Bell Laboratories

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Search-Radar Tracking in Heavy Seas

Electronically Scanning Radar Antenna

Soil-Testing Materials and Apparatus
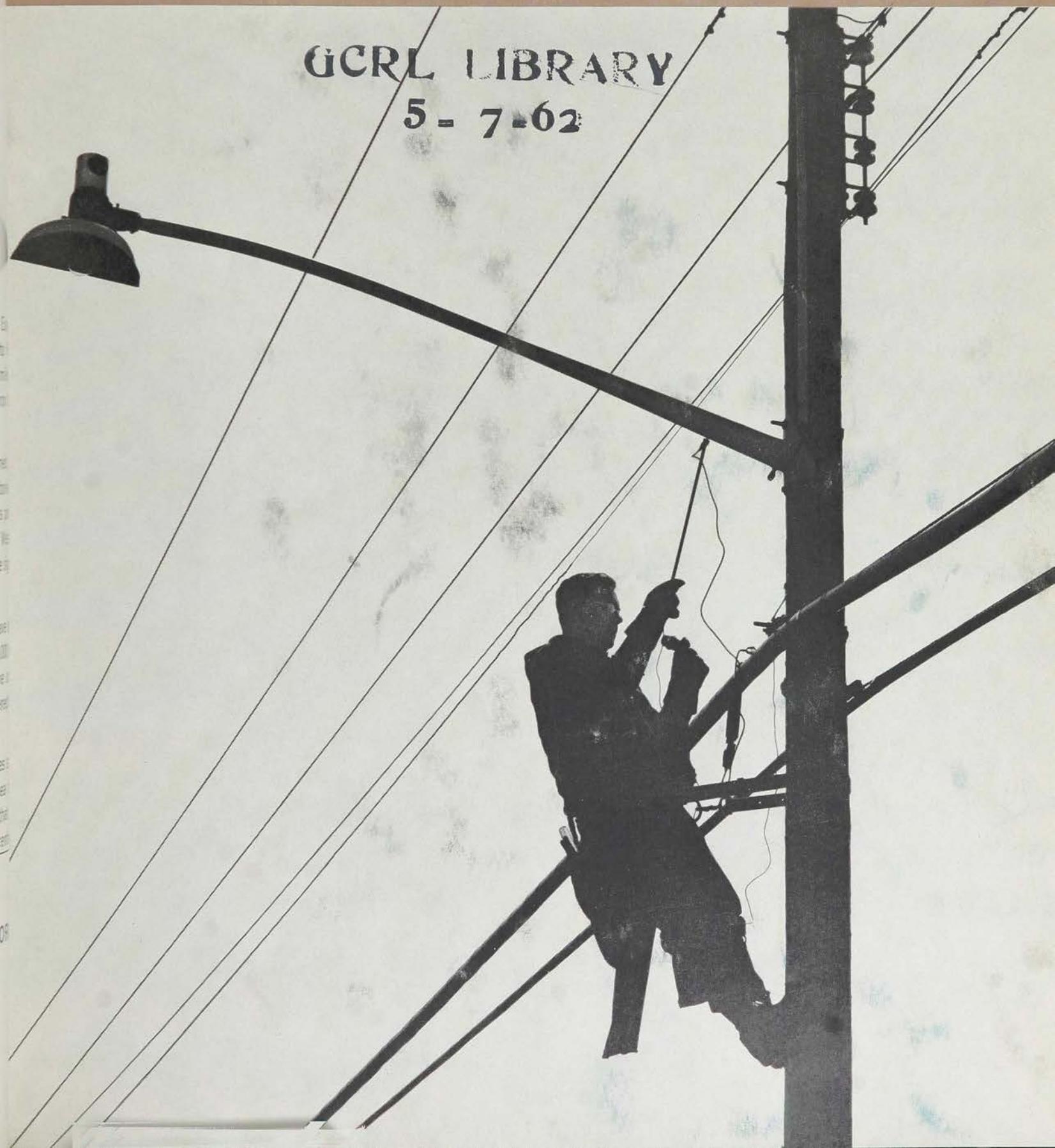
Human Factors in Transmission Maintenance

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Cover   *Richard Dein of the New York Telephone Company uses the B Voltage Tester to probe for hazardous voltages before working on telephone lines (see article on page 144).*

Search-Radar Tracking
In Heavy Seas

Roll of the U.S.S. Ingraham, shown here, may make search-radar tracking difficult. (Official U. S. Navy Photograph)

One way to test the performance of naval search radars is on shipboard under a mock attack. Another is to program a digital computer to simulate a ship that is being attacked by enemy planes.

W. G. Graves

A naval ship gets its first warning of an airborne enemy attack from its search radars. These radars survey the entire hemisphere above and around the ship in order to detect enemy targets. Their data is transmitted to computers that track these targets, evaluate their relative threat, determine the order of handling them and, finally, designate targets to individual missile or gun directors. An effective defense, or disaster, may turn on how well a ship's search radars perform.

Naval weapon direction systems use two types of search radars. The first type reports data in three dimensions: range, bearing and elevation angle. It radiates its transmitted energy in a series of pencil beams stacked one above the other. Each beam is fixed at one value of elevation angle from close to zero (deck level) to almost 90 degrees (directly overhead). A receiver is associated with each beam and the radar can single out the elevation angle of any target by referring to the receiver that detected it. The array of beams is rotated to cover the entire hemisphere.

If the antenna followed the roll and pitch of the ship, its attitude would corrupt the elevation information. In fact, in relatively heavy seas the information would be useless. Therefore, the antenna of a three-dimensional search radar is generally mounted on a platform which is stabilized so that it is always parallel to the earth's surface. The combination of antenna, stabilized platform and drive mechanism is necessarily quite heavy and it must be carried at the top of the mast. These factors generally restrict the use of this type of radar to ships at least as large as cruisers.

The second type of search radar is simpler. It reports its data in two dimensions only: range and bearing. To provide adequate elevation coverage, it radiates energy in a fan-shaped beam that covers an elevation angle considerably greater than its bearing angle. The antenna of this radar usually is not stabilized. It therefore does not incur the penalty of weight at the masthead imposed by the first type, and it is generally used on small, fast, highly-maneuverable ships, such as destroyers, where this weight must be minimized.

Two questions are suggested. Does the unstabilized, two-dimensional radar give the kind of information that enables satisfactory performance of the functions of target detection, tracking, threat evaluation and designation? If not, can anything be done to make it satisfactory without incurring an unacceptable masthead weight penalty? Bell Laboratories engineers, who have assisted the Navy on many radar problems, were asked to answer these questions. Their task was not to design new equipment, but to evaluate the performance of unstabilized radar and determine if the data it reports are good enough for a weapon control system; if fully stabilized, three-dimensional search radar is necessary; or if some partial stabilization arrangement is practical and capable of giving satisfactory information.

An intelligent decision could be made only on the basis of a large amount of performance data. These data could be collected on shipboard under conditions of, say, a mock attack. The hazards of this method, and its expense, are evident. The problem is a natural one to solve, however, with a technique pioneered by Laboratories engineers —simulation on a digital computer. The first step in this method is to define the errors that an unstabilized antenna may introduce into a weapon control system. The most important factors in tracking are deduced from observing the effect
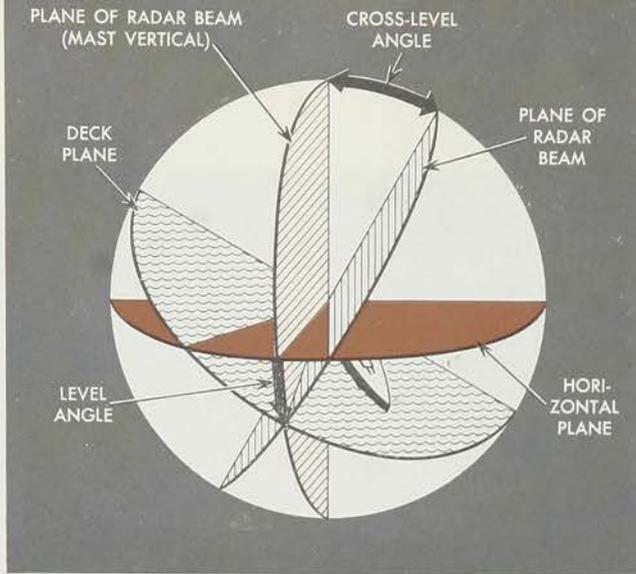
Cross-level and level angles of an unstabilized antenna beam in relation to the earth's surface.

of these errors on radar scope displays. Then, quantitative values are assigned to these factors and a series of tracking runs is programmed for the computer. This is the plan the Laboratories followed. Evaluation of the computer's output yielded much pertinent data on the performance of search radars in rough seas.

Effect of Pitch and Roll

The pitch and roll of an unstabilized search radar antenna degrades the performance of a shipborne weapon control system in two ways. It reduces the range at which there is a high probability of detecting targets and it causes errors in the target-position data, so that the target's bearing from the ship seems to change erratically. These errors arise from unwanted changes in two direction angles of the antenna's beam.

The first angle, the level angle, (see the drawing above) is equal to the ship's pitch when the antenna is pointed directly forward and equal to the roll when the antenna is pointed directly abeam. Quite simply, the level-angle component of the antenna's motion moves the center of the beam up or down relative to the earth's surface. If the level angle is large enough, the beam will overshoot or undershoot the target. As the amplitude of the swing of the level angle increases on a particular bearing the radar beam will miss a target on that bearing a greater number of times. This shortens the range at which the plan position indicator (PPI) operator will detect the target.

A large swing in the level angle means that the target may not be detected until it is fairly close to the ship. Roughly, every six degrees of level angle swing reduces the detection range of the fan beam radar used in the Laboratories study about 15 per cent. Moreover, although the cumulative probability that a target will be detected increases as the range shortens, it rises more

slowly with a large level-angle swing. (In the graph opposite, Ei_m is the amplitude of this swing.)

The second unwanted direction angle is the cross-level angle. Ideally, the vertical plane of a radar's fan beam is perpendicular to the earth's surface. Roll and pitch cause a deviation from the perpendicular. The amount of this deviation is the cross-level angle. A target return from this tilted beam appears on the PPI at a bearing which is actually at a small angle from its true bearing. This effect becomes more severe as the elevation angle of the target increases. Thus, because the instantaneous values of roll and pitch change between radar "looks", the apparent bearing of a radially approaching target changes from scan to scan.

These are the basic effects of an unstabilized antenna on information presented by search radars. They imply two criteria of performance that can be expressed quantitatively. The first is the accuracy of target data that the radar produces, or simply, tracking accuracy. A good measure of this is the average error between the target's true position and the corresponding track-while-scan data. The symbol for this is ϵ_m. The second criterion is the difficulty involved in tracking a target on the PPI. A measure for this is the average time between data corrections made by the operator. Its symbol is T_m. Because of the method of computing it, it never has a value less than four seconds—the data interval assumed for the search radar.

An important factor affecting both ϵ_m and T_m
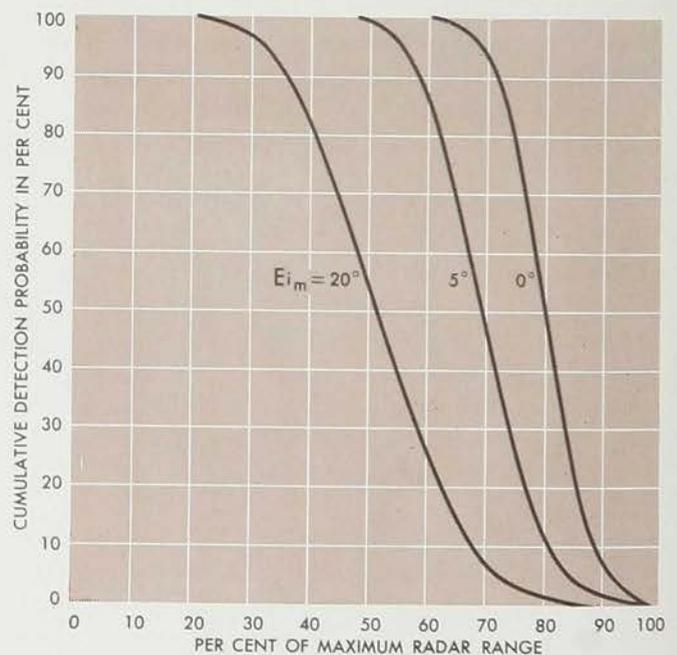
Effect of an unstabilized search radar antenna on target detection. Target is at 15,000 feet altitude.
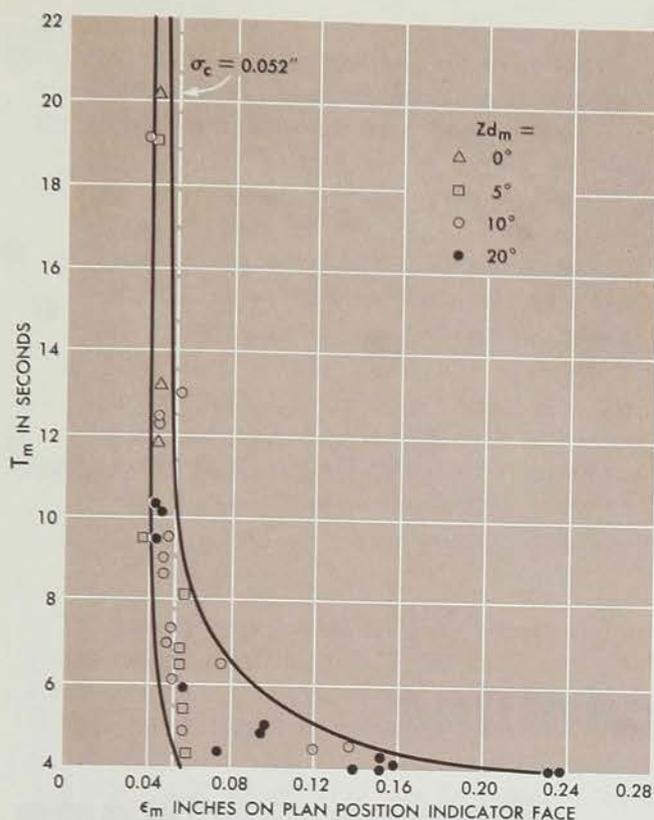
Graph of the relationship between average data insertion interval and the mean tracking error.

is the PPI operator's ability to perceive that the position of a track-while-scan channel marker does not coincide with the target return on his screen. When he detects this, he inserts data into the track-while-scan channel to correct the marker's position. The symbol for this factor is σ_c—it represents the standard error in position that motivates the operator to insert correcting data.

Results of Computer "Tracking"

On the basis of this data the simulated tracking runs were programmed for a digital computer. The graph above reflects the results and clearly shows the interrelationship of ϵ_m and T_m. Although the mean error of the track-while-scan data tends to increase as tracking becomes more difficult, it is not until it becomes so difficult that a correction must be made at very nearly every search radar look that ϵ_m becomes much larger than σ_c. When tracking is so difficult that T_m approaches its lower limit of four seconds, the track-while-scan data is very unsatisfactory.

Nearly all the tracking runs made for a swing of 20 degrees fall in the region of large errors and very frequent data corrections. This is very unsatisfactory tracking. However, the runs made for a swing of 10 degrees are accurate in tracking and not difficult for the PPI operator. Apparently,

a rather abrupt transition between satisfactory and unsatisfactory tracking occurs as the cross-level-angle swing increases. The amount of peak cross-level-angle swing on each tracking run is denoted Zd_m on the graph opposite.

The roll and pitch of a cruiser under "average" sea conditions are respectively 6 degrees and 2 degrees. Under heavy sea conditions this may increase to 20 degrees and 5 degrees. Because tracking is so unsatisfactory with a swing of 20 degrees, some sort of stabilization is necessary, or the search radar will not perform effectively in heavy seas.

Additionally, there is the detection range loss we have discussed of 15 per cent for every six degrees of level-angle swing. This loss, too, can be reduced only through stabilization. However, since roll is the most severe component of the ship's motion, a system to stabilize the antenna against roll alone would be effective, and it would not require as much weight at the masthead as a full-stabilization system. If the antenna is stabilized only for roll, the maximum detection range loss in heavy seas is about 15 per cent, a considerable improvement over the possible 45 per cent loss with an unstabilized antenna.

Finally, there are some effects of roll and pitch which could not be accounted for in the computer program. These are actually human factors. The PPI operator, in the final analysis, is the key to successful tracking. However, certain salient features of human behavior could not be programmed. For example, when the roll of a ship directs the antenna beam into the water, "sea return" clutters up the PPI; the operator alone can distinguish sea return from target returns. No factor can easily be introduced in a computer program that would account for the difficulty an operator finds in separating these returns.

Another effect that defies programming is the physiological stability of the PPI operator. Severe rolling and pitching may distract him from the screen or even cause seasickness. The only absolute prevention for this is stabilization of the whole ship—obviously impossible. Under these conditions it is important to lessen the hazards that deter the operator from performing his job with highest efficiency. These effects reinforce our conclusions: An unstabilized search radar is not capable of satisfactory target detection and tracking in heavy seas, but an antenna stabilization system to stabilize only for roll will lead to satisfactory performance. On the basis of these conclusions, Laboratories engineers recommended that the Navy study the possibility of lightweight stabilization systems for small ships.

A radar can normally be recognized by the mechanically scanning antenna that is its contact with the outside world. New techniques in electronic scanning may soon change this picture, leaving a motionless array of radiators as the only sign that a radar may be in operation nearby.

