the United States. Mr. Maunsell joined Bell Laboratories in 1957, and worked on both the FM terminal equipment and the protection switching circuits for the TH Radio System. Recently, he has been engaged in working on the microwave communication circuit in the Telstar satellite. He is a member of the IRE.

Joel Schill

Joel Schill was born in Newark and now resides in Verona, N. J. During the Korean War, he served in the U. S. Marine Corps as a radar technician and instructor at Quantico, Va. Mr. Schill holds an Associate Engineering degree from Newark College of Engineering and is completing his senior year there. In 1954, Mr. Schill joined the Laboratories and worked on the evaluation of portable microwave equipment for black and white and color television transmission. Later, he transferred to the TH radio group where he worked on the development of the TH terminal transmitter and receiver. Mr. Schill, co-author of "TH Radio Terminals" has recently been engaged in the development of the ground transmitter for Project Telstar.

J. C. Maclay

John C. Maclay received his B.M.E. in 1958 from Cornell University, where he held three scholarships. He obtained his M.S. in Engineering Mechanics in 1960 from N.Y.U. while in the CDT Program. Upon graduation from Cornell, he came to the Construction Methods group of the Outside Plant Laboratory where he has been engaged primarily in the development of methods and equipment for buried urban and rural plant. The author of "Evolution of Cable Laying Plows" in this issue, he is a member of Tau Beta Pi, Pi Tau Sigma, and the Society of automotive Engineers.

Roland M. Kriegel, author of "Centralized Supervisor Facilities," was born in New York,

Roland M. Kriegel

and received the B.S.M.E. degree from Polytechnic Institute of Brooklyn in 1949. He served in the Army Chemical Corps working on biological warfare research and development. Mr. Kriegel joined the Laboratories in 1960 and is now working on equipment design and development for common systems local switching laboratory.

Mr. Kriegel has taken graduate courses at the Drexel Institute of Technology and is now completing work at the Polytechnic Institute of Brooklyn for a degree in electrical engineering. He is a licensed professional engineer, member of the ASME, and an audiophile.

New high-purity alloys make better electron tubes

Ingot of high-purity nickel alloy is removed from controlled atmosphere melting fu
Alloy is virtually free of impurities which inhibit electron emission. The new alloying tec
and the methods for making cathodes and evaluating their electron-emitting propertie
developed by K. M. Olsen and H. E. Kern.

Scientists at Bell Telephone Laboratories have developed new high-purity nickel alloys which are proving highly effective in lengthening the life of advanced-design electron tubes used in the Bell System. This development meets the demand of new electronic technology for long life and high reliability in electron tubes.

One of the new alloys is now providing the outstanding performance required in the electron-emitting cathode of the traveling wave tube in the Telstar satellite.

The first step was to devise new means for the fabrication of ultra-pure nickel to eliminate those impurities harmful to cathode performance. It was then possible to add to the ultra-pure nickel the alloy constituents and activating agents desired for optimum cathode performance, and at the same time to hold the undesirable impurities at levels below 50 parts per million. These techniques involved purifying the nickel raw materials and melting, alloying and casting in controlled atmospheres of hydrogen and helium.

This development is an example of how metallurgical scientists work to improve communications. The new nickel alloys are now being produced by the Western Electric Company, manufacturing unit of the Bell System.

Bell Telephone Laboratories

World center of communications research and development