Wilhelm H. von Aulock

An Electronically Scanning

Radar Antenna

From its modest beginnings prior to World War II, radar has developed into one of the most versatile tools of modern aircraft and space technology—locating and identifying aircraft, guiding missiles, tracking satellites, and probing into outer space. All these tasks have been performed by transmitting a powerful, sharply focused, and accurately directed beam of microwave energy into space and observing the reflected echoes. The level of radar performance has steadily improved to the point where signals can be bounced back from the moon, the sun, and Venus, and satellites can be guided into predetermined orbits with pinpoint accuracy. These accomplishments have led to new demands on receiver sensitivity, transmitter power, and antenna characteristics.

The last demand is perhaps the most challenging one because a good radar antenna must satisfy two seemingly conflicting requirements. First,

it must be large enough to radiate high power in a narrow beam, and second, it must be able to be steered with little inertia and great accuracy.

Up to now, most radars have used parabolic reflector antennas, called "dishes", to focus and steer the radar beam. But as radar systems are called upon to perform more and more difficult jobs, three shortcomings of dish antennas become apparent. First, parabolic reflectors need an unobstructed spherical volume for scanning, and the dish generally must be protected by a radome. Second, parabolic reflectors have mechanical inertia which increases very rapidly with size. This makes it difficult to steer a high-gain, narrow-beam dish with speed and precision. The third drawback involves the single transmission line that connects the focal point of a parabolic reflector with the transmitter. This transmission line has a limited rating of peak-power, which de-

creases rapidly with increasing frequency.

Substantially improved and more versatile radar systems could be obtained if an antenna with the following characteristics were found:

1. It should be fixed in space, with no mechanical motion of any part. It should be an integral part of the supporting structure, such as the wing of an airplane, skin of a missile, superstructure of a ship, or one of the faces of an explosion-resistant building.
2. The radar beam should be steered very rapidly and without mechanical inertia. A thousandth or even a millionth of a second should be the speed to switch a radar beam from one position to another in space.
3. There should be no inherent limitation of radiated power.

The need for improved radar antennas and new beam steering techniques led in 1955 to a study contract between the Air Force at the Wright Air Development Department and Bell Laboratories to investigate a new technique called Electronic Scanning and Stabilizing of Antennas (ESSA). Work on Project ESSA was to culminate in the development, construction and operation of a model of an antenna that scanned electronically. At that time Sputnik had not yet been launched, and the manned supersonic bomber was America's first line of defense. The developers planned to equip airplanes with radar antennas which did not need radomes or protrude in any way from the aerodynamically designed wings and fuselage of the plane. Project ESSA was to provide just such an antenna.

Bell Laboratories went to work on this problem without a precedent for a flush-mounted radar antenna with no moving parts. However, the principle of electronic scanning with "phase shifters" was already known and tested. A phase shifter is a passive circuit component which introduces a precisely adjustable time delay into a transmission path. In general, such a device makes adjustable phase shifts between zero and 360 degrees, corresponding to variable time delays up through one full wavelength. The Laboratories had made major contributions to this art prior to and during World War II. In the meantime, significant advances had been made in phase shifters for microwave applications, in flush-mounted radiators, and in control circuitry. Therefore, it looked as if the desired radar antenna was just around the corner if these new devices and techniques could be combined into a working system.

It has been known for many years that both the fan beam of an acquisition radar and the pencil
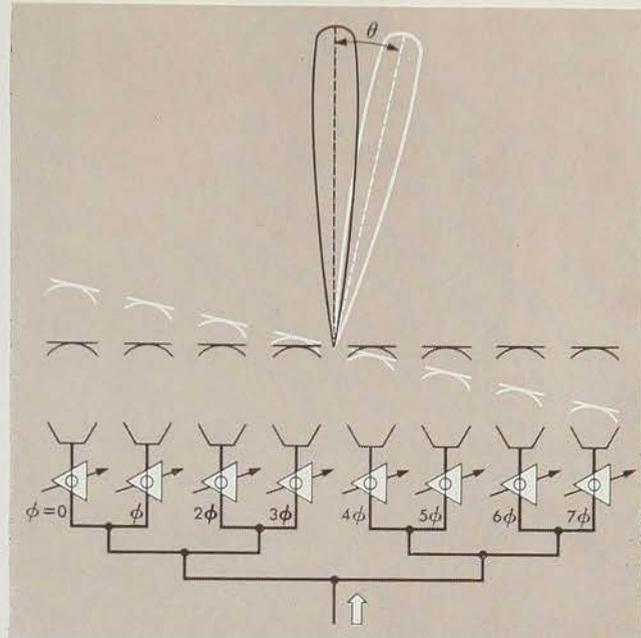
Signals from all radiators combine to form wavefront close to the array and perpendicular radar beam farther out. Time delay in antenna feed structure changes wavefront orientation to array.

beam of a tracking radar can be formed by linear and planar arrays, respectively, of equi-spaced "radiators." These radiators may have many forms and shapes—horns, dipoles, dielectric rods, slots in waveguides and flat spirals are the most frequently used. The shape and the direction of a radar beam depends mostly on the size of the array, the number and spacing of the elements, and on the "excitation function." This last term describes the relative amplitude and phase of the microwave signal at each of the radiating elements. Amplitude variations in the excitation function are mainly responsible for beamwidth and the side-lobes of the antenna pattern, whereas a linear relative phase variation can be used to control the direction of the beam.

Engineers have analyzed in great detail the dependence of beam shape and direction on the excitation function. For understanding, however, it is sufficient to consider a linear array fed by a system of lossless transmission lines of equal length. Each feedline has a variable phase shifter adjustable from zero to 360 degrees. Let us assume that one of these phase shifters introduces a variable time delay of one-half period into the feedline. Measured in seconds this is very small, perhaps one ten-thousandths of a microsecond. But measured in wavelengths in free space, the signal from this radiator will be one-half wavelength—perhaps one or two inches—behind the signal from the adjacent radiator.
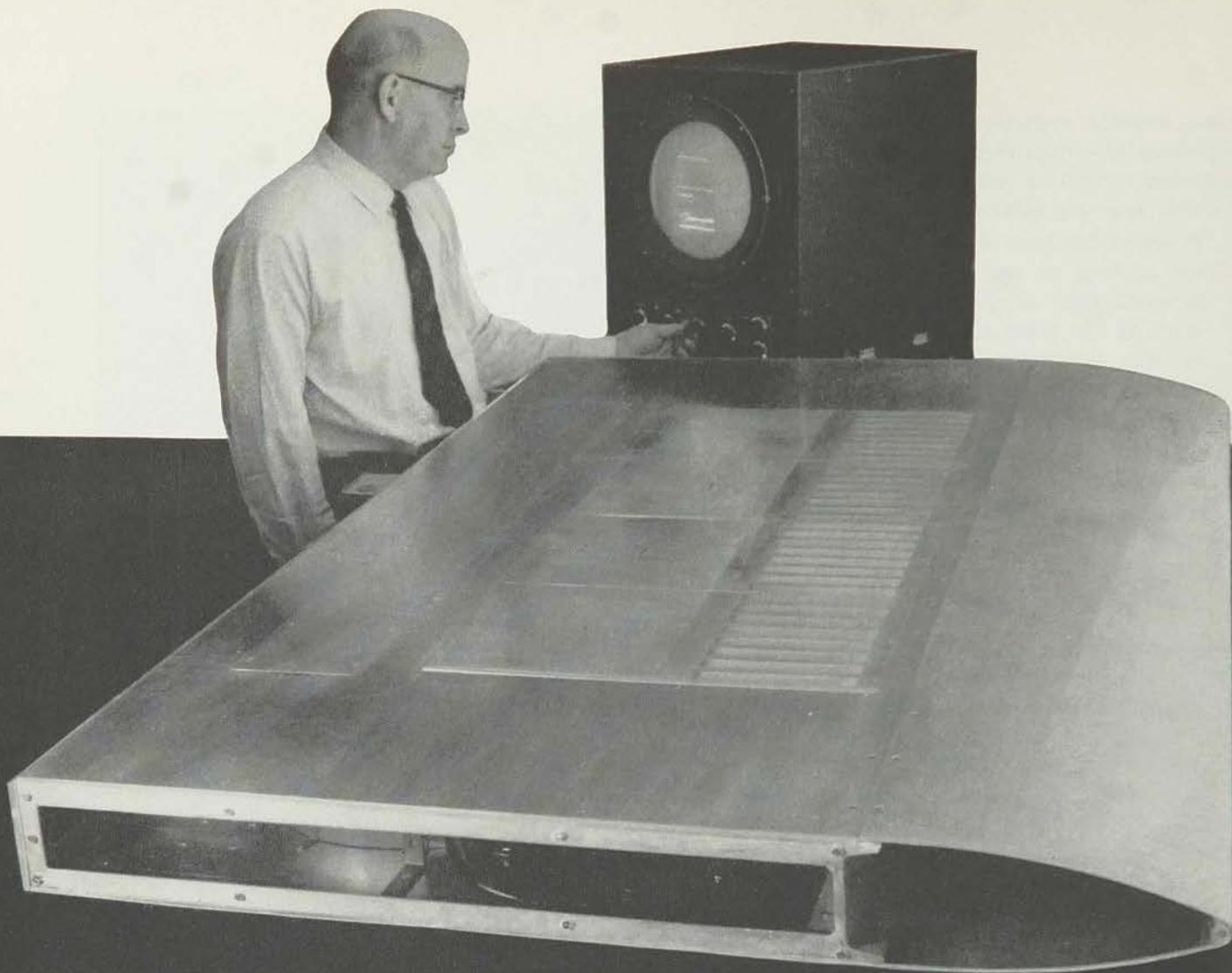
J. P. Hart "tunes" in radar picture of country-side outside Whippany, N. J., laboratory. Model of electronically scanning radar antenna, in simulated airplane wing, scans through plastic window.

Signals from all radiators combine to form a wavefront a short distance from the array, and a radar beam perpendicular to the wavefront is formed farther out. Adjusting all phase shifters to zero, and remembering that the radar pulse reaches all radiators simultaneously, we expect a wavefront parallel to the array and a radar beam in the broadside direction. Readjusting all phase shifters to linearly increasing values of phase shift, we introduce a linearly increasing time delay into the excitation function, and change the orientation of the wavefront relative to the array. This amounts to steering the radar electronically.

At first glance it might appear that phase shifts of many thousand degrees are needed to steer the beam of a multi-element array. This is indeed true if operation is required over a very wide frequency band. However, for ordinary, narrow-band radar applications one may take advantage of the fact that phase shifts repeat themselves every 360 degrees. Thus all required phase shifts may be reduced to values between zero and 360 degrees.

Applying this principle to a linear array permits a fan beam to be steered in one direction, for example in azimuth. The same principle can be extended to a planar array to steer the beam in azimuth *and* elevation. As the beam is steered away from broadside it begins to broaden slightly, first very little for angles up to 30 degrees, but more and more as the scan angle increases, until the beam is twice its broadside width for a scan angle of 60 degrees. Scan angles larger than 60 degrees from broadside are impractical. This leads us to an inherent limitation of phased arrays, indicating that more than one array is needed to scan a complete circle.

Thus there exists a new scanning technique using arrays of radiators and phase shifters. The antenna stays fixed in space and the radar beam scans by changing the settings on a bank of phase shifters.

An excellent mechanical microwave phase shifter with a rotating vane was invented during World War II by Gardner Fox, Electronics and

Radio Research Laboratory. Equipped with a motor drive, this phase shifter successfully scans an array of polyrods. The method permits a very rapid sector scan with a large and heavy antenna, but it cannot be used for tracking where the beam must be steered by commands from a computer.

True electronic scanning and beam steering had to wait for a electronically controlled microwave phase shifter that would receive its commands from a high-speed computer. Such a phase shifter should permit a change in phase setting within a very short time, perhaps a millisecond or even a microsecond, and it should introduce very little loss for either the transmitted pulse or the received echo. Not until the invention of the new ferromagnetic insulating material ferrite (RECORD, *April*, 1957) was it possible to build this kind of microwave phase shifter.

A ferrite rod placed inside a waveguide forms the center of a solenoid, and a variable phase shift can be produced by varying the current through the coil. This provides a biasing longitudinal magnetic field which changes the permeability of the ferrite, and consequently, the velocity of propagation through the device. Thus one obtains a variable time delay or phase shift as a function of the solenoid current. Ferrite-loaded waveguides and coaxial cables of many configurations can be used to produce a similar effect. However, the device discussed here—invented by Reggia and Spencer at the Diamond Ordnance Fuze Laboratory in 1957—combines the advantages of low insertion loss, high phase shift per unit length, light weight, and modest requirements for control current.

The heart of this phase shifter is a rod of magnesium-aluminum-copper ferrite, developed in the Metallurgical Research Laboratory by L. G. van Uitert. This material has exceptionally low loss at frequencies above 8000 Mc. It will operate at peak power levels up to 8 kw. As in most ferrite devices, phase shift and control current are related by a function exhibiting a distinct hysteresis loop, a feature that must be considered in the design of the control circuitry.

To design an electronically scanning radar antenna around this phase shifter requires two additional building blocks. The first is a flush-mounted array with an appropriate feed structure. The second is electronic control circuitry to program each of the phase shifters in such a manner that the radar beam is either scanned in a regular pattern or steered according to commands from a computer. In addition, the array must be integrated with a radar system to permit its performance to be demonstrated.
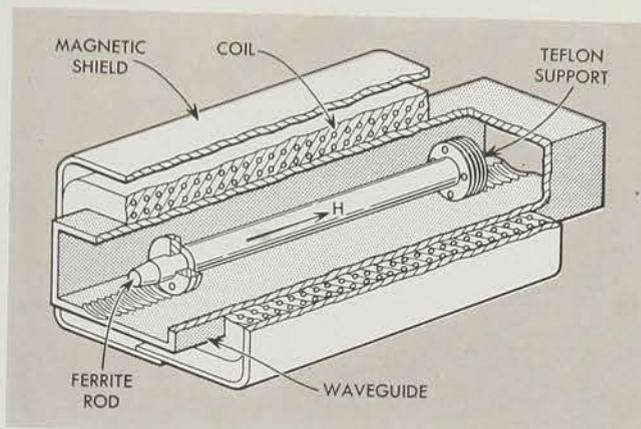
Phase shifter consists of ferrite rod in waveguide forming center of solenoid. Variable phase shift results from changes in the current through coil.

In the early stages of Project ESSA, much effort was devoted to studying ferrite phase shifters. When a good ferrite device became available, a working radar set was needed to prove that the idea was practical, and furthermore, to show that this new scanning technique was superior in many ways to conventional mechanical methods. Thus, it became necessary to design, construct, and operate a whole electronically scanning antenna system with a suitable conventional radar set. This antenna system would find itself competing with highly developed, mechanically scanning parabolic reflectors. Hence, it became advisable to design a phased array of some sophistication with control circuitry which would show electronic scanning with phase shifters to best advantage.

Airborne Radar System Selected

An airborne radar system operating at 9.375 Mc was selected for the demonstration. The antenna of this radar was designed for a beamwidth of 2 degrees, a maximum scan angle of 20 degrees and a variable scanning rate from 2 to 20 "looks" per second. Control circuitry was available to stop the radar beam at any desired scan angle and to select different scan sectors between four and forty degrees. The antenna had to be able to handle peak-power levels above 100 kilowatts.

As seen in the schematic diagram on the next page, all phase shifters are fed in parallel because of their relatively low peak-power rating. The antenna is fed at the center to simplify control circuitry by taking advantage of symmetry. There are 32 phase shifters and 32 radiating elements spaced one wavelength apart. The radiators are tapered waveguides, open-ended and filled with a dielectric material. They are flush mounted in a simulated aircraft wing section 64 inches

The labels in the figure read:

1 2 3 16 17 30 31 32

FLUSH-MOUNTED RADIATORS

CENTER-FED TRAVELING-WAVE FEED

FERRITE PHASE SHIFTERS

LOAD

LOAD

RF INPUT

ANTENNA HOUSING

CONTROL NO. 16   CONTROL NO. 17
ELECTRONIC SWITCH

CONTROL NO. 3   CONTROL NO. 30
ELECTRONIC SWITCH

CONTROL NO. 2   CONTROL NO 31
ELECTRONIC SWITCH

CONTROL NO. 1   CONTROL NO. 32
ELECTRONIC SWITCH

SCANNING CONTROL CIRCUITS WITH 16 DPDT ELECTRONIC SWITCHES

Simplified block diagram of controlling circuitry used with flush-mounted electronic scanning antenna.

long, 42 inches wide, and 4 inches thick as shown on page 120. A temperature-control system consisting of blowers, heaters and a thermostat maintains a constant air temperature inside the wing section. This is required because the electrical properties of the ferrite phase shifters are very sensitive to temperature changes.

To avoid synchronization problems for 32 phase shifters with different programs and tolerances in their characteristics, the designers decided to scan this antenna in steps rather than continuously. Ten beam positions spaced 2 degrees apart are provided on each side of the array normal. At the maximum scan rate of 20 looks per second, the radar beam changes position 400 times in one second. Hence, it can stay in one beam position

for only 2.5 milliseconds. This severely limits the time interval for switching the beam from one position to the next, because the radar is inoperative during this switching period.

The switching problem is further aggravated by the fact that the ferrite phase shifter uses for control a solenoid whose time constant is approximately 1 millisecond. Thus it was necessary to develop a feedback-controlled current source to reduce beam switching time to 0.25 millisecond and to maintain pre-selected constant currents during the intervals between switching steps. Electronic beam-switching tubes provide between 40 and 400 switching pulses per second.

Simplified Control Circuits

The cost of the control circuit is proportional to the product of the number of phase shifters and the number of distinct beam positions. By taking advantage of the inherent symmetry of a center-fed array, however, the designers made a simple switching technique double the number of beam positions. In such an array, the program required to scan the array from broadside to the right is the exact image of the program required to scan from broadside to the left. It suffices then to interchange the appropriate leads between symmetrically located phase shifters and their respective control circuits.

The antenna system was connected to a radar and to a specially designed display unit showing azimuth and range. Looking out through a large plexiglass window at the Whippany location of the Laboratories, the experimenters could identify and compare hills and prominent structures ten miles away, and could see on the display screen the echoes from airplanes approaching Newark Airport. The fast scan made observation nearby very easy, similar to the viewing of a TV screen.

Extensive tests of the antenna showed it insensitive to changes in ambient temperature and quite reliable in operation.

This successful demonstration of electronic scanning with ferrite phase shifters proves that radar systems with new and improved characteristics can be designed. Flush mounted arrays, as structural parts of airplanes, missiles and combat ships, can be very rugged, strong, and resistant to damage. Switching speeds much higher than 0.25 milliseconds appear possible with improved circuitry and better phase shifters. Thus a single radar beam may be "time-multiplexed" and used to look at many targets simultaneously. Electronic beam steering in steps is ideally suited to control by an electronic high-speed computer, programmed to use a single radar system for several different functions.

Maximum scan angles can be made substantially larger than the 20 degrees in our experimental model because scan angles are not limited by phase shifter characteristics but subject only to antenna theory. In addition, individual power amplifiers may be inserted between phase shifters and radiating elements to boost the radiated power of an array to values never before attained with this type antenna.

All-in-all, electronic scanning has opened the door to a whole new world of improved radar. Important contributions to this art have been made by many organizations, and large-scale radar systems with electronically steered planar arrays have been built by Hughes Aircraft Company, the Bendix Corporation and others. At Bell Laboratories, work in this field has lead to a major research and development program which applies electronic beam steering techniques to a defense system against intercontinental ballistic missiles.

Soil-Testing Materials an

Since the early 1880's, the Bell System has considered the possibility of placing telephone cables directly in the soil. It was not until recent years, however, with the advent of polyethylene insulated conductor, that a concerted program of burying exchange-area telephone cable became a reality. In addition, improvements in placing techniques and new developments in wire, and associated terminals have allowed telephone operating companies to bury more and more of their distribution plant economically.

The long-range economy of buried plant depends in large measure on the ability of materials to withstand the many deteriorating factors in soil environments which may affect their performance. Some materials may be sensitive to moisture or the chemical properties of the soil. Nylon plastics, for instance, absorb moisture readily and swell. Moisture may also leach the plasticizer from certain plastics.

Some materials may provide nourishment for microorganisms, such as fungi and bacteria, which abound in all soils. Accelerated aging tests have shown, for example, that the exposure of certain vinyl plastics to fungi results in stiffening of the materials. Deterioration by all these factors may be slow but relentless, causing a gradual change in important chemical and mechanical properties.

The effect of other factors such as rodent and insect damage is more spectacular. A typical example is the neoprene-jacketed wire shown on
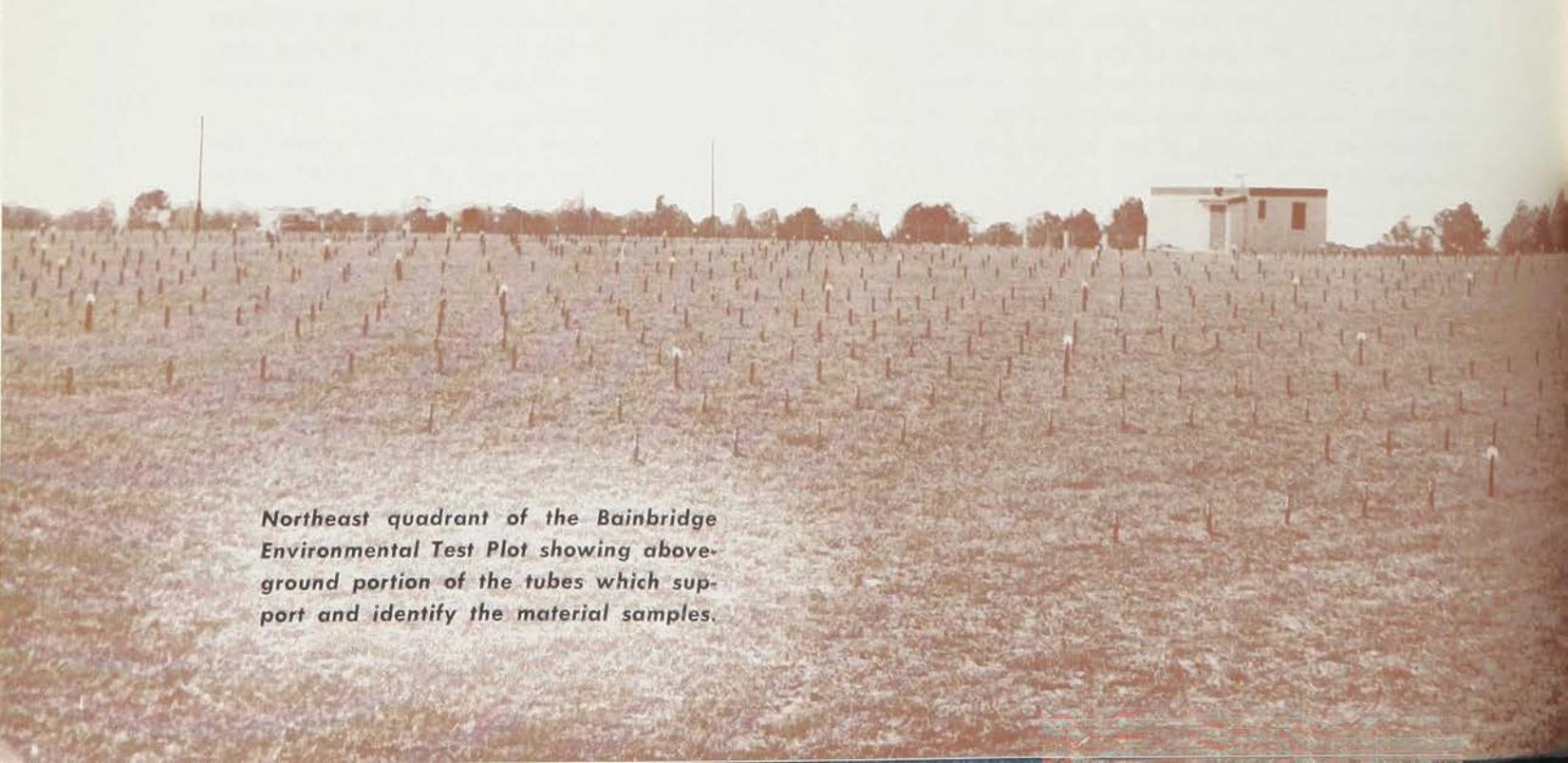
Northeast quadrant of the Bainbridge Environmental Test Plot showing aboveground portion of the tubes which support and identify the material samples.

pparatus

More than 25,000 specimens of outside plant materials and apparatus are being exposed in the soil to determine the effect of such an environment. This program, which has already yielded significant data, will continue for up to 25 years.

R. A. Connolly

page 127 which failed because of extensive termite damage. After the neoprene was eaten away, the steel armor tapes were exposed to corrosion, and the inner jacket and insulation failed after 26 months of service.

In 1956, the Soil Burial Program was initiated to obtain systematic information on the performance of materials that are, or may be, used in the buried plant and to correlate short-term laboratory tests with long-term field performance. In this controlled field experiment, particular materials as well as items of apparatus are exposed in the soil at two test plots for one to 25 years or more.

Soil factors affecting the durability of buried materials are numerous and vary with time and location. Consequently, Bell Laboratories engineers decided that the Soil Burial Program would require two exposure plots: one typical of acid and one typical of alkaline soil. The plots selected are representative of practical extremes of soil conditions prevalent in the United States. Although more extreme conditions do exist, these are limited to small areas of the distribution plant. Another requirement was a high mean annual temperature and the availability of water to be sure of a biologically active soil environment.

The first step in selecting the sites was to examine the isolayetal, isothermal, and regional soil maps of the United States to define areas of interest. Then detailed soil maps of the states

and counties in the selected regions were examined to find the most appropriate soil types. With this information, local telephone company personnel assisted in locating specific sites. Laboratories' scientists then extracted soil samples at various locations and depths in more than 25 candidate tracts. They analyzed these samples chemically and physically, and ultimately selected an 11-acre site in Georgia and a 15-acre site in New Mexico, designated respectively the Bainbridge and Roswell Environmental Test Plots.

A grass cover crop was planted at each location to prevent erosion which in time would alter the soil conditions. The Bainbridge plot receives ample rainfall to support the grass cover crop. In Roswell, there is scant rainfall, a condition which contributes to the formation of the more alkaline soils of the West. Therefore, the plot is irrigated to maintain the grass cover and to typify the more

severe environment which prevails in irrigated suburban and rural areas where buried distribution plant will find its greatest use.

The Outside Plant and the Chemical Research laboratories are cooperating in supplying and analyzing samples of materials and apparatus for this program. Where practicable, test and control samples for both sites are prepared at the same time. Each sample is tested before and after exposure to detect any changes in basic properties. Comparison of the data permits correlation of deterioration with location in the soil. A punched card system is used to maintain permanent records. One card is punched with all the pertinent information for each of the specimens in the plots and also for each of the control or shelf specimens retained at the Laboratories in Murray Hill, N. J.

Even by carefully selecting test plots, there is always some variation in environmental factors

R. A. Connolly examines microorganisms isolated from materials exposed in the Bainbridge Test Plot.
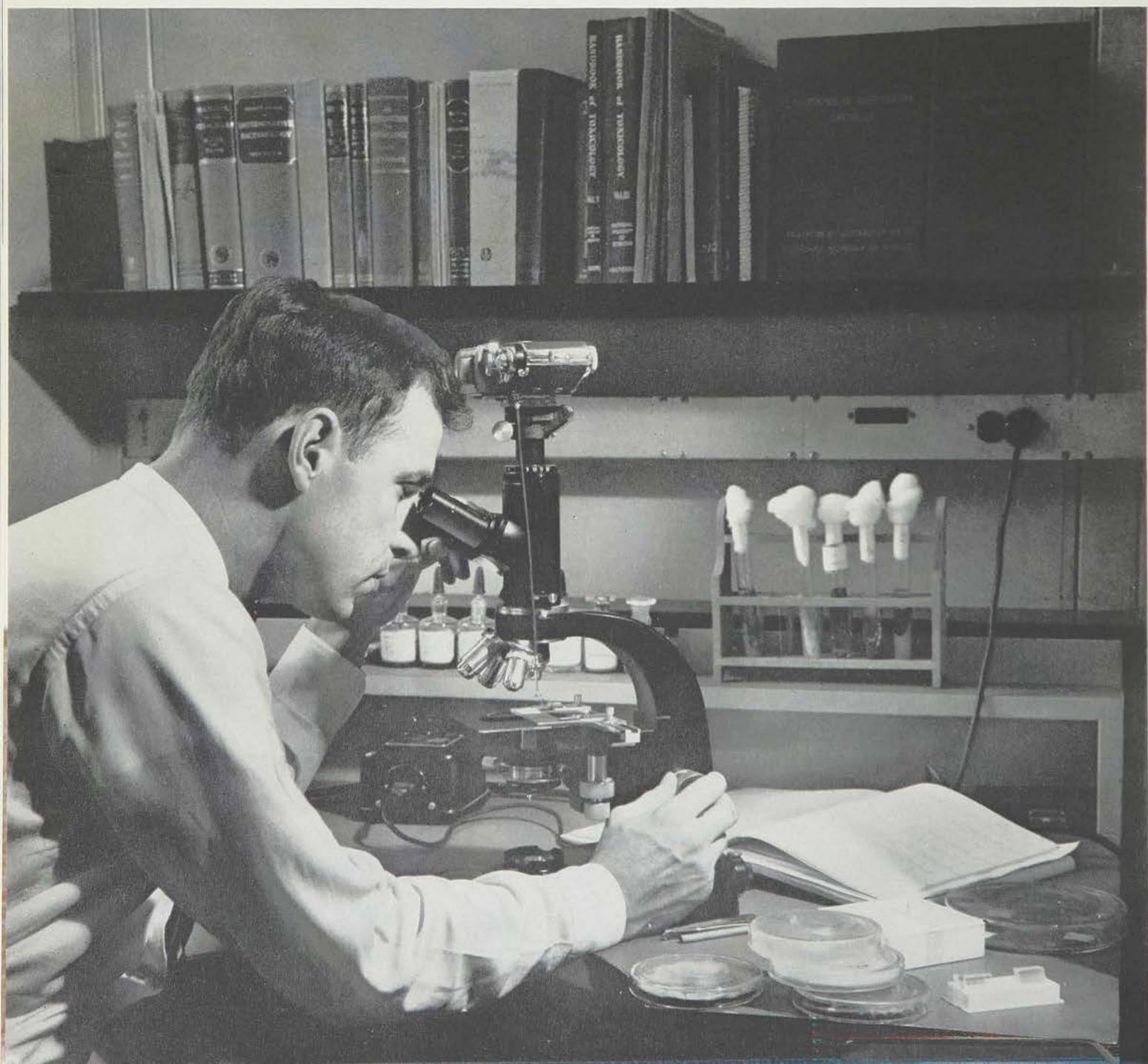
This neoprene-jacketed wire was severely damaged by termites under actual service conditions.

within such areas. These factors include depth of topsoil, detailed soil type, biological activity, and physical and chemical composition of the soil. To minimize the effects of these variations on test results, a statistical method of group-randomization of the specimens is applied to all materials except the large cables and splice cases.

Specimens Buried

The first specimens were buried at Bainbridge and Roswell in the fall of 1958 and in the spring of 1960, respectively. The plots are arranged in a system of rows and tiers, and maps were prepared to show where each specimen is installed. The specimen numbers are placed on the map in their predetermined "random" locations. Using this map and aluminum identification tags above ground, each specimen can be readily located. The northeast quadrant of the Bainbridge Environmental Test Plot is shown on pages 124 and 125.

Because topsoil (the earth from the surface to about 12 inches depth) is more active biologically than subsoil, a record is kept to designate in which soil "horizon", or stratum, each specimen is installed. In digging holes for the specimens, great care is used to keep the topsoil and subsoil separate. Thus, in covering the samples, the soil can be replaced in the same order that it is removed, disturbing the natural state as little as possible.

The specimens are mounted on polyethylene tubes so that some are in the topsoil, about six inches below the surface, and some in the subsoil, about 18 inches from the surface. The illustration on page 129 shows a variety of material specimens at the two depths. All specimens are fastened to the tubes with polyethylene rivets. The use of such an inert material eliminates the effects of corrosion products on the specimens which would be encountered if metal fastenings were used.

Most of the cable, conduit, and splice cases are buried in the subsoil, since they are normally installed at depths of 24 to 36 inches. The wire and conductor specimens are buried in the form of coils, about 24 inches deep; thus, parts of each of these specimens pass through both soil horizons. The cable, wires, and conductors are connected

Environmental Factors	Roswell, New Mexico	Bainbridge, Georgia
Temperature: Mean annual Mean min. Daily max.	60°F 44.4°F 74.5°F	67°F 56.9°F 78.2°F
Mean annual precipitation (inches)	13	52
pH of soil	8.2	5.4
Plot (acres)	15	11
Cover crop	Tiffgreen Bermuda grass	Centipede grass

Test plots typify acid and alkaline soil conditions.

	Items	Types	Number of Samples
Materials	Molded plastics	29	2860
	Casting resins	3	108
	Unclad laminates	23	4140
	Structural laminates	20	1200
	Bonded structural laminates & stainless-steel samples	17	1020
	Rubber	15	540
	Rubber-to-metal bonds	15	150
Outside-Plant Structures	Rubber-covered conductors	28	560
	Plastic-covered conductors	72	1440
	Tapes	6	504
	Conduit	14	228
	Wires	4	80
	Cables	9	55
	Splice cases	8	43
	Total in each plot	263	12,928

Materials and structures samples, by type and number, installed at the two Laboratories test plots.

above ground in terminal boxes. Half of the wire and conductor specimens are supplied with constant 48-volt dc potential throughout the test and a resistor is used in the circuit to prevent excessive current drain if a specimen fails. The aboveground portions of the wire specimens are protected from sunlight by black polyethylene tubes.

The projected schedule for removing specimens is after 1, 2, 4, 8, 16 and 32 years exposure. The actual schedule will be governed by the findings of early inspections. At each inspection, approximately 2000 specimens (one-sixth of the total) are removed, examined in the field, and brought to the Laboratories for a thorough evaluation of properties. During the inspection period, any new materials of interest which have become available since the last examination of specimens are added to the program.

The first specimens from the Bainbridge plot were examined in the fall of 1959. A mobile field laboratory (shown above) including a binocular microscope and camera was set up so that the specimens could be examined immediately after removal. The field examination is primarily for visual observations. Changes in color or dimensions and amount of erosion of the specimens are recorded and when appropriate, photographs are taken. Fungi and bacteria are isolated from colonies on selected specimens. This is done under a microscope and a portion of the organism is transferred to a sterile agar slant for later examination or identification.

Testing at the Laboratories

It is impractical to conduct tests on specimens immediately after their removal from the test plot. Consequently, after the initial examination, the specimens are sent back to the Laboratories at Murray Hill for more intensive observation and testing. At the Laboratories, the specimens are reconditioned to meet standard laboratory testing requirements before undergoing selected chemical, electrical, or mechanical and electrical tests to determine permanent changes.

Data after the first exposure period are now available from one plot. Some of the samples show substantial changes compared with controls. While few conclusions regarding service life of any of the specimens can be drawn after one year's results, some interesting observations have been made. For instance, few of the plastics and none of the large structures suffered any ill effects after 12 months exposure. Certain cellulose-based specimens exhibited a striking change in color,
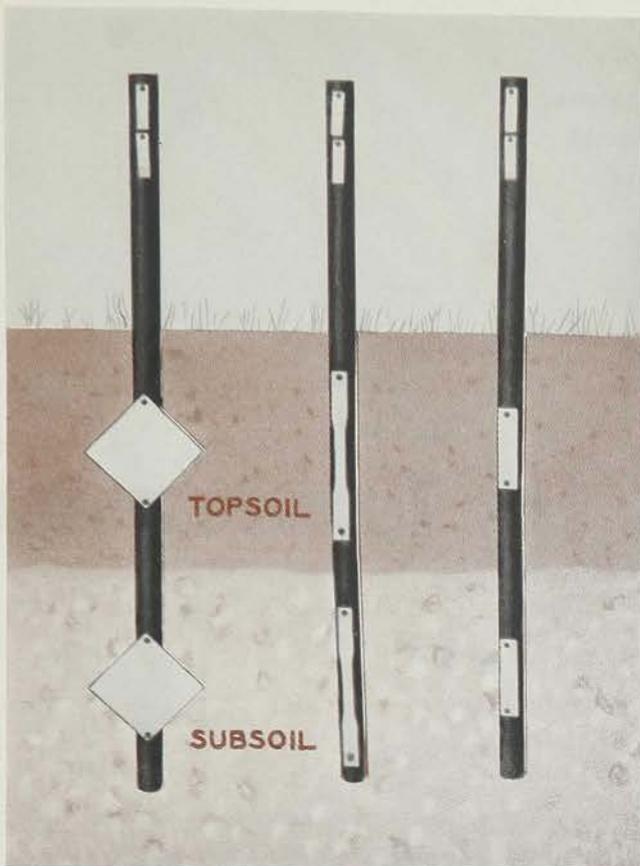
Material samples are mounted on polyethylene tubes for exposure in both topsoil and subsoil and identified by aluminum tags above ground.

caused in part by fungal activity. Many of these materials, however, showed only slight mechanical deterioration. In some of the plastic and rubber specimens, surface deposits which probably originated from the material itself were observed.

Many of the rubber-covered conductors showed serious deterioration in electrical properties, although the mechanical properties remained almost unchanged. This may be inconsequential, since in certain of the rubber coatings, electrical properties are of minor importance; they are used only for mechanical protection.

Judgments as to the cause and implications of the changes to date must await data from future removals to establish trends and to determine the extent to which physical properties have been influenced.

The Soil Burial Program is intended to provide a body of knowledge which design engineers can ultimately use in selecting materials to meet the requirements for new buried plant. In the interim, the systematic examination of small material specimens will provide information of use to engineers in developing new, more economical and versatile apparatus for use in the telephone plant.

New Handset Will Aid The Hard of Hearing

A new telephone handset, designed at Bell Laboratories as an aid to people with impaired hearing, is now being manufactured by Western Electric Company. Known as the Amplifier Handset, it has a self-contained voice amplifier which allows the customer to adjust the sound volume in the telephone receiver to meet his individual needs.

For some time, Western Electric has been manufacturing a special telephone for persons with impaired hearing that was available only in a desk set. The new amplifier will fit almost any telephone handset so that the customer may choose a Princess set, a Call Director, or any of the newer telephones as well as a desk set.

News of Apparatus Development

Almost the exact duplicate of a regular telephone handset, the new device is the same size and has many of the same components as the ordinary one. The only visible difference is a small volume control on the underside of the Amplifier Handset. Operated by a flick of the thumb, this control raises or lowers the volume of sound reaching the listener's ear.

The new handset was developed for manufacture by a team of Bell Laboratories and Western Electric engineers at the Indianapolis Laboratory. To keep production costs low, they developed a miniaturized amplifier to fit a standard handset. It contains rather complex circuitry which utilizes transistors, transformers and printed flexible circuits. The Laboratories-Western Electric team is now developing a companion product which will amplify voice transmission to aid customers with impaired speech.

Standard handset, left, and new amplifier set with its circuitry.

Good performance in telephone transmission implies
well designed circuits operating near design values.
Matching the system characteristics to maintenance
facilities and procedures requires consideration of . . .

Human Factors in Transmissio

Good performance in telephone transmission requires not only that circuits be designed to meet adequate objectives, but also that they operate reasonably close to these design values. To attain this performance, we must have not only stable transmission systems, but in addition maintenance facilities and procedures which are carefully tailored to fit the characteristics of both the system and the maintenance forces. This matching of the system to the forces constitutes the basic Human Factors problem in transmission maintenance.

The difficulties of maintaining good transmission in the long distance telephone plant have been increasing for many years as circuits have become longer and more complex. They have been emphasized by the introduction of Direct Distance Dialing (DDD). When long distance calls were switched manually, an operator talked over each link in the connection as it was being established, and could detect and remove from service any circuit having noticeable transmission degradation. DDD operation, obviously, does not provide this constant monitoring of circuits. As long as the circuits transmit the dialing signals satisfactorily, there is no check on transmission until the connection has been established between customers. If the circuit then proves unsatisfactory, it is practically impossible to locate the source of trouble, since the customer must normally release the circuit before he can report the trouble. Circuits in trouble, therefore, should properly be detected before becoming numerous

enough to affect a significant number of calls.

In 1957, engineers from Bell Laboratories, A.T.&T. and the operating telephone companies began a joint study of the causes of variation in circuit loss and on methods for reducing this variation. A number of circuits between Dallas, Texas, and Oklahoma City, Okla., furnished by a radio relay system about 200 miles long, provided the "laboratory in the field" for this work.

The Oklahoma experiments showed that some minor parts of our systems needed improved stability, but to a large extent the systems were potentially capable of meeting DDD requirements. However, as operated, this potential was not realized. One important cause was the poor match between the requirements imposed by the system and human characteristics. When people are asked to perform tasks not suited to them, we can expect errors of both commission and omission. Operational errors result from the use of incomplete or incorrect information, maintenance procedures that are complex, illogical, ambiguous or difficult, alternative procedures which are incompatible, and programs which call for adjustments out of natural sequence.

Sources of Errors

Lack of correct and complete information is one large source of error. If the necessary operation is not obvious from the labels on equipment, the user must either seek guidance from an instruction book, which is frequently not at hand, or trust to his memory, which all too often proves

J. W. Emling

Maintenance

unreliable. Unnecessarily complex procedures contribute greatly to this problem. They not only make self-explanatory labeling difficult, but also increase the burden on memory.

Illogical procedures also put a strain on the memory process. One example is the procedure for checking pilot supply output which is illustrated at left below. In this arrangement, there is a common supply feeding a number of outputs. The check point, which is separated from the main supply by a large pad to avoid an output change when the check measurement is made, was originally intended to be —40 dbm. The testing procedure was later changed to require an

additional transformer with 0.3-db loss, and the test level was changed accordingly. This seemed adequate to the designer, but the maintenance man, using logic as a prop to memory, quite naturally finds it hard to believe that 40 is not the number intended. Another interesting example involved a tone with carefully controlled frequency which was provided only for adjusting the frequency of a measuring set. Coincidentally, the tone was close to, but not controlled at, a value often used as a standard amplitude test source. As a consequence, maintenance personnel used this particular tone not only for frequency calibrations, but also, with considerable error, for
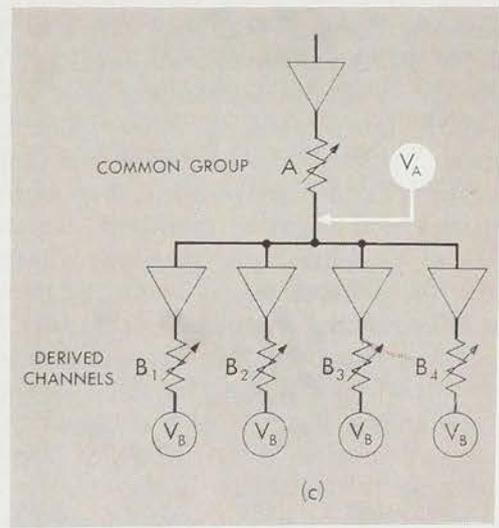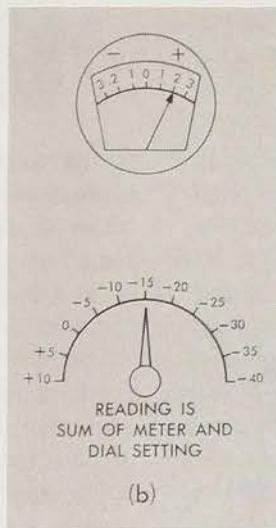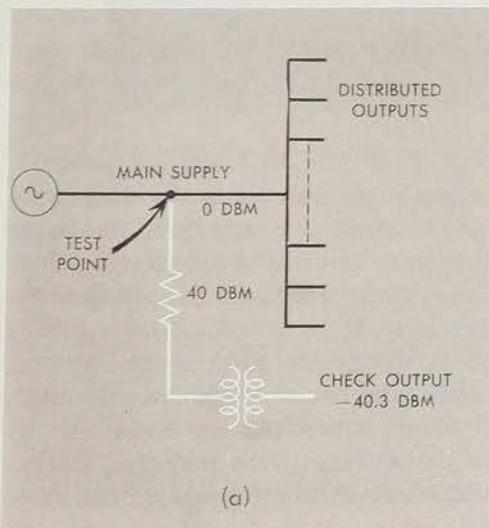
Errors in maintenance come from (a) illogical or ambiguous check values; (b) confusing dial meter combinations; and (c) operations which are difficult to carry out in the proper sequence.

A5 CHAN BANK
J68853B-( )
SD59736-01

MOD OUTPUT ADJ

TIGHT ●   LOOSE ○

db CHANGE	SCREW POS 2	3	4	5
−2.5	●	●	●	○
−2.3	●	●	○	●
−2.0	●	●	○	○
−1.7	●	○	●	●
−1.4	●	○	●	○
−1.1	●	○	○	●
−0.8	●	○	○	○
−0.4	○	●	●	●
0.0	○	●	●	○
+0.4	○	●	○	●
+0.7	○	●	○	○
+1.2	○	○	●	●
+1.6	○	○	●	○
+2.0	○	○	○	●
+2.5	○	○	○	○

Gain adjustment on early A5 channel bank (right above) was done with soldered connections. New form uses a screwdown connector. Instruction table indicates tightened screw with black circle, loose connection with white.

amplitude calibrations. In both cases, somewhat more logical design would have led to fewer errors; even better results would have come from adequate labeling and less dependence on memory.

Some procedures lead to errors because of ambiguity or by their very difficulty. Even apparently negligible burdens can lead to errors. Meter scales which are too small to read conveniently with the desired precision, scales which require interpolation or those which favor particular values all lead to errors. A more serious source of error is the diae-meter combination with positive and negative markings, which requires algebraic addition. A synthetic illustration of this combination at its worst is shown in the center drawing on the previous page.

In complex systems there are often several approaches to a single goal. In a telephone office, for example, it may be possible to find several access points in a circuit which are at nearly identical transmission levels. To avoid errors from minor level variations between access points, it is possible to designate one of these as a standard test point. However, if another point is approximately equal in level, there is a natural temptation to use it rather than the standard when it proves convenient. Therefore, we have found it necessary to eliminate alternative test points, except in cases where they can be adjusted for identical levels.

Perhaps the largest source of error results from adjustments which are made in improper sequence. Telephone systems are made up of many elements in tandem. For instance, many voice channels are multiplexed together into successively larger blocks for transmission over the line. At the distant end they are again separated into the individual channels. As a result we have

situations as illustrated in the right-hand drawing on page 131, in which an adjustment (A) of a common group is performed in tandem with adjustments (B) on several derived channels.

Obviously, to arrive at the correct value V_B at the channel output, we should first adjust A to give its correct value V_A; then B_1, B_2, B_3 and B_4 can be correctly set. If the B values are adjusted first, they will all be made incorrect by a subsequent adjustment of A. Since A and B are often physically separated, sometimes by hundred of miles, the difficulty of correct sequential adjustment on a manual basis becomes obvious.

Aside from these errors of commission there are errors of omission. Common causes of neglected operations include procedures which are difficult, fatiguing, boring or repetitious. Other causes are excessive preparatory work, inconvenient access, the need for special tools or materials, and the need for coordinated action with others.

The complexities of life place many demands on the time of individuals today. Operations that are unduly difficult, boring, or fatiguing are among those least likely to receive attention from a busy man. The telephone man is no exception. Test points near the floor, and especially those near the ceiling which require a ladder to reach, are less likely to get attention than those more easily accessible. In some cases, as many as forty patching operations have to be performed to remove a device from service prior to measurement. Even though these tests are called for only infrequently, the chances of their getting done at all are reduced by this large preparatory effort. The need for special tools or parts is also highly inhibiting.

Finally, the need for coordinated action with someone at a distance, or the need for sequential action may present problems which seem to be most easily solved by ignoring them.

Solving the Human Factor Problems

Instead of pursuing this path further, it is perhaps more profitable to ask how this situation came about, and what can be done to correct it. Looked at historically, the situation has developed logically enough. Formerly, it was reasonable to expect the maintenance man to have a detailed knowledge of the telephone plant. He dealt with only a few systems and could master each. Telephone offices were small, and it was logical and economical to keep the amount of test gear required at a minimum by designing it to perform many functions. The added complexity of the test gear was of little importance. Plant layout was also relatively simple, with fewer services, and little switching, branching, and bypassing. Thus the problems of sequential adjustment were not formidable. Finally, there was less appreciation of the importance of the human element. Under these circumstances, it is not surprising that the system designer emphasized technical solutions to his problems. Technically, it is no more difficult, of course, to measure 40.3 db than 40 db. It is only present circumstances that make the latter a more practical measurement.

Today, we have a highly complex plant and great mobility of plant and staff. We can no longer use techniques designed for a less complex world. Good technical solutions are not enough. They must additionally be suitable for the man who uses them. We are trying to meet this situation by bringing the human factor problems we have encountered to the attention of the designer. In addition to the use of specific examples, we have endeavored to work up some precepts to guide both the engineer in his systems planning, and the designer in executing the plan. For instance, people perform two main kinds of maintenance operations. One is *adjustment*, to give the desired performance, and the other is *measurement*, to determine performance. In each case, the same two simple rules for good maintenance are applicable: (1) Reduce the dependence on people for purely mechanical operations, and (2) reduce unnecessary burdens on the people who are needed.

Methods of using automatic measurement and adjustment to eliminate manual operations are well known and will not be dealt with in detail here, except to point out that our plans for improving maintenance call for their extensive use. The decision between manual and automatic operation will be greatly influenced by economic factors, but we believe that automatic measures should be considered whenever adjustments need to be made frequently, sequentially, or at remote points. Automatic adjustment may, in fact, be the only practical way to solve the problems of sequen-

Operator can adjust shaping network knobs to match the visual display of the loss-frequency characteristics of the line.
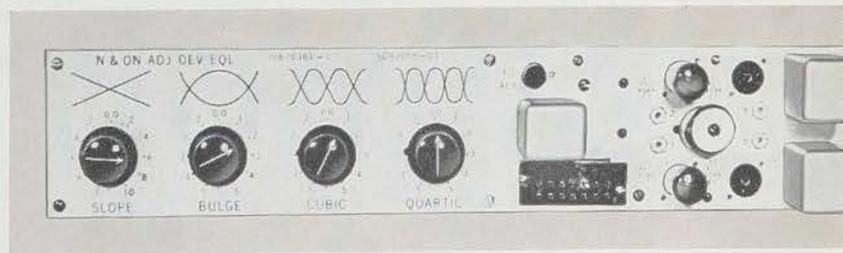
tial adjustment, particularly when the adjustment points are physically separated. Automatic measuring techniques should be considered for highly repetitious, routine, and tedious work.

Reducing the Adjustment Burden

Of more interest, from the human factors standpoint, are the measures that can be used to reduce the maintenance burden for those cases still requiring manual operations. Some effective ways to reduce this burden include:

In-Service Adjustments
Simple Operations Without Special Tools
Self-Explanatory Arrangements
Readily Available Instructions
Logical Arrangements
Unambiguous Arrangements

Independent operations also reduce the need for sequential or iterative operations.

Where practical, adjustment during service is desirable to reduce the often-large burden of removing equipment from service. This places the emphasis on the adjustment procedure, where it belongs, and not on the purely supporting operations of patching and switching. In some cases

R. C. Boyd shows plug-in arrangement of a spectrum generator used in testing the line equalizer. At right is another new set, for precisely adjusting standard test tones.

there are sound reasons for out-of-service adjustment, but even here the burden can often be reduced by simpler procedures and better instructions. For example, the gain adjustment on the early A5 channel bank, shown at right on page 132, called for soldering wire straps between the numbered terminals. This was burdensome because of the small size and the need for a soldering iron. In addition, the complex strapping plan required use of an instruction book. A redesign provided a screwdown connector instead of a wire strap as shown at left in the photo. The small size and complex adjustment plan prevented self-explanatory labeling, but the simple instruction table shown with the drawing was a good substitute.

A case of ambiguity involved a test bay which has jacks for connecting a measuring set to the system, as well as a screwdriver-controlled potentiometer for adjustment. Since the jacks occupied more space than the potentiometer, they were arranged in two rows, one above and one below each row of potentiometers. This was not a logical arrangement to begin with, and with the panel layout used, the association between jack and potentiometer was not at all clear. As a result, the wrong potentiometer was often adjusted. By adding a few more white lines, this association is improved without any basic change in panel layout. For new installations where redesign is possible, new arrangements with a more logical association between jacks and adjustment are being considered.

An example of a device incorporating several of the above principles is the equalizer shown on page 133. The problem here was to provide a variable network which could equalize irregularities in a telephone line. At best this is a difficult job, but inexperienced personnel can accomplish it by using a visual display of the loss-frequency characteristic of the line, and by designing an equalizer with four independently adjustable shaping networks using knobs with clearly marked functions. The human factor de-

sign is supported by a good technical design, in that no shape interacts with any other. Thus, the operator very soon reaches the best possible adjustment, and can arrive at a definite conclusion quickly with minimum decision-making.

Reducing the Measurement Burden

Design from the user's standpoint has been particularly rewarding in the measurement area. Among the approaches found to be most useful for reducing the measurement burden are:

In-Service Testing
Easily Accessible Test Points
Centralized Positions for Routine Measurements
Measuring Positions Near Adjustments
Precise, Foolproof, but Easily Used Test Gear
  Calibration made a natural step in operation
  Meter scales large enough to read easily to desired precision.
  No need to know absolute frequency or level. (Describe adjustments functionally.)
  Readings which do not require the addition of dial and meter. (If unavoidable, design for arithmetic not algebraic addition.)
  Minimum number of easily understood operations. (Use function switches and plug-in units.)

In addition, instructions should always be readily available, and, as much as possible, the equipment should be designed to tell its own story.

Some of these considerations reduce the preparatory burden and place emphasis on the measurement process. Others avoid dissipating effort on subsidiary matters. They may often appear conflicting, but usually can be reconciled. For example, the apparent conflict between centralized testing and tests near the point of adjustment can be solved by the use of dual meters or projection-type meters.

Probably the most useful idea in developing easily-used, foolproof test gear has been the concept of design for a specific purpose. Traditionally, test gear has been made for a wide field of application. Oscillators, for example, have been made with a wide range of frequencies and outputs. Measuring sets have been designed to work with a wide range of frequencies, input levels, and impedances. In this way, the number of devices required in an office, as well as their total cost, could be kept at a minimum. But this approach leads to complex equipment, requiring time-consuming operations and highly trained operators. This keeps the equipment from being used as often as required. If the operations are poorly understood, they will be carried out either

carelessly or incorrectly. Today, we are designing more and more test gear for specific purposes, aimed at performing only a few operations, which can be set up by simple plug-in units or function switches. Operations can then be described in terms of the desired results, instead of the technical details of measurement.

One of the simplest measuring sets recently developed is for measuring the group and supergroup pilot frequencies in long-haul systems. A universal analyzer could be used for these measurements, and was, in fact, used to some extent. Now, however, we are providing the test arrangements shown below. These instruments are connected by either jacks or switches to the desired test points and display the necessary measurements with no further effort on the part of the operator. The digital read-out at the top indicates the equipment being measured and helps to avoid errors from incorrect switch settings. Two sets of meters are provided: one for supergroup and the other for group pilots, and a colored border around the meters corresponds with the color code used on the equipment in the bay. The top meter in each bay indicates the state of the automatic adjustment device in the carrier equipment. The lower meter shows pilot level. Since levels are to be adjusted to within 0.1 db of the standard, the meter scale covers only ± 1 db and the desired precision is easily obtained.

A single-purpose device cannot always be justified. A slightly more complex device, a source of multifrequency test tone, is shown at left on the opposite page. It is used in adjusting the equalizer mentioned previously. Such a device is needed in connection with several types of carrier systems. The signal source is a plug-in function-determining unit, which defines the frequencies, output,

Pilot frequency analyzer mounted on left panel directly indicates departure from test point, and shows condition of automatic adjustment gears.

impedance, and other characteristics. The operator need only plug it in, and make a simple calibration to put the device into service.

One of the most useful principles in test set design is to build it to tell its own story with minimum reliance on instruction books and memory. One illustration, a high-precision measuring set for adjusting standard test tones, is shown at right on page 134. To achieve this precision, three successive internal calibrations must be made. The function switch at the right provides a natural way to make these checks in the correct order before measurement, and also serves to point out the particular potentiometer which should be adjusted if the calibration needs correcting. Instructions are on the face of the panel.

A device on trial in Oklahoma City, shown below, may well typify future telephone office maintenance gear. This is a central console designed to measure, on an in-service basis, pilot frequencies, regulator gain, battery voltage, or any other parameter needed for determining transmission system performance. The device can be operated manually, for tracing troubles or analyzing performance, by selecting the particular test point desired with a pushbutton. The measurement is then indicated on the large central meter, as a reading relative to the objective. It may also be printed on a trouble card to provide a permanent record. During routine monitoring of system performance, the machine can be operated automatically to scan all significant test points systematically. The results of each measurement can be printed on a continuous paper strip, or, if desired, the printed record can be limited to only those measurements exceeding a preselected departure from the normal value. This, together with automatic gear already available for measuring the voice-frequency loss of individual circuits, will form a complete test station capable of handling all the measurements required for monitoring transmission performance from a centralized point, on a largely automatic basis. Thus, craftsmen will be freed for the more challenging jobs of trouble-shooting and analysis.

The work described has shown the importance of matching the maintenance plan not only to the transmission systems, but also to the maintenance forces. Measures for accomplishing this are well known and involve few new principles. Perhaps the biggest difficulty in accomplishing this objective is reorienting the thinking of the system designer. In the past, he has concerned himself largely with problems of technology. He must now be convinced of the importance of human factor problems, and must look toward their solution as he begins to work out his technical design. Where this reorientation has been accomplished, the designer displays just as much enthusiasm and ingenuity in the human factors filed as in the strictly technical field which has claimed his interest in the past.

With transmission system in service, W. J. Simpkins at central console in Oklahoma City measures

pilot frequencies, regulator gain, battery voltage or other characteristics by pushing button.

news in brief

AT&T Signs Agreement For Transpacific Cable

AT&T, Hawaiian Telephone Company and Kokusai Denshin Denwa Co., Ltd., of Japan, signed an agreement recently for a transpacific telephone cable to be laid in 1964. The $84 million project will be one of the most extensive ocean cable systems ever undertaken. The cable will stretch some 6,300 miles (5,500 nautical miles) between Hawaii and Japan, routed via the islands of Midway, Wake and Guam. It will have a capacity of 128 simultaneous conversations.

AT&T's Long Lines Department will build and operate the Hawaii-Japan system in conjunction with the Hawaiian company and K. D. D., the Japanese overseas telecommunications company. AT&T estimated that its share of the cost of the cable and connecting facilities will be about $46 million.

C. E. Schooley, Long Lines director of operations, said that requirements for more and better communications services between the U. S. and points in the Western Pacific and Far East have been growing rapidly. "With other existing and planned cables," Mr. Schooley said, "the new system will provide an extentive cable network serving the Pacific area."

The new cable ship, *Long Lines* (RECORD, *February*, 1962), will lay the deep-sea telephone line.

The system will connect on Oahu with the communication system serving the state of Hawaii. By means of the existing and proposed underseas telephone cables between Hawaii and California, the transpacific system will connect with the U. S. continental telephone network.

The transpacific system also will connect with a proposed British Commonwealth cable between Canada and Australia, which will be routed via Hawaii. In Midway, Wake and Guam, it will connect with communications facilities serving those islands.

Darnell, Goldthwaite Receive Reliability Symposium Awards

Paul S. Darnell, director of the Reliability Engineering Center at the Whippany Laboratories and Mrs. Lynn R. Goldthwaite, of the Data Systems Department, each received a major award at the 8th National Symposium on Reliability and Quality Control held in Washington, D.C. earlier this year.

Mr. Darnell received the 1961 annual award of the Institute of Radio Engineers Professional Group on Reliability and Quality Control for a major contribution to the field of reliability in electronic component parts. He was cited for his "leadership in the preparation of the publication *Parts Specification Management for Reliability*." The publication, commonly called "The Darnell Report," was prepared when Mr. Darnell headed the Department of Defense Ad Hoc Study Group on Parts Specification Management for Reliability.

Mrs. Goldthwaite received the 1961 National Reliability Award for the best paper presented at the 7th National Symposium, held in Philadelphia in January, 1960. The paper was entitled "Failure Rate Study for the Lognormal Lifetime Model." Mrs. Goldthwaite has worked on transmission development and has engaged in reliability studies of semiconductors.

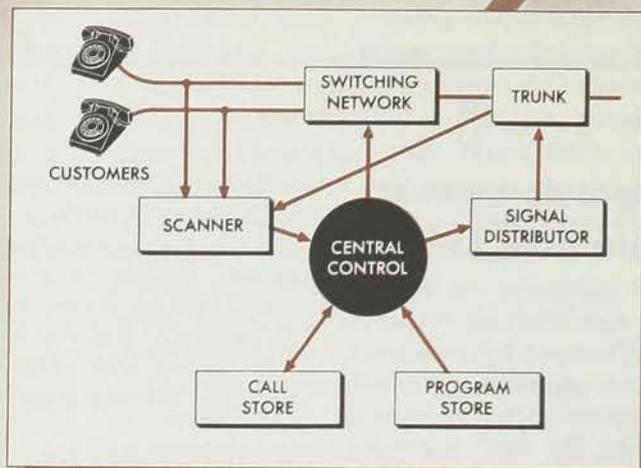## Rutgers University and Laboratories To Erect Particle Accelerator

Bell Laboratories and Rutgers University have announced that they will collaborate in erecting a 15-million electron volt tandem Van de Graaff accelerator near the University's new physics building in Piscataway Township, New Jersey. The announcement was made jointly by Dr. Mason W. Gross, president of the University, and W. O. Baker, vice president for research of Bell Laboratories.

The 15 MEV model ordered by Rutgers will develop the highest energy of any Van de Graaff accelerator in the world, according to the builders, the High Voltage Engineering Corporation. The Atomic Energy Commission and another university have each ordered accelerators of the same size and energy.

Intense beams of particles whose energies can be controlled and measured with great precision are produced by the accelerator. These beams of electrically-charged nuclear particles are "shot" at the nuclei of various atoms, enabling scientists to learn more about their structure.

Dr. Gross said that in addition to helping to develop basic research in nuclear physics, the accelerator will be "an invaluable asset to graduate training in physics, chemistry and allied sciences." He pointed to the collaboration between the University and the Laboratories as an "exciting example of the benefits which can be gained through closer cooperation of industry and the colleges."

Mr. Baker said, "this collaboration with Rutgers University will notably extend Bell System scientists' study of nuclear physics as related to the communications technology of the future. The coupling of modern solid-state and electronics science with research in nuclear physics is a particularly valuable example of mutual strengthening of industrial and academic research."

SWITCHING NETWORK — TRUNK

CUSTOMERS

SCANNER — CENTRAL CONTROL — SIGNAL DISTRIBUTOR

CALL STORE — PROGRAM STORE

D. Danielson tests the circuitry of the central control of the experimental ECO, in Morris, Illinois. As the diagram above shows, this logic-loaded component is the brain of an electronic switching system.

An Electronic Central Office operates with the precision of a fine watch. Its mainspring is a single circuit called the central control which performs all the system control functions.

H. N. Seckler and J. J. Yostpille

Electronic Switching Control Techniques

An electronic telephone switching system, like the electronic central office (ECO) which had its field trial in Morris, Illinois (RECORD, *December,* 1960) and the one which will be installed in Succasunna, New Jersey, (RECORD, *January,* 1962) does not simply substitute electronic devices for relays; it solves the problems of handling telephone calls in a completely new way. Figuratively speaking an electronic system does not have to work out the detailed logic of each telephone call from scratch, it simply "looks up the answer in the book." The book is a program of instructions stored in an electronic memory. Answers can be found thousands of times faster than it takes electromechanical systems to solve call-handling problems and the program can be easily changed to deal with specific situations.

An electronic switching system separates the basic system functions—memory and logic, for example—into efficient, functionally concentrated blocks of equipment. A single circuit, "central control," performs all the system control functions. The electronic system needs no special connectors, preference circuits, or lockout circuits as do present-day telephone offices where a number of control circuits in a single system compete with each other for work. However, the system must be capable of processing a number of telephone calls from a number of customers at the same time and the central control cannot remain associated with one call for an appreciable time; it must be capable of coping with simultaneous events. In other words, it must be organized on a "time-shared" basis. (RECORD, *July,* 1959).

One simple analogy of time-shared control is that of a chessmaster playing a number of games simultaneously. He need not consider all games and plan all moves at the same time. He merely goes from game to game acting on each one individually. If an opponent at a game being considered has moved since the master's last move, he counters that move and goes to the next game; if not he passes the game until the next time around. The master is limited in the number of games he can play only by his opponent's patience and his rate of moving from game to game.

The central control of an electronic switching system functions in much the same way. However, to play its "game" efficiently the electronic control must divide its work very finely and devote a minimum amount of time to each segment of work. As an example of this, consider just two of the many tasks a switching system must perform: (1) the recognition of service requests

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┌─────────────────────────────────────────┐
│     DIRECT SCANNER TO LINE                │
│   READ LINE CELL IN CALL STORE (CS)       │
└─────────────────────────────────────────┘

┌──────────┬──────────┬──────────┬──────────┐
│ SCANNER=1│ SCANNER=0│ SCANNER=1│ SCANNER=0│
│   CS=0   │   CS=0   │   CS=1   │   CS=1   │
└──────────┴──────────┴──────────┴──────────┘

┌──────────┬──────────┬────────────┐
│ NEW CALL │NO CHANGE │ DISCONNECT │
│ORIGINATED│          │  ON OLD    │
│          │          │    CALL    │
└──────────┴──────────┴────────────┘
```
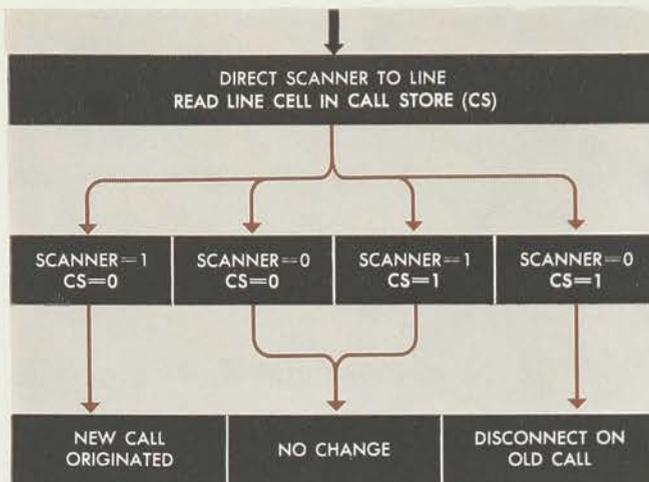
Sequence chart shows how central control of an electronic system recognizes supervisory signals.

from telephone customers, and (2) the detection of dialed information.

Let us consider the factors in applying time-shared control techniques to the first job. A telephone customer originates a request for service by lifting the telephone handset from its cradle. This closes a path causing current to flow in his telephone line; the current can be detected in the telephone office at the line circuit so that action may be started to return dial tone to the customer. Now let us assume that the central control has the ability to examine each telephone line in the office individually and determine if a new call has been started. If the control is arranged to examine each line ten times per second for new calls, then there is only a negligible delay (no more than one-tenth of a second) before dial-tone action starts. The high-speed electronic control spends only a small fraction of the total work time available on this task.

The factors determining the frequency at which the first task is performed are primarily customer service considerations. Similar factors for the second task—detection of dialed information—are more technical in nature. When a telephone customer dials he generates a string of dial pulse signals on his telephone line. The number of pulses corresponds to the digit dialed, except for zero which is represented by ten pulses. These signals can also be observed in the telephone office, but they are transient in character, usually persisting between one one-hundredth and one-tenth of a second. If the electronic control can examine any line in the telephone office individually and determine if a dial pulse is present, and if it is arranged to examine each dialing telephone line 100 times per second, it will detect all dial pulses.

The examining rate of 100 times per second is selected so that the shortest dial pulse (one one-hundredth of a second) will not be missed. Electronic control spends only a small percentage of the total available work time on detecting dial pulses—in spite of the fast examining rate—because only a small percentage of the customers in a telephone office will be dialing at any one time.

This, in a very general way, is how the electronic control handles two representative tasks on a time-shared basis, going from telephone line to telephone line in much the same way that the chessmaster goes from table to table. In a large telephone office there are hundrds of similar jobs, each of which can be handled at the proper rate. The limiting factors are the total telephone traffic and the speed of the equipment. The details of how signals from customers—including service requests—are processed in terms of the action the equipment takes will be discussed against this background on the basis of an experimental electronic system.

An electronic switching system (see the diagram on page 138) is composed of six major components; the switching network, the scanner, the call store, the program store, the signal distributor and the central control.

Functions of Major Components

The switching network provides voice transmission connections between telephone customers; it can be considered as the primary output of the system. Talking connections are established in the switching network as a result of orders given to the network by the central control.

The scanner (RECORD, *May*, 1959) is an input circuit—it can be thought of as the "eyes" of the system—that determines, one-at-a-time, the state ("on-hook" or "off-hook") of each telephone line and trunk in the office. It senses originations and disconnects and gathers dialed information. The central control samples a customer line by directing the scanner to one of its inputs (a line circuit); the scanner, in turn, returns one of two answers corresponding to the state of the line.

The call store is the bulk temporary memory for the system. It can be thought of as a scratch pad—used for dynamic records such as telephone line and trunk busy-idle conditions and dialed information. This information is stored in individual cells in binary form; that is, each cell holds a two-valued record called a "bit", usually indicated by a "0" or a "1". The central control can read or write at any cell in the store.

The program store is a bulk semi-permanent memory file which also stores information in

binary form. It contains the office telephone translation records which correlate line equipment numbers, directory numbers, and line classes of service; and a stored program. Information is recorded in this store on a word-organized basis; that is, as a fixed number of bits at each storage location. The central control can read any word recorded in the program store.

The signal distributor is an output circuit that can operate any one of a number of output amplifiers, which in turn may operate an electro-mechanical relay. Primarily, it controls relays in trunk circuits that communicate with conventional electro-mechanical systems. It insures compatibility of the high-speed electronic system and the low-speed mechanical system.

One of the functions of a telephone switching system is the recognition of "supervisory" signals from a customer. These include new requests for service and terminations of established calls. The scanner can recognize the state of a line when directed to it by the central control and return the appropriate answer. Since there are only two possible answers (on-hook or off-hook, signifying an open or closed line), they can be represented as a single binary digit: the assignment of the value 0 is "on-hook" and the value 1 is "off-hook".

Because the scanner can determine only the present state of a customer line some memory must be present to recognize changes in line state. Therefore, an individual call store cell is assigned to each line. Each cell holds one binary digit, or

Fragment of a typical electronic system program.

bit, of information. To obtain a record of each line's last known state, a zero is stored in the line cell when the line is idle, and a one is stored when the line is busy. Supervisory signals from lines are recognized when the scanner indications and line cell records are compared.

Control Action on Customer Lines

The experimental system is arranged to start action on supervisory signals from customers within one-tenth second of their occurrence. To this end, a special control action for each telephone line in the office is repeated once every tenth of a second. The central control directs the scanner to determine if a line is "on-hook" or "off-hook". At the same time it orders the call store to read the corresponding line cell. From the resulting answers, the central control decides whether during the previous tenth of a second the examined line originated a new call, disconnected (hung-up) an old call, or did not change. It is convenient to represent this system action in the form of a sequence chart (see the drawing on page 140). Many hundreds of complex sequence charts are required to describe all the actions an electronic switching system must take to provide telephone service.

Any plan for implementing this broad control philosophy must include a precise program containing the intelligence required to process telephone calls and to perform other system functions. In present telephone systems the control philosophy is implemented by wired relay circuits which, for a given set of input conditions, control the sequence of events leading to the required system actions. Where economical, large-capacity, rapid-access memory is available, it is attractive to use a stored program, and this alternative was chosen for the electronic system. The pattern of sequences is imaged in the program, with the control circuitry designed to interpret and carry out a relatively small number of different types of basic program orders.

In the stored program system, the central control reads a program word from the program store every few microseconds. Each program word contains an instruction (what to do) and usually an address (where to do it), and each word is interpreted and executed by the central control. The control accepts program orders at successive address locations in the program store until a decision must be made.

A decision operation occurs at a branch point of a sequence and provides for a choice of alternative actions to follow it. This category includes reading of the call store, scanner, and
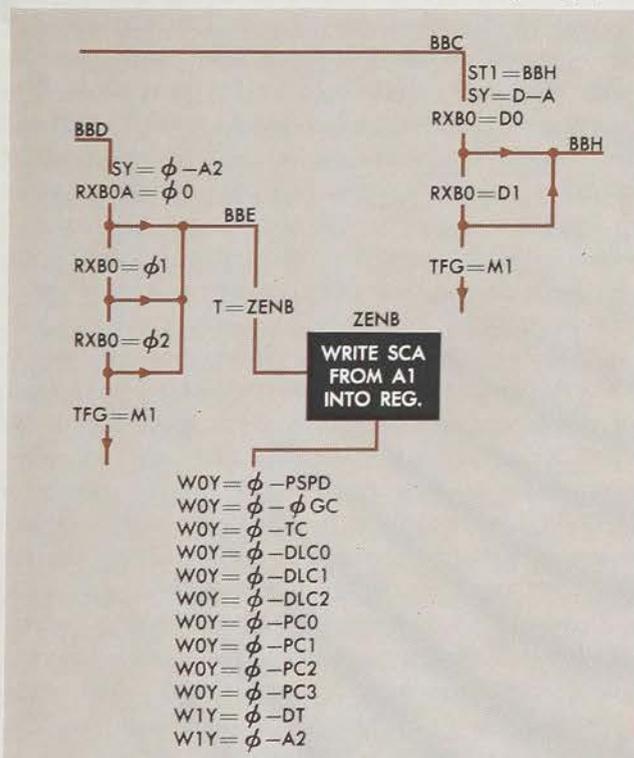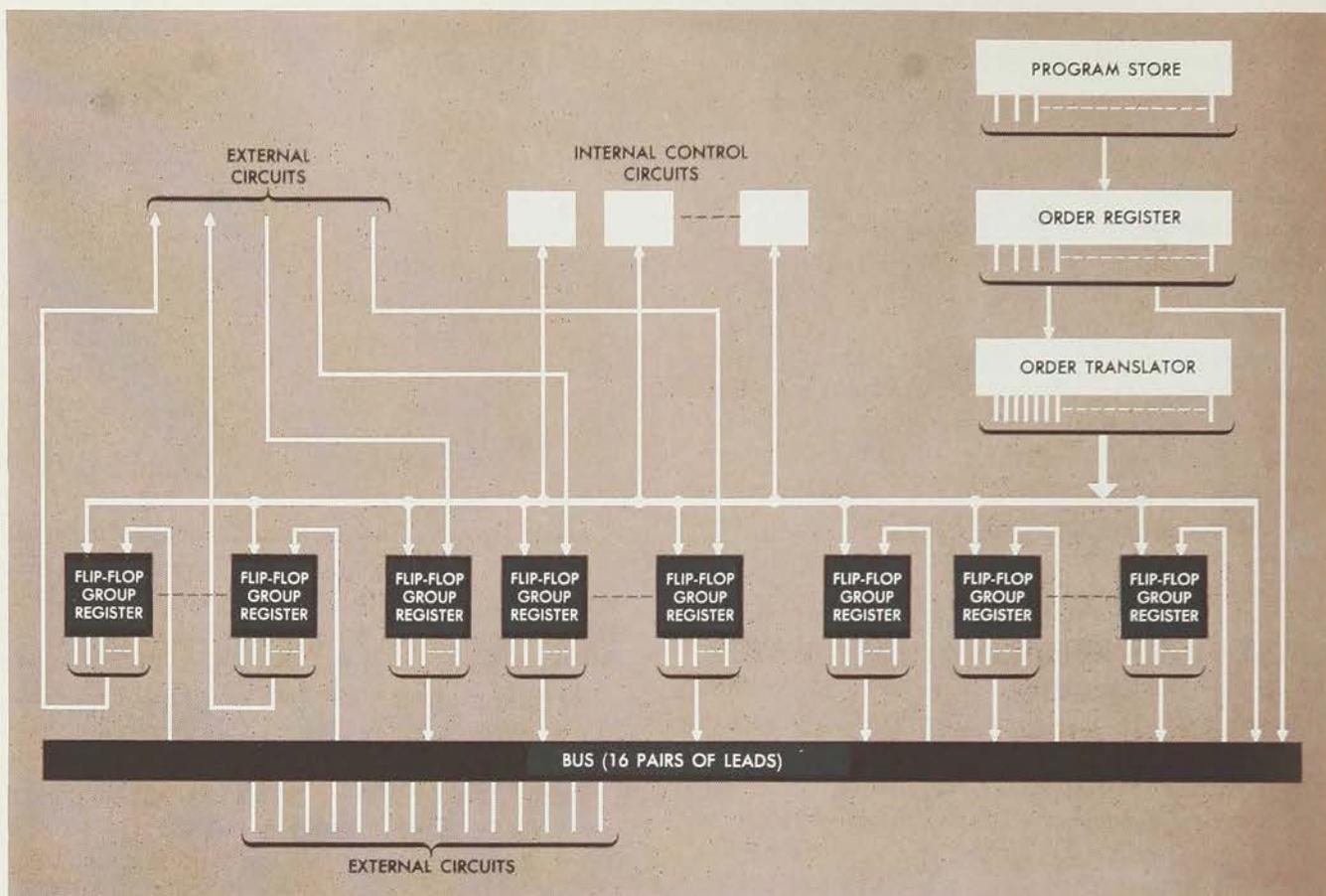
Organization of central control. The common bus establishes communications between the flip-flop register groups after the order translator establishes the necessary circuit conditions.

individual flip flops (two-state circuits). A modifier that determines which of two alternatives is to correspond to each of the two possible results further specifies a decision operation. Two alternative actions follow the decision point: One, to continue with the next operation appearing sequentially in the program; the other, to transfer control to some other location in the program.

Non-decision operations perform work resulting from decision operations and each non-decision operation is followed directly by the succeeding operation specified in the program. This category includes writing in the call store, transferring information from the call store to flip flops, and unconditionally transferring control to a specified program location.

The central control is the heart of the electronic switching system. Its actions are required for all system functions. It consists almost entirely of semiconductor circuitry arranged in logic configurations which interpret and execute each of the program orders originating from the program store. Central control processes these orders one at a time. Progress through the program, order-by-order, is controlled by a clock whose period is a few microseconds. When a program order is

passed from the program store to the central control upon the reception of a clock pulse, the central control logic circuits within the ensuing clock period decode the order and prime the circuits that will participate in its execution. The succeeding clock pulse causes the execution of the order and simultaneously causes the next order in the program to pass from the program store to the central control for similar processing.

An order register in the central control (See the drawing on this page) receives and stores a program order from the program store for one clock period. The order register is connected to an order translator that converts the binary form of the program order into a form which can be used for establishing the circuit condition necessary for its execution. The order translator outputs are connected in some manner to almost every circuit of the central control. Much of this circuitry consists of flip-flop registers, employed mainly for short term high-speed storage of addresses associated with the various major system units. Communication among the flip-flop registers is achieved through a common bus. The order translator establishes conditions for communication via the bus. It also actuates circuits

having control rather than register functions. All central control circuits consist of diode AND gates and OR gates, flip flops and inverters; added to this basic logic are amplifiers, emitter followers and other supporting circuitry.

After the system sequences are planned in full detail and a program order structure is formed, the system is programmed. To do this, the programmer refers to the sequence charts which depict the complex succession of actions the system must perform to do its work. These actions may all be accomplished with some combination of program orders. Frequently there are a number of ways to program a given sequence. The one chosen will depend on such things as the probabilities of the alternative actions following a decision point, whether real time or program memory space is more at a premium, and other similar considerations. A fragment of a program written for an electronic switching system is shown in the drawing on page 141. The program orders are represented symbolically to relieve the programmer from the details of numerical coding and are arranged in the same type of geometric configuration as a sequence chart. Each program order contains an instruction, at the left of an equal sign, and an address, at the right.

Programs are written in symbolic form and must be converted eventually to the binary form in which they are recorded in the program store. This process is called 'assembly'. It consists of feeding a symbolic program, a series of tables—specifying the conversions from symbols to binary numbers—and a program for applying the conversions with a digital computer. The computer output is a binary encoded result ready to be recorded in the program store.

There are a number of differences between a stored program telephone system and one in which the sequences of action are designed into wired circuits. These differences apply to the physical devices used, the basic time-shared mode of operation, and also to the electronic system's greater flexibility.

The flexibility of a stored program system results from the ease with which the system characteristics may be altered. To change its mode of operation, one can reprogram a system as desired and record the new program in the program store. Thus, the program store contents may be altered to incorporate changes in translation and routing information, and also in the stored program. The ultimate in flexibility would be a universal telephone system which could be adapted to any use—local, tandem, or toll—by equipping it with the appropriate program.

Laboratories System Guides
NASA Solar Observatory
Into Orbit

The National Aeronautics and Space Administration's Orbiting Solar Observatory (OSO), launched last month with a Thor-Delta rocket from Cape Canaveral was guided into orbit by the Bell Laboratories Command Guidance System. This launch marked the seventh consecutive success for the Laboratories-guided Delta vehicle and the seventh consecutive use of the command guidance system on both developmental Air Force Titan I ICBMs and space research shots without a failure.

News of Space Research

The 440-pound OSO spacecraft, which carries 13 separate experiments, is the first of a series of such satellites designed to probe the heart of the universe. NASA officials have described the observatory as "the most promising instrumentation advance in the study of the sun since the development of the coronagraph 30 years ago." One official said the spacecraft is pointing at the sun with an accuracy equivalent to "sighting a one-cent piece from a half-mile away."

For the first time scientists will be able to "look" at the sun by interpreting data sent from the satellite from a point far beyond the blanketing veil of the earth's atmosphere. Experiments in the observatory are designed to provide information about radio communications interference from sun spots, weather changes due to heating of the upper atmosphere, auroral displays, the behavior of magnetic compasses and various effects on vegetation and foliage.

The OSO was launched into its 350-mile circular orbit—an apogee of 371.7 miles and a perigee of 341.6 miles—by the Laboratories-Western Electric crew at Cape Canaveral. This crew, many of whom have served at the guidance facility at the Cape since its inception in 1956, is under the technical direction of J. B. D'Alboro, Jr. of the Laboratories. Western Electric field forces supporting the Bell Laboratories activities there are lead by R. E. Kimmel.

The guidance programs for all types of launches that use the command guidance system —ICBM test, orbiting satellites and interplanetary probes—are developed and analyzed in the guidance system's laboratory at Whippany.

The National Safety Council has consistently awarded the communications industry top honors for its record of safety. Items such as the B Voltage Tester have contributed to making this industry the one with the least number of accidents.

J. H. King

The B Voltage Tester and Auxiliaries

A telephone craftsman must frequently work on poles that carry both power and telephone facilities. To enable him to work safely, the pole lines as well as the tools he uses must meet strict standards of design and construction. Also, the telephone craftsman has specific safety equipment for use when the need arises; for example, insulating gloves and insulating blankets. The most recent addition to such items of safety equipment is the B voltage tester, which is used to detect accidental power voltage on certain pieces of pole hardware and ground wires. The B shunting capacitor and the B temporary bond are auxiliaries for the B voltage tester.

The current-carrying parts of the power system are usually placed higher on the pole than the telephone lines so that a telephone craftsman does not have to climb past energized power wires or equipment. Sometimes, however, as in the case of street lamps and vertical ground wires, power facilities must be located in or below the space assigned to the telephone lines. Ordinarily, such items are safe to touch because they are adequately insulated or grounded and the circuits are properly connected. Even so, there is the remote but everpresent possibility that the craftsman may encounter an accidentally energized light fixture or ground wire. The new safety items described here enable a craftsman to test for such accidental voltages, and assure him that hardware within his area will remain unenergized while he is there.

Every telephone craftsman who climbs joint-use poles needs a B voltage tester. Therefore, the tester had to be simple, rugged and inexpensive. The ground connection used is sometimes no better than that obtained by placing a metal object on the pavement. For this reason, the tester had to be very sensitive. Another controlling factor in the design was the range of voltages which might be encountered. The practical upper limit of 7600 volts covers the more common primary

B Voltage Tester is shown diagrammatically below, actual tester and its auxiliaries are shown above.

INSULATING
WAND

CONNECTING
LEAD

SERIES
RESISTORS

CONTACT
INPUT

GROUND
CLIP

EYEPIECE
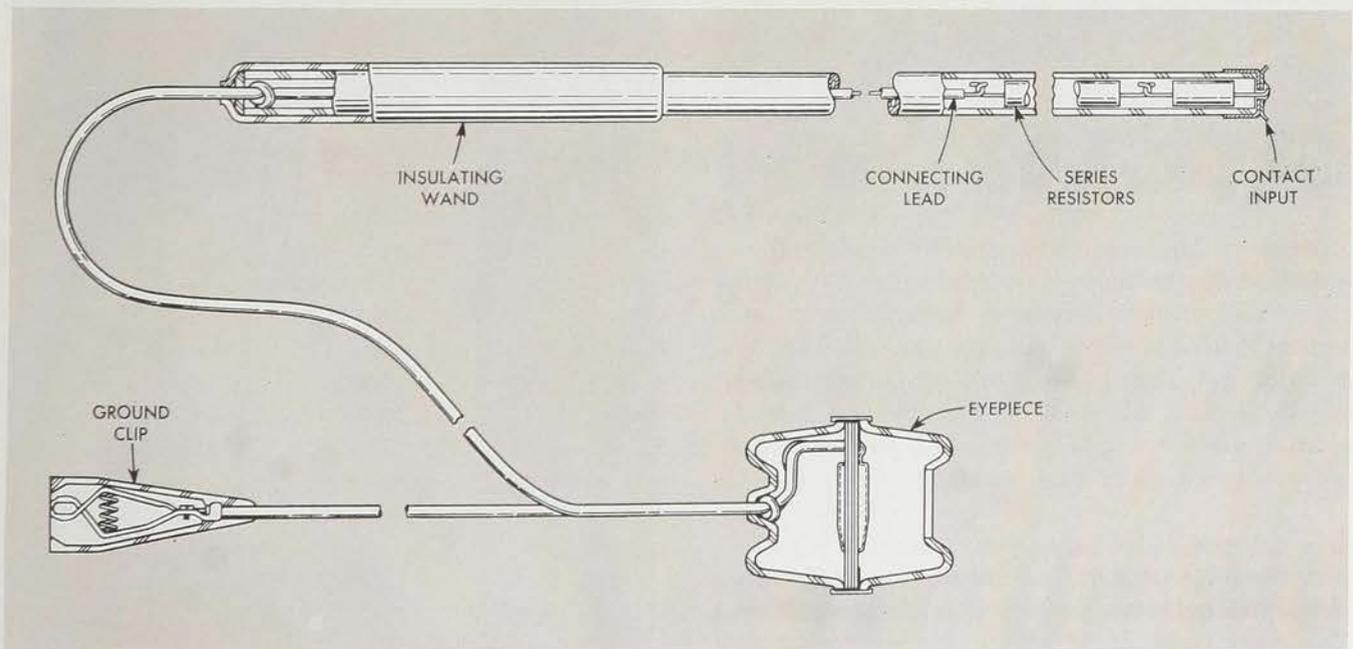
power distribution and lighting voltages. A lower limit of sensitivity in the order of 100 volts is required to test energized plant at the standard secondary distribution voltage. A neon-type indicator was satisfactory over this range.

Components and Operating Procedure

The B voltage tester consists of a plastic wand about two-feet long connected to a neon indicator by a flexible insulated wire. The indicator, in turn, is connected to an insulated grounding clip by a similar wire. A metal-toothed contacting spur, or washer, is provided on the end of the wand. Within the hollow wand are seven 2-watt resistors. These resistors, which are wired in series and total approximately 500,000 ohms resistance, connect the spur on one end of the wand to the test wire on the other end. The small neon lamp within the indicator glows whenever the metal washer contacts sufficient voltage while the grounding clip is properly grounded. The tester, wand, and indicator housings are made of plastic materials that maintain a high dielectric insulation over the circuitry of the tester to protect the user. This design results in a low-cost assembly which is highly reliable and has high impact strength.

To increase the versatility of the voltage tester, two auxiliary devices are provided—the B shunting capacitor and the B temporary bond. The shunting capacitor consists of a high-voltage, oil-filled capacitor encapsulated in a phenolic tube. One end of the tube is equipped with a short cord and battery clips. The other end has a stud for a terminal. The temporary bond is simply a five-foot length of heavy-gauge insulated stranded conductor with a large battery clip on each end.

Before climbing a joint-use pole, a telephone craftsman uses the voltage tester to probe for hazardous voltages at ground level. The metallic items usually found at the base of poles are vertical power ground wires or metallic power conduits.

Before probing for voltages on these items, the craftsman connects the grounding clip of the voltage tester to ground through a screwdriver blade inserted in the soil a few feet away from the pole. If no soil is available, he can connect the grounding clip to a nearby fire hydrant, a projection on a manhole cover, or a metal curb box may be used instead. If nothing else is available, the grounding clip of the voltage tester can be connected to a metal object, such as a piece of lead sleeving or a bar of solder placed on the pavement about five feet from the pole. After the voltage tester is connected to such a ground, the craftsman, standing clear of the pole, touches the metal-toothed washer on the end of the wand to the power ground wire or metallic power conduit on the side of the pole. If the neon lamp in the indicator glows, the ground wire is energized. When this occurs, the workman reports the condition to his supervisor and does not climb the pole until the power company corrects the fault. If there is no voltage on power grounds and power conduits, the workman climbs the pole using prescribed safety precautions, such as wearing insulating gloves when testing street light fixtures.

Should there be a street lamp near the work area on the pole, the metallic bracket of the lighting fixture is also tested for potential. In this

In checking unsheathed vertical ground wires, Mr. Dein attaches battery clip of voltage tester to screwdriver blade which he inserts in soil.
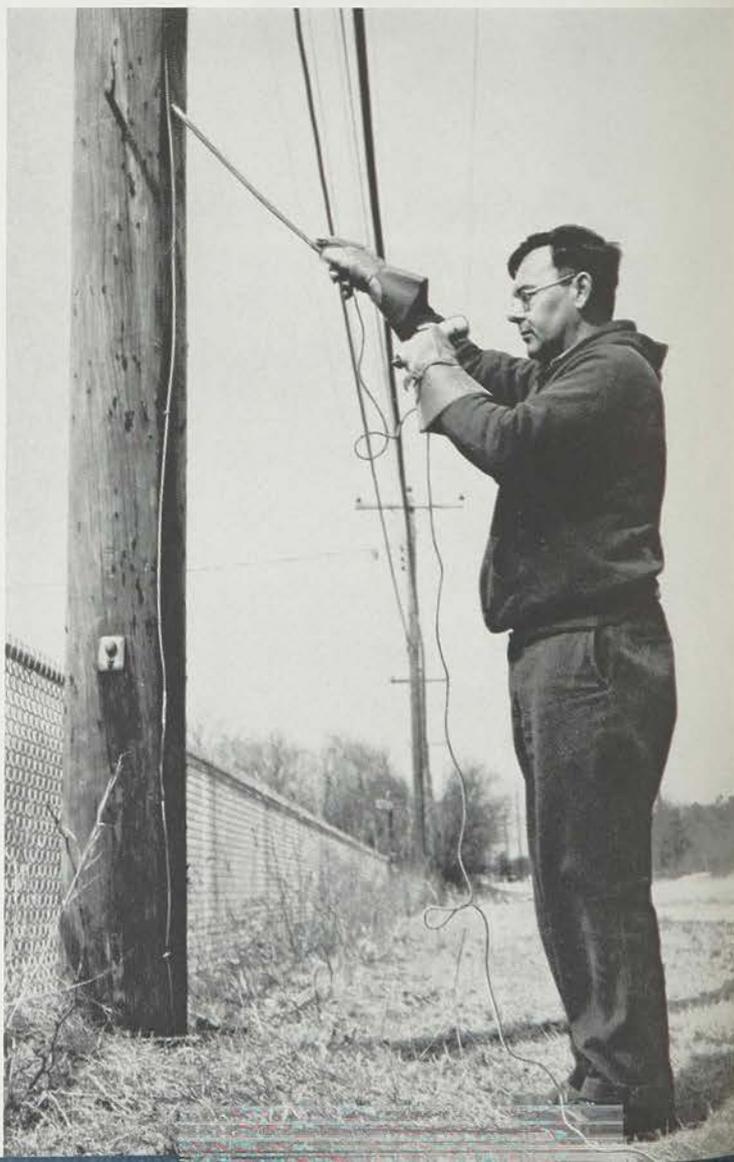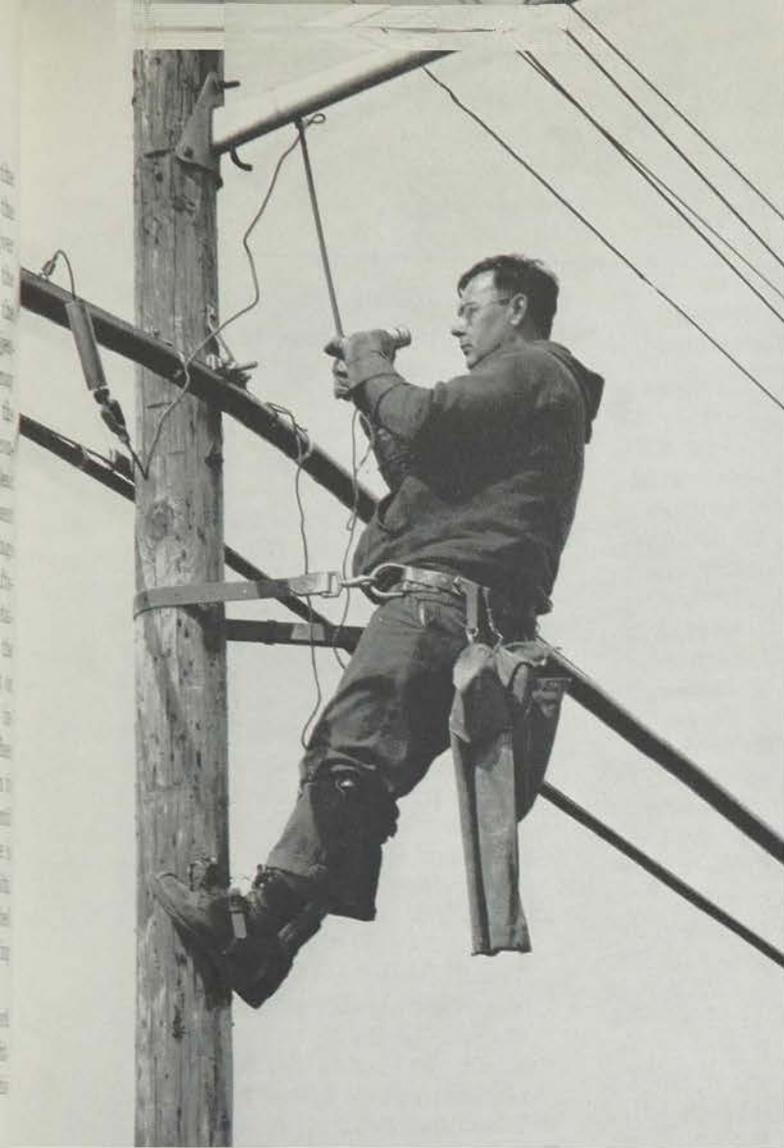
Telephone craftsman probing lighting fixture bracket with the voltage tester in conjunction with the shunting capacitor and temporary bond.

case, there are two additional factors to be considered: (1) the detection of harmless voltages and (2) the assurance that there will be no hazardous voltages during the time while the craftsman is on the pole.

How Auxiliaries Work

Because the tester is sensitive enough to detect even high-resistance grounds, it is also sensitive enough to detect harmless voltages caused by capacitance coupling or minor leakage. The shunting capacitor and the temporary bond enable the voltage tester to differentiate between a dangerous, direct metal-to-metal contact on a lighting fixture and capacitance coupling. In use, the B shunting capacitor and the B temporary bond are connected in series. The clip of the B shunting capacitor is attached to the cable support strand. The other end of the temporary bond is connected to the metal cap behind the disk of the insulated probe. The voltage-tester grounding clip is also connected to the cable strand. At least one foot separation must be maintained between the B temporary bond and voltage tester leads.

When the craftsman touches the wand of the voltage tester to the lighting fixture, the 0.05-microfarad capacitance in the shunting capacitor is in series with the small stray capacitance between the power wiring and the lighting fixture and acts as a voltage divider. This minimizes the effect of the stray capacitance. If the neon lamp glows under these circumstances, the craftsman knows that the fixture is directly energized and therefore dangerous.

If the shunting capacitor is not available, the grounding clip of the voltage tester is attached to the cable support strand or other approved ground, and the craftsman touches the toothed washer of the voltage tester to the lighting fixture. If the neon lamp glows, the craftsman can only assume that there is a hazardous voltage on the lighting fixture; he cannot differentiate stray capacitance coupling from a direct contact.

In testing street lighting fixtures, the tester may not indicate voltage because the street lights are not turned on. When the lights are turned on, however, the fixture may become energized while the craftsman is on the pole. To guard against this possibility, the telephone craftsman connects the temporary bond from the cable strand to the street lamp. If the insulation on this bond later begins to smoke, the fixture has obviously become energized, and the craftsman immediately puts on his insulating gloves and descends the pole without removing the bond.

Since the B voltage tester has been available, a number of cases have been reported where craftsmen have detected dangerous voltages on power ground wires, conduit, and street lighting fixtures. Measurements on two street lamps, for example, showed a potential of 580 to 750 volts. Undoubtedly, the B voltage tester has prevented a number of lost-time accidents, and most likely several fatalities.

The B voltage tester is no substitute for caution and good judgment, but its use in conjunction with other safety items can do much to reduce the likelihood of electric-shock accidents.

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

Barnett, C. H., Large, W. V. K., and Pruden, H. M.—*Continuous Checking of Circuit Continuity of a Signaling System*—3,021,398.

Barnett, C. H., Large, W. V. K., and Pruden, H. M.—*Repeater for Checking Circuit Continuity of a Signaling System*—3,021,397.

Becker, F. K.—*Monaural-Binaural Transmission of Sound*—3,022,378.

Black, H. S. and Edson, J. O.—*Pulse Code Modulation Communication System*—3,020,350.

Bowers, F. K. and Schafer, J. P.—*Broad-Band Ferrite Polarization Rotator*—3,023,384.

Brattain, W. H. and Wade, N. G. 3rd—*Scanning Infra-Red Detector and Recorder*—3,022,374.

Brown, E. F.—*Time Division Multiplexing of Television and Telephone Messages*—3,021,384.

Cath, P. G.—*Signaling Circuits*—3,020,348.

Comstock, R. L.—*Microwave Pulse Amplifier*—3,022,463.

Davey, J. R. — *Synchronizing Start-Stop Digital Transmission System*—3,022,375.

Dickieson, A. C.—*Torpedo Steering System*—3,020,868.

Edson, J. O., see Black, H. S.

Edson, R. C.—*Monostable Multivibrator Responsive to Positive and Negative Trigger Pulses from Single Source*—3,021,488.

Ewin, J. C.—*Remote Telephone Line Concentrator*—3,022,382.

Foulkes, J. D.—*Communication System*—3,023,309.

Garrison, R. F. and Saal, F. A.—*Counting Circuit*—3,022,003.

Grubbs, W. J., Jr., Hines, M. E. and Varnerin, L. J., Jr.—*Integrated Semiconductive Device*—3,021,459.

Hines, M. E., see Grubbs, W. J., Jr.

Jacobson, O. D.—*Automatic Wiring Apparatus*—3,019,822.

Jacobson, O. D.—*Circuit Controller*—3,020,369.

James, D. B. and Kretsch, K. P.—*Four Wire Line Concentrator Circuit*—3,023,278.

Jones, W. C. and Ridinger, P. G.—*Transistor Memory Cell*—3,021,436.

Kaenel, R. A.—*Analog-to-Digital Converter*—3,021,517.

Kingsbury, E. F.—*Reflector Optical System*—3,020,792.

Kohman, G. T. and McAfee, K. B., Jr.—*Separation of Gases by Diffusion*—3,019,853.

Kompfner, R.—*Parallel High Frequency Amplifier Circuits*—3,021,490.

Kompfner, R.—*Scanning Horn-Reflector Antenna*—3,021,524.

Kretsch, K. P., see James, D. B.

Kuch, F. C.—*Electrical Connector for Preformed Panel Circuit Arrangement*—3,020,510.

Landau, H. J.—*Signal Recovery Circuits*—3,022,473.

Large, W. V. K., see Barnett, C. H.

Large, W. V. K., see Barnett, C. H.

Li, T.—*Cross-Talk Cancellation Apparatus for Broadband Microwave Radio Links*—3,020,543.

Logan, M. A.—*Electric Wave Synchronization*—3,020,476.

Lovecky, A. J.—*Wire Unwrapping Tool*—3,019,517.

Mallery, P.—*Binary Adders*—3,021,070.

Mathews, M. V.—*Reduction of Sampling Rate in Pulse Code Transmission*—3,023,277.

Mattke, C. F. and Reynolds, F. W.—*Radiant-Energy Translation System*—3,021,428.

McAfee, K. B., Jr., see Kohman, G. T.

Meacham, L. A.—*Wave Analysis and Representation*—3,021,478.

Miller, R. A., Munson, V. E., Owendoff, H. M. and Taris, C. M. — *Announcing System* — 3,022,380.

Miller, S. E.—*Wave Mode Converter*—3,020,495.

Munson, V. E., see Miller, R. A.

Mumford, W. W.—*Noise Generator*—3,023,374.

Owendoff, H. M., see Miller, R. A.

Pferd, W.—*Credit Card Operated Telephone*—3,022,381.

Pohl, K. H.—*Connector Assembly*—3,021,500.

Prestigiacomo, A. J.—*Apparatus for Deriving Pitch Information from a Speech Wave*—3,020,344.

Pruden, H. M., see Barnett, C. H.

Pruden, H. M., see Barnett, C. H.

Reynolds, F. W., see Mattke, C. F.

Riley, R. M.—*Electrical Cable*—3,020,334.

Ridinger, P. G., see Jones, W. C.

Saal, F. A., see Garrison, R. F.

Schafer, J. P., see Bowers, F. K.

Tanenbaum, M. and Wallace, R. L., Jr.—*Variable Equalizer Employing Semi-conductive Element*—3,022,472.

Taris, C. M., see Miller, R. A.

Turner, E. H. — *Transversely Magnetized Non-Reciprocal Microwave Device*—3,023,379.

Van Uitert, L. G.—*Magnesium Ferrite Containing Aluminum and Method of Making Same*—3,023,165.

Varnerin, L. J., Jr., see Grubbs, W. J.

Votaw, C. J.—*Station Selection System*—3,022,372.

Wade, N. G. 3rd, see Brattain, W. E.

Wallace, R. L., see Tanenbaum, M.

Weiss, M. T. — *Ferromagnetic Parametric Microwave Amplifier*—3,022,466.

TALKS

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

Alexander, E. J., McAlexander, J. C., Young, L. H., and Salhany, R. J., *A Permanent Magnet Twister Memory Element of Improved Characteristics*, Magnetism and Magnetic Materials Conf., Phoenix, Ariz.

Allen, T. E., *A New Voice Communication System for Air Traffic Control*, A.I.E.E., N. Y. C.

Anderson, T. C., see Favin, D. L.

Bennett, W. R., Jr., *Recent Experiments with He-Ne Optical Masers*, Phys. Colloq., Brandeis Univ., Waltham, Mass.; Rutgers Univ., New Brunswick, N. J.

Berreman, D. W., *Debye Temperatures of NaCl and KCl by Houston's Method*, Am. Phys. Soc., N. Y. C.

Blumberg, W. E., *Sign of Electron-Nuclear Interaction of F-Center Electrons in KCl*, Am. Phys., Soc., Los Angeles, Calif.

Blumberg, W. E., see Eisinger, J.

Clogston, A. M., *Magnetization of Localized States in Transition Metals*, Am. Phys. Soc., N. Y. C.

Collins, R. J., and Kisliuk, P., *Feedback Modulation with a Ruby Optical Maser*, Am. Phys. Soc., Univ. of Chicago, Chicago, Ill.

Collins, R. J., *Optical Maser*, McGill Univ., Montreal, Can.; Internat. Electron. Conf., Chicago, Ill.; A.I.E.E., N. Y. C.

Collins, R. J., *A Review of the Properties of the Optical Maser*, A.I.E.E., Ames, Iowa

Curtis, H. E., *Interference Between Satellite Communication Systems and Common Carrier Surface Systems*, A.I.E.E. N. Y. C.

Decker, V., Forster, J. H., and Howard, B. T., *Hot-Glass Sealed Silicon Diodes*, PGED, Washington, D. C.

De Benedictis, T., see Hansen, R. H.

De Motte, F. E., *A Reliable Base-Frequency Signal Source for Compared Redundant Count-Down Chains*, East Coast Conf. Aerospace and Navigational Electron., Baltimore, Md.

Dillon, J. F., *Ferromagnetic Resonance in $CrBr_3$*, Conf. Magnetism and Magnetic Materials, Phoenix, Ariz.

Eisinger, J., Blumberg, W. E., and Shulman, R. G., *Proton Relaxation Enhancement*, Am. Phys. Soc., Los Angeles, Calif.

Favin, D. L., and Anderson, T. C., *Data System Performance as Evaluated by Eye Patterns*, A.I.E.E., N. Y. C.

Fierito, L. E., *A Rapid Duct Corrosion Survey for Lead Sheath Telephone Cables*, Nat. Assoc. Corrosion Engg., Toronto, Can.

Forster, J. H., see Decker, V.

Foyt, A. G., see Nelson, J. T.

Frisch, H. L., *Percolation Processes*, Am. Statis. Assoc., N. Y. C.

Geballe, T. H., *The Isotope Effect in Superconductivity*, Am. Phys. Soc., Los Angeles, Calif.

Giordmaine, J. A., *Atmosphere and Surface Conditions of Venus and Mars*, Astronautics Symp., Toronto, Can.

Giordmaine, J. A., *Optical Mixing in Crystals*, M.I.T., Boston, Mass.

Glaser, J. L., *The Design of Medium Height Random Orbit Satellite Systems*, Internat. Sci. Radio Union, Paris, France

Gnanadesikan, R., see Wilk, M. B.

Gucker, G. B., *Long Term Frequency Stability for a Reflex Klystron Without the Use of External Cavities*, A.I.E.E. N. Y. C.

Hammock, J., *Reconstruction in Instruction*, Mid-West Conf. for Educ., Purdue Univ., Lafayette, Ind.

Hammock, J., *Communication of Knowledge*, Western Electric Co., Fourteenth Engg. Symp., Winston-Salem, N. C.

Hansen, R. H., and De Benedictis, T., *Studies of the Decomposition of Blowing Agents. II: Azodicarbonamide and other Compounds*, Am. Chem. Soc., N. Y. C.

Hansen, R. H., and Martin, W. M., *The Induction Period in the Thermal Oxidation of Polyolefins*, Am. Chem. Soc., N. Y. C.

Harmon, L. D., *Automatic Reading of Cursive Script*, Symp. on Opt. Character Recog., Washington, D. C.

Herriott, D. R., *Optical Properties of the Cavity and Output Beam of a Continuous Gas Maser*, Quantum Electron. Conf., Berkeley, Calif.

Hogg, D. C., *Propagation and Antenna Effects in Space Communication*. IRE, Toronto, Can.

Howard, B. T., see Decker, V.

Hutson, A. R., *Ultrasonic Propagation and Scattering in Piezoelectric Semiconductors*, Am. Phys. Soc., N. Y. C.

Jepson, J. W., *Elementary Principles of Cryogenics Design for the $2.5°-80°$ K Temperature Range*, A.S.M.E., Madison, N. J.

Kaminow, I. P., *Microwave Modulation of Light by the Electrophi Effect*, IRE, Nutley, N. J.

Kisliuk, P., see Collins, P. J.

Kunzler, J. E., *Magnetoresistance, Hall Effect, and the Fermi Surface of Pure Metals*, Ohio State Univ., Columbus, Ohio

Kunzler, J. E., *Superconductivity at High Magnetic Fields and Superconducting Magnets*,

Wright Patterson Air Force Base, Ohio

Martin, W. M., see Hansen, R. H.

McAlexander, J. C., see Alexander, E. J.

McCall, D. W., *Nuclear Magnetic Relaxation in Polymers*, Chem. Dept., Univ. Wisconsin, Madison, Wis.

Meinken, R. H., *Magnetic Materials*, Am. Ceram. Soc., Teterboro, N. J.

Meitzler, A. H., *Ultrasonic Delay Lines for Digital Data Storage*, Acous. Soc. Am., Cincinnati, Ohio

Mumford, W. W., *Some Technical Aspects of Microwave Radiation Hazards*, Wright-Patterson Air Force Base, Dayton, Ohio

Mumford, W. W., *Microwave Noise Figures*, IRE, Boulder, Colo.

Nassau, K., *Communication at Optical Frequencies*, A.I.E.E., Sharon, Pa.

Nassau, K., *Optical Masers and Calcium Tungstates*, Univ. Pittsburgh, Pittsburgh, Pa.

Nelson, D. F., *A Continuously Operating Ruby Optical Maser*, Am. Phys. Soc., N. Y. C.

Nelson, D. F., *Optical Masers*, Research Soc. Am., Midland, Mich.

Nelson, L. S., *Flash Heating: A New Technique for Studying High Temperature Reactions*, Am. Chem. Soc., University Park, Pa.

Nelson, J. T., and Foyt, A. G., *Germanium Transistors for Opperation Above 1 Kmc*, IRE, Washington, D. C.

Nimmcke, F. E., *The Nike-Zeus Story*, IRE, Lynchburg, Va.

Norem, P. C., and Wertheim, G. K., *Fe⁵⁷ Isoner Shifts in Silicon and Germanium*, Am. Phys. Soc., N. Y. C.

Pfann, W. G., *Why Pure Metals*, Am. Soc. Metals, Detroit, Mich.

Pollak, H. O., *The First Two Years*, Thirty-first Annual Meeting Am. Assoc. Physics Teachers, N. Y. C.

Pollak, H. O., *On the Nature of Mathematical Research in Industry*, Port Chester High School, Port Chester, N. Y.

Porto, S. P. S., *Present Status of Optical Maser Research*, Pennsylvania State Univ., University Park, Pa.

Reed, E. D., *Microwave Solid State Masers*, Lehigh Univ., Bethlehem, Pa.

Richards, P. L., *Anisotropy of the Superconducting Energy Gap in Pure and Impure Tin*, Phys. Colloq., Rutgers State Univ., New Brunswick, N. J.

Rogers, C. E., *Stress Cracking and Sorption of Polyethylene*, Am. Chem. Soc., N. Y. C.

Russell, C. A., *Some Requirements of Plastic Wire Coatings in Telephone Service*, Soc. Plastics Engrs., West Boylston, Mass.

Salhany, R. J., see Alexander, E. J.

Schroeder, M. R., *My Job at Bell Labs*, Gillette Kindergarten, Gillette, N. J.

Shulman, R. G., see Eisinger, J.

Smith, W. H., *Insertion Loss Synthesis of Transmission Transformers with Butterworth and Chebycheff Response*, A.I.E.E. N. Y. C.

Smolinsky, G., *The Chemistry of the Monovalent Nitrogen Species, Azenes*, Mellon Insti., Pittsburgh, Pa.

Story, P. R., *Chemistry of Nonclassical Reactive Intermediates*, Univ. Kansas, Lawrence, Kans.

Tanenbaum, M., *Metallurgy and Electronics*, Am. Soc. Metals, Providence, R. I.

Thomas, U. B., *The Use of Electroplated Metal in Static Contacts*, Univ. Maine, Orono, Maine

Vaughan, H. E., *Communications Systems Research*, Science Stud., N. Y. C.

Welk, M. B., and Gnanadesikan, R., *Analysis of Multi-response Experiments*, Insti. Mathe. Statis., N. Y. C.

Wernick, J. H., *Metallurgical Aspects of High Field Superconducting Materials*, A.I.M.E., N.Y.C.

Wertheim, G. K. *The Mossbauer Effect Isomer Shift in Fe⁵⁷*, Dartmouth College, Hanover, N. H.; Westinghouse Research Laboratory, Pittsburgh, Pa.

Wertheim, G. K., see Norem, P. C.

White, D. L., *Depletion Layer High Frequency Transducers*, Acous. Soc. Am., Cincinnati, Ohio

White, D. L., *Ultrasonic Traveling Wave Amplifier*, Solid-State Circuits Conf., Philadelphia, Pa.

Williams, W. H., *Some Economic and Engineering Aspects of Operations Research*, Am. Statis. Assoc., N. Y. C.

Witt, F. J., *Satellite Communications*, A.I.E.E., Charleston, W. Va.; Western Electric Engrs. Dinner Meeting, Kansas City, Mo.

Wolff, P. A., *Light Scattering as a Probe of Plasma Structure*, Phys. Dept., Ford Motor Co., Dearborn, Mich.

Wood, Mrs. E. A., *Epitaxial Deposition*, A.I.M.E., N. Y. C.

Wood, Mrs. E. A., *Minerals, Molecules and Magnets*, Univ. of N. Dakota, Grand Forks, N. D.

Wood, Mrs. E. A., *The Strange Case of Ferroelectricity in Sodium Niobate*, Univ. of N. Dakota, Grand Forks, N. D.

Yariv, A., *Recent Developments in Lasers*, Opt. Soc. of Am., Stamford, Conn.

Young, L. H., see Alexander, E. J.

THE AUTHORS

William G. Graves II, a native of Spokane, Washington, is the author of "Search-Radar Tracking in Heavy Seas." He attended Yale University, and after a three year interruption for service in the Army Signal Corps, received the B.E. degree in Electrical Engineering. Following two years as a toll transmission engineer with an independent telephone company, Mr. Graves joined Bell Laboratories in 1951.


W. H. von Aulock
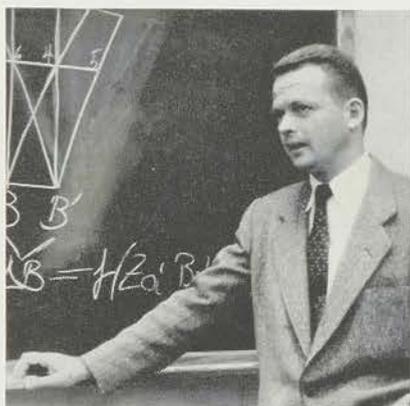
W. G. Graves II

His first assignment at the Laboratories was on the automatic switching system for TD-2 microwave radio. After that he worked on the Mark 65 project. Specifically, he was concerned with the design of the Terrier missile systems that were installed on the USS Boston, the USS Canberra, and other ships. He also did systems study for the Mark 65 project and his article in this issue is based on that work. At present Mr. Graves is concerned with the design of digital data processing equipment for Nike-Zeus.

W. H. von Aulock was born in Pirna, Germany on January 24, 1915. He received the Dip.Ing. degree from the Technische Hochschule, Berlin, in 1937 and the Dr.Ing. degree from the Technische Hochschule, Stuttgart, in 1953. In 1947 he accepted an in-

vitation to work for the U. S. Navy Bureau of Ships, Washington, D. C., where he was involved in work on torpedo countermeasures and studies of electromagnetic fields in sea water. Mr. von Aulock joined the Bell Telephone Laboratories in Whippany in 1954, where he was engaged in preliminary studies of microwave ferrite phase shifters. The electronically scanning radar antenna, which is the subject of his article in this issue, was the first large application of these devices. He continued work on ferrite devices and materials after his appointment to supervisor in 1958. His most recent assignment involves application of electronically scanning radar systems to the defense against intercontinental ballistic missiles.
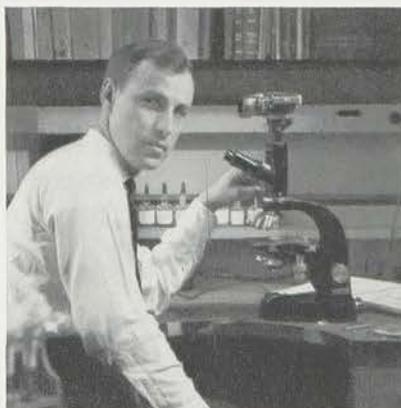
R. A. Connolly

Richard A. Connolly, a native of South Portland, Me., received his B.S. degree in Forestry from the University of Maine in 1952 and his M.S. in Wood Utilization from the Yale School of Forestry in 1954. Mr. Connolly started work at the Laboratories in 1956 in the Outside Plant Department's Timber Group, specializing in problems relating to the strength of timber. Later, he was concerned with test programs for the evaluation of materials and structures in soil and ocean environments, and the analysis of wood preservatives. He is presently in charge of the Environmental Protection and Corrosion group. Mr. Connolly is the author of the article "Soil-Testing Materials and Apparatus" in this issue. He is a member of the Society of American Foresters, American Society of Testing Materials, the Society of Industrial Microbiology, and XI Sigma Pi.

J. W. Emling

J. W. Emling, native of Erie, Pa., received his B.S. in E.E. from the University of Pennsylvania in 1925. After graduation, he joined the Development and Research Department of A.T.&T. Co., where he remained till 1934 when he joined Bell Laboratories. While at A.T.&T., Mr. Emling was concerned with transmission standards and rating. He continued this work at the Laboratories. In World War II, he was engaged

in studies in underwater acoustics. Subsequently he has been concerned with systems engineering studies in engineering economy, voice-frequency transmission, rural carrier, radio, television, and the early transmission and planning studies of the transatlantic telephone cable system. He is currently director of Transmission Systems Engineering, responsible for systems engineering aspects of exchange and toll transmission, carrier transmission over wire, telephone stations, some forms of digital transmission, and human factors research on communication systems. The author of "Human Factors in Transmission Maintenance" in this issue, he is a member of the Acoustical Society of America, American Institute of Electrical Engineers and the American Association for Advancement of Science. He also belongs to the Eta Kappa Nu and Tau Beta Pi Honorary Engineering Societies.

H. N. Seckler

Howard N. Seckler was born in New York City and attended Columbia University, receiving the BSEE degree in 1948 and the MSEE degree in 1949. Mr. Seckler participated in the Communications Development Training Program and later was an instructor in this program specializing in switching circuits and systems. His principal experience has been in the development of the experimental electronic telephone switching system. Elements of this system had a successful field trial in the ECO of Morris, Illinois which was recently terminated. Mr. Seckler was also concerned with the planning of a commercial system for large scale production. In this work he was concerned with broad system organization, logical design and stored program aspects. Since August, 1960 Mr. Seckler has headed a department concerned with the development of UNI-COM, a global military system for secure voice, teletypewriter, data and facsimile communications. Mr. Seckler is the co-author of "Electronic Switching Control Techniques" in this issue.

J. J. Yostpille

John J. Yostpille, the co-author of "Electronic Switching Control Techniques" in this issue, was born in Long Island City, New York. He received a BS in Electrical Engineering from M.I.T. in 1948 and an MEE from the Polytechnic Institute of Brooklyn in 1955. He first joined Bell Laboratories in 1942. After time out for service in the Navy and studies at M.I.T., Mr. Yostpille rejoined the Laboratories in 1948. He was a member of the first class in the Communications Development Training Program which he completed the following year. He first worked on design of toll switching equipment and then electronic switching. He later supervised a group engaged in systems planning. At present Mr. Yostpille is in the Systems Engineering Department as head of the Electronic Switching Planning Department. Among his assignments is the responsibility for coordinating work between the Laboratories and New Jersey Bell on the electronic system planned for Succasunna, New Jersey. He is a member of the I.R.E., and Sigma Xi.

J. H. King

John H. King is a native of Amityville, Long Island, New York. He received his primary education on Long Island and a degree in Mechanical Engineering from Stevens Institute of Technology in 1925. After a period with an elevator accessary company, he joined the Technical Staff of the Laboratories in 1927. His first assignment was with the Station Apparatus Department and involved work on telephone receivers, loudspeakers and reproducing equipment. During World War II his assignments included work on underwater sound devices. He transferred to the Outside Plan Development Laboratory in 1950 and is currently engaged in test set and methods development. Mr. King holds nine patents. Author of "The B Voltage Tester and Auxiliaries" in this issue, Mr. King is a licensed Professional Engineer.

What sets the stage for scientific discovery?

$$\eta_M = \frac{\nu_P}{\nu_S} = \eta_c$$

H. E. D. Scovil, pioneer developer of the solid state microwave maser, explains a point at a symposium at Bell Telephone Laboratories.

There is no one answer. But surely discovery is more likely when people are stimulated to think in new ways. And nothing more powerfully stimulates scientists and engineers than up-to-the-minute discussion of the latest developments.

Bell Laboratories scientists and engineers make a point of exchanging information on their latest advances not only among themselves but with the great world-wide professional community to which they belong. Last year, for example, Bell

Laboratories specialists delivered over 1200 talks to technical societies and universities. The stimulating exchange of new ideas plays an indispensable role at the world center of communications research and development